PROGRAM REVIEW AND EXAM PREP

RADIOGRAPHY PREP

- CONCISE SUMMARY OF ALL THE ESSENTIAL CONCEPTS IN RADIOGRAPHY

- 860+ REVIEW QUESTIONS IN ARRT FORMAT

- ANSWERS WITH COMPLETE EXPLANATIONS & REFERENCES

- THE LATEST INFORMATION ON COMPUTED & DIGITAL IMAGING

D.A. SAIA

EDITION

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RADIOGRAPHY
PREP

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EDITION

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Dedicated

Spiritus Sancti gratia, illuminet sensus et corda nostra.

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Preface

Radiography PREP (Program Review and Examination Prep), fifth edition, is for use throughout all phases of radiography education. This text is useful for regular coursework, helping the student extract fundamental key concepts from reading assignments and class notes, and for making study and test preparation easier and more productive.

PREP is also useful for students preparing for their American Registry of Radiologic Technologists (ARRT) certification examination. It helps students direct their study efforts toward examination-related material and includes registry-type multiple-choice questions designed to help students practice test-taking skills they will need for the ARRT radiography examination.

The ARRT's Content Specifications for the Examination in Radiography lists the examination's five content categories and provides a detailed list of the topics addressed in each category. *Radiography PREP* is divided into five parts reflecting each of the five content categories. Part content reflects changes to the ARRT Content Specifications implemented January 2008. Particularly important is updated and expanded information on Digital/Electronic Imaging. Thus, study becomes even more directed and focused on examination-related material. Used with its companion book, *Lange Q&A for the Radiography Examination*, *PREP* provides a thorough preparation for the certification examination administered by the ARRT.

KEY FEATURES AND USE

- More than 400 ***illustrations and images*** appeal to the visual learner as well as the verbal learner. The essence of radiography is visual and *PREP*'s graphics and radiographic images visually express the written words.
- The ***summary boxes*** serve to call the student's attention to the most important facts in a particular section. Students can use summary boxes as an overview of key information.
- ***Inside covers*** list a number of formulae, body surface landmarks, digital imaging facts, acronyms, and abbreviations, radiation quality factors, and minimum filtration requirements. A "last-minute cheat sheet" is provided for some things that students often forget because they do not use them on a regular basis.
- The ***final review sections*** allow students to assess chapter material in two ways. The first review section, ***Chapter Exercises,*** requires short essay answers; exact page references follow each question, providing answers in chapter material. The second section, ***Chapter Review Questions,*** consists of registry-type multiple-choice questions followed by detailed explanations.

- Chapter 16 is a practice test; a simulation of the actual certification examination with questions designed to test your problem-solving skills and your ability to integrate facts that fit the situation. The questions are designed to provide focus and direction for your review, thus helping you do your very best on your certification examination.

Following completion of the chapter review questions and the practice test, the student is ready for final self-evaluation by answering more "registry-type" questions in the companion text, *Lange Q&A for the Radiography Examination*, seventh edition, and supplemental study at its website *RADREVIEWEasy.com*.

Acknowledgments

One of my most satisfying tasks is having the opportunity to thank those who have most generously contributed their insights, talents, and concerns to this project. Foremost among those are my teachers and colleagues who have contributed to my knowledge over the years and my students on whom I have the privilege of sharpening my knowledge and skills. Particular recognition goes to my current students—the class of 2009: Christina, Jason J., Jason S., Pascale, Graham, Pasha, and Joby. I greatly appreciate the friendship, encouragement, and support generously offered by my colleague Olive Peart, MS, RT(R) (M). I am grateful to the professional staff of McGraw-Hill, with special notes of appreciation to Catherine A. Johnson, Christie Naglieri, Midge Haramis, Sherri Souffrance, and Aptara project manager Satvinder Kaur for their patience, support, and assistance. Everyone at McGraw-Hill has been helpful in the development of this project; it is always a pleasure to work with their creative and skilled staff.

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Patient Care and Education

Legal and Ethical Aspects

I. PATIENT'S RIGHTS

A. PATIENT CONSENT

Patient *consent* can be verbal, written, or implied. For example, if a patient arrives for emergency treatment alone and unconscious, implied consent is assumed. A patient's previously granted or presumed consent can be withdrawn at any time. Written patient consent is required before any examination that involves greater than usual risk, for example, invasive vascular examinations requiring the use of injected iodinated contrast agents. For lower risk procedures, the consent given on admission to the hospital is generally sufficient.

It is imperative that the radiographer takes adequate time to thoroughly explain the procedure or examination to the patient. An informed patient is a more cooperative patient, and a better examination is more likely to result. Patients should be clear about what will be expected of them and what they may expect from the radiographer. This must be considered the *standard of care* for each patient, to fulfill not only legal mandates, but also professional and humanistic obligations.

B. PATIENT PRIVACY

Most institutions now have computerized, paperless systems to accomplish information transmittal; these systems must ensure *confidentiality* in compliance with Health Insurance Portability and Accountability Act (HIPAA) of 1996 regulations. The health care professional generally has access to the computerized system only via personal password, thus helping ensure confidentiality of patient information. All medical records and other individually identifiable health information—whether electronic, on paper, or oral—are covered by HIPAA legislation and by subsequent Department of Health and Human Services (HHS) rules that took effect in April of 2001.

All health care practitioners must recognize that their patients compose a community of people of all religions, races, and economic backgrounds, and that each patient must be afforded their best efforts.

Conditions for Valid Patient Consent

- The patient must be of legal age.
- The patient must be of sound mind.
- The patient must give consent freely.
- The patient must be adequately informed of the procedure about to take place.

Every patient should be treated with consideration of his or her worth and dignity. Patients must be provided *confidentiality* and *privacy*. They have the right to be informed, to make *informed consent*, and to refuse treatment.

C. BILL OF RIGHTS/PATIENT CARE PARTNERSHIP

The American Hospital Association's (AHA) Management Advisory presented *A Patient's Bill of Rights* that was first adopted by the AHA in 1973, then revised and approved by the AHA Board of Trustees in October of 1992. The 1992 *Patient's Bill of Rights* detailed 12 specific areas of patients' rights and the health care professional's ethical (and often, legal) responsibility to adhere to these rights. The *Patient's Bill of Rights* was summarized as *the right to*

1. considerate and respectful care;
2. be informed completely and understandably;
3. refuse treatment;
4. have an advance directive (e.g., a living will, health care proxy), describing the extent of care desired;
5. privacy;
6. confidentiality;
7. review his or her records (access to his/her health care information);
8. request appropriate and medically indicated care and services;
9. know about institutional business relationships that could influence treatment and care;
10. be informed of, consent to, or decline participation in proposed research studies;
11. continuity of care;
12. be informed of hospital policies and procedures relating to patient care, treatment, and responsibilities.

The AHA recently replaced the Patient's Bill of Rights with *The Patient Care Partnership—Understanding Expectations, Rights, and Responsibilities*. Their plain-language brochure includes the essentials of the Bill of Rights and reviews what patients can/should expect during a hospital stay.

The Patient Care Partnership statement addresses *high quality hospital care*—combining skill, compassion, and respect and the right to know the identity of caregivers, whether they are students, residents, or other trainees. It includes *a clean and safe environment*, free from neglect and abuse, and information about anything unexpected that occurred during the hospital stay. The Patient Care Partnership identifies *involvement in your care*: it elaborates on patient discussion/understanding of their condition and treatment choices with their physician, the patient's responsibility to provide complete and correct information to the caregiver, understanding who should make decisions for the patient if the patient cannot make those decisions (including "living will" or "advance directive").

The Patient Care Partnership statement also identifies *protection of your privacy*—describing the ways in which patient information is safeguarded. It also describes *help when leaving the hospital*—availability of and/or instruction regarding follow-up care. Lastly, The Patient

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The Patient Care Partnership

What to expect during your hospital stay:
- High quality hospital care
- A clean and safe environment
- Involvement in your care
- Protection of your privacy
- Help when leaving the hospital
- Help with your billing claims

Source: The American Hospital Association.

Care Partnership statement addresses *help with your billing claims*—including filing claims with insurance companies, providing patient physicians with required documentation, answering patient questions, and assisting those without health coverage.

The above-mentioned patient rights can be exercised on the patient's behalf by a *designated surrogate or proxy* decision maker if the patient lacks decision-making capacity, is legally incompetent, or is a minor. Many people believe that potential legal and ethical issues can be avoided by creating an *Advance Health Care Directive* or *Living Will*. Since all persons have the right to make decisions regarding their own health care, this legal document preserves that right in the event an individual is unable to make those decisions. An Advance Health Care Directive, or Living Will, names the individual authorized to make all health care decisions and can include specifics regarding *DNR* (do not resuscitate), *DNI* (do not intubate), and/or other end-of-life decisions.

> **Advance Health Care Directive/ Living Will:**
>
> - preserves a person's right to make decisions regarding their own health care
> - names the individual authorized to make all health care decisions for them
> - can include specifics regarding DNR, DNI, and other end-of-life decisions.

II. LEGAL ISSUES

It is essential that radiographers, like other health care professionals, be familiar with their *Practice Standards* published by the American Society of Radiologic Technologists (ASRT). The Standards provide a legal role definition and identify Clinical, Quality, and Professional Standards of practice—each Standard has its own rationale and identifies general and specific criteria related to that Standard. The student radiographer can access the individual Standards, their rationale, and criteria on the ASRT Web site.

A. X-RAY EXAM REQUESTS

X-ray examinations may be requested by a physician or physician assistant. Request forms for radiologic examinations must be carefully reviewed by the radiographer prior to commencement of the examination. Many hospitals and radiology departments have specific rules about exactly what kind(s) of information must appear on the requisition.

The requisition is usually stamped with the patient's personal information (name, address, age, admitting physician's name, and the patient's hospital identification number). The requisition should also include the patient's mode of travel to the radiology department (e.g., wheelchair vs. stretcher), the type of examination to be performed, pertinent diagnostic information, and any *infection control* or *isolation* information. The radiographer, having access to confidential patient information, must be mindful of compliance with HIPAA regulations.

The radiographer must be certain to understand and, if necessary, clarify the information provided, for example, any abbreviations used and any vague terms such as "leg" or "arm" (femur vs. tibia, humerus vs forearm). The radiographer must also be alert to note and clarify conflicting information, for example, a request for a left ankle examination when the patient complains of, or has obvious injury to, the right ankle. Computerized systems or department policy may require

that there be appropriate and accurate diagnosis information accompanying every request for diagnostic procedure.

B. LAW/MEDICOLEGAL ISSUES

The four primary *sources of law* are the Constitution of the United States, statutory law, regulations and judgments of administrative bureaus, and court decisions.

The *Constitution* expresses the categorical laws of the country. Its impact with respect to health care and health care professionals lies, in part, in its assurance of the *right to privacy*. The right to privacy indicates that the patient's modesty and dignity will be respected. It also refers to the health care professional's obligation to respect the confidentiality of privileged information. Inappropriate communication of privileged information to anyone but the appropriate health care professionals is inexcusable.

Statutory law refers to laws enacted by congressional, state, or local legislative bodies. The enforcement of statutory laws is frequently delegated to administrative bureaus such as the Board of Health, the Food and Drug Administration, or the Internal Revenue Service. It is the responsibility of these agencies to enact *rules and regulations* that will serve to implement the statutory law.

Court decisions involve the interpretation of *statutes* and various regulations in decisions involving individuals. For example, the decision of an administrative bureau can be appealed and the court would decide if the agency acted appropriately and correctly. Court decisions are referred to as common law.

There are two basic kinds of law: *public law* and *private (civil) law*. *Public* laws are any that regulate the relationship between individuals and government. *Private*, or civil, law includes laws that regulate the relationships among people. *Litigation* involving a radiographer's professional practice is most likely to involve the latter.

A private (civil) injustice or injury is a *tort*, and the injured party may seek reparation for damage incurred. Torts are described as either *intentional* or *negligent*.

Examples of *intentional* torts include false imprisonment, *assault* and *battery*, defamation, and invasion of privacy. *False imprisonment* is the illegal restriction of an individual's freedom. Holding a person against his or her will or using unauthorized restraints can constitute false imprisonment.

Assault is to threaten harm; *battery* is the carrying out of the threat. A patient might feel sufficiently intimidated to claim assault by a radiographer who threatens to repeat a difficult examination if the patient does not try to cooperate better. A radiographer who performs an examination on a patient without his or her consent, or after the patient has refused the examination, can be guilty of *battery*. A charge of battery may also be made against a radiographer who treats a patient roughly or who performs an examination on the *wrong* patient.

A radiographer who discloses confidential information to unauthorized individuals can be found guilty of *invasion of privacy*. A radiographer whose disclosure of confidential information is in some way detrimental to the patient (causing ridicule or loss of job, for

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Tort:

- a private/civil injustice
- reparation can be sought
- is either intentional or unintentional

example) can be accused of *defamation*. *Spoken* defamation is *slander*; *written* defamation is *libel*.

The assessment of *duty* (what *should* have been done) is determined by the professional *standard of care* (that level of expertise generally possessed by reputable members of the profession). The determination of whether or not the standard of care was met is usually made by determining what another reputable practitioner would have done in the same situation. Examples of negligent torts can include patient injury as a result of a fall while unattended on an x-ray table, in a radiographic room, or on a stretcher without side rails or safety belt. Radiographing the wrong patient or opposite limb are other examples of *negligence*.

The term *malpractice* is usually used with reference to negligence. Three areas of frequent litigation in radiology involve patient falls and positioning injuries, pregnancy, and errors or delays in *diagnosis*.

Patient falls and positioning injuries. Examples: A sedated patient left unattended in the radiographic room falls from the x-ray table; a patient with a spinal injury is moved from the stretcher to the x-ray table, resulting in irreversible damage to the spinal cord.

Pregnancy. Example: The radiographer fails to inquire about a possible pregnancy before performing a radiologic examination. Some time later, the patient contacts the health care facility, expressing concern about the fetus.

Errors or delays in diagnosis. Example: The patient undergoes an x-ray examination in the emergency department and is sent home. The radiologist interprets the images and fails to notify the emergency department physician of the findings. The physician gets a written report 2 days later. Meanwhile, the patient suffers permanent damage from an untreated condition.

If patient injury results from misperformance of a duty in the routine scope of practice of the radiographer, most courts will apply *res ipsa loquitur*, that is, "the thing speaks for itself." If the patient is obviously injured as a result of the radiographer's/caregiver's actions, it becomes the radiographer's/caregiver's burden to *disprove* negligence. Examples of this include imaging the wrong patient/incorrect limb, surgical removal of a healthy organ or limb, leaving a sponge or clamp in a patient's body after surgery. In many instances, the hospital and/or radiologist will also be held responsible according to *respondeat superior*, or, "let the master answer." The "master," or employer, can be held liable for wrongful acts of the "servant," or employee, in causing injury during employed activities.

For Negligent Tort Liability, Four Elements Must Be Present

- Duty (what should have been done)
- Breach (deviation from duty)
- Injury sustained
- Cause (as a result of breach)

Legal Doctrines

- *Res ipsa loquitur*:
  "the thing speaks for itself"
- *Respondeat superior*
  "let the master answer"

III. ARRT STANDARDS OF ETHICS

Practitioners of the profession of radiologic technology, like other health care professionals, have an ethical responsibility to adhere to principles of professional conduct and to provide the best services possible to the patients entrusted to their care. These principles are detailed in the American Registry of Radiologic Technologists (*ARRT*) two-part *Standards of Ethics* (Fig. 1–1), which includes the Code of Ethics and the Rules of Ethics. The 10-part *Code* of Ethics is aspirational; the 22 *Rules* of Ethics are enforceable and any violation can result in sanction/injunction.

ARRT Standards of Ethics Composed of:

- Code of Ethics (aspirational)
- Rules of Ethics (enforceable)

ARRT® Standards of Ethics

Last Revised: August 1, 2006
Re-Published: August 1, 2007

PREAMBLE
The *Standards of Ethics* of the American Registry of Radiologic Technologists shall apply solely to persons holding certificates from ARRT who either hold current registrations by ARRT or formerly held registrations by ARRT (collectively, "Registered Technologists" or "Registered Radiologist Assistants"), and to persons applying for examination and certification by ARRT in order to become Registered Technologists ("Candidates"). Radiologic Technology is an umbrella term that is inclusive of the disciplines of radiography, nuclear medicine technology, radiation therapy, cardiovascular-interventional radiography, mammography, computed tomography, magnetic resonance imaging, quality management, sonography, bone densitometry, vascular sonography, cardiac-interventional radiography, vascular-interventional radiography, breast sonography, and radiologist assistant. The *Standards of Ethics* are intended to be consistent with the Mission Statement of ARRT, and to promote the goals set forth in the Mission Statement.

A. CODE OF ETHICS

The Code of Ethics forms the first part of the *Standards of Ethics.* The Code of Ethics shall serve as a guide by which Registered Technologists and Candidates may evaluate their professional conduct as it relates to patients, healthcare consumers, employers, colleagues, and other members of the healthcare team. The Code of Ethics is intended to assist Registered Technologists, Registered Radiologist Assistant, and Candidates in maintaining a high level of ethical conduct and in providing for the protection, safety, and comfort of patients. The Code of Ethics is aspirational.

1. The radiologic technologist conducts herself or himself in a professional manner, responds to patient needs, and supports colleagues and associates in providing quality patient care.

2. The radiologic technologist acts to advance the principal objective of the profession to provide services to humanity with full respect for the dignity of mankind.

3. The radiologic technologist delivers patient care and service unrestricted by the concerns of personal attributes or the nature of the disease or illness, and without discrimination on the basis of sex, race, creed, religion, or socio-economic status.

4. The radiologic technologist practices technology founded upon theoretical knowledge and concepts, uses equipment and accessories consistent with the purposes for which they were designed, and employs procedures and techniques appropriately.

5. The radiologic technologist assesses situations; exercises care, discretion, and judgment; assumes responsibility for professional decisions; and acts in the best interest of the patient.

6. The radiologic technologist acts as an agent through observation and communication to obtain pertinent information for the physician to aid in the diagnosis and treatment of the patient and recognizes that interpretation and diagnosis are outside the scope of practice for the profession.

7. The radiologic technologist uses equipment and accessories, employs techniques and procedures, performs services in accordance with an accepted standard of practice, and demonstrates expertise in minimizing radiation exposure to the patient, self, and other members of the healthcare team.

8. The radiologic technologist practices ethical conduct appropriate to the profession and protects the patient's right to quality radiologic technology care.

9. The radiologic technologist respects confidences entrusted in the course of professional practice, respects the patient's right to privacy, and reveals confidential information only as required by law or to protect the welfare of the individual or the community.

10. The radiologic technologist continually strives to improve knowledge and skills by participating in continuing education and professional activities, sharing knowledge with colleagues, and investigating new aspects of professional practice.

B. RULES OF ETHICS

The Rules of Ethics form the second part of the *Standards of Ethics.* They are mandatory standards of minimally acceptable professional conduct for all present Registered Technologists, Registered Radiologist Assistants, and Candidates. Certification is a method of assuring the medical community and the public that an individual is qualified to practice within the profession. Because the public relies on certificates and registrations issued by ARRT, it is essential that Registered Technologists and Candidates act consistently with these Rules of Ethics. These Rules of Ethics are intended to promote the protection, safety, and comfort of patients. The Rules of Ethics are enforceable. Registered Technologists, Registered Radiologist Assistants, and Candidates engaging in any of the following conduct or activities, or who permit the occurrence of the following conduct or activities with respect to them, have violated the Rules of Ethics and are subject to sanctions as described hereunder:

1. Employing fraud or deceit in procuring or attempting to procure, maintain, renew, or obtain: reinstatement of certification or registration as issued by ARRT; employment in radiologic technology; or a state permit, license, or registration certificate to practice radiologic technology. This includes altering in any respect any document issued by the ARRT or any state or federal agency, or by indicating in writing certification or registration with the ARRT when that is not the case.

Figure 1–1. The American Registry of Radiologic Technologists Standards of Ethics. (Reproduced, with permission, from the ARRT Standards of Ethics. ARRT: 2008. Copyright © 2008 The American Registry of Radiologic Technologists.)

2. Subverting or attempting to subvert ARRT's examination process. Conduct that subverts or attempts to subvert ARRT's examination process includes, but is not limited to:
   (i) conduct that violates the security of ARRT examination materials, such as removing or attempting to remove examination materials from an examination room, or having unauthorized possession of any portion of or information concerning a future, current, or previously administered examination of ARRT; or disclosing information concerning any portion of a future, current, or previously administered examination of ARRT; or disclosing what purports to be, or under all circumstances is likely to be understood by the recipient as, any portion of or "inside" information concerning any portion of a future, current, or previously administered examination of ARRT;
   (ii) conduct that in any way compromises ordinary standards of test administration, such as communicating with another Candidate during administration of the examination, copying another Candidate's answers, permitting another Candidate to copy one's answers, or possessing unauthorized materials; or
   (ill) impersonating a Candidate or permitting an impersonator to take the examination on one's own behalf.

3. Convictions, criminal proceedings, or military court-martials as described below:
   (i) Conviction of a crime, including a felony, a gross misdemeanor, or a misdemeanor, with the sole exception of speeding and parking violations. All alcohol and/or drug related violations must be reported. Offenses that occurred while a juvenile and that are processed through the juvenile court system are not required to be reported to ARRT.
   (ii) Criminal proceeding where a finding or verdict of guilt is made or returned but the adjudication of guilt is either withheld, deferred, or not entered or the sentence is suspended or stayed; or a criminal proceeding where the individual enters a plea of guilty or nolo contendere (no contest).
   (ill) Military court-martials that involve substance abuse, any sex-related infractions, or patient-related infractions.

4. Failure to report to the ARRT that:
   (i) charges regarding the person's permit, license, or registration certificate to practice radiologic technology or any other medical or allied health profession are pending or have been resolved adversely to the individual in any state, territory, or country (including, but not limited to, imposed conditions, probation, suspension, or revocation); or
   (ii) that the individual has been refused a permit, license, or registration certificate to practice radiologic technology or any other medical or allied health profession by another state, territory, or country.

5. Failure or inability to perform radiologic technology with reasonable skill and safety.

6. Engaging in unprofessional conduct, including, but not limited to:

   (i) a departure from or failure to conform to applicable federal, state, or local governmental rules regarding radiologic technology practice; or, if no such rule exists, to the minimal standards of acceptable and prevailing radiologic technology practice;
   (ii) any radiologic technology practice that may create unnecessary danger to a patient's life, health, or safety; or
   (iii) any practice that is contrary to the ethical conduct appropriate to the profession that results in the termination from employment.
   Actual injury to a patient or the public need not be established under this clause.

7. Delegating or accepting the delegation of a radiologic technology function or any other prescribed healthcare function when the delegation or acceptance could reasonably be expected to create an unnecessary danger to a patient's life, health, or safety. Actual injury to a patient need not be established under this clause.

8. Actual or potential inability to practice radiologic technology with reasonable skill and safety to patients by reason of illness; use of alcohol, drugs, chemicals, or any other material; or as a result of any mental or physical condition.

9. Adjudication as mentally incompetent, mentally ill, a chemically dependent person, or a person dangerous to the public, by a court of competent jurisdiction.

10. Engaging in any unethical conduct, including, but not limited to, conduct likely to deceive, defraud, or harm the public; or demonstrating a willful or careless disregard for the health, welfare, or safety of a patient. Actual injury need not be established under this clause.

11. Engaging in conduct with a patient that is sexual or may reasonably be interpreted by the patient as sexual, or in any verbal behavior that is seductive or sexually demeaning to a patient; or engaging in sexual exploitation of a patient or former patient. This also applies to any unwanted sexual behavior, verbal or otherwise, that results in the termination of employment. This rule does not apply to pre-existing consensual relationships.

12. Revealing a privileged communication from or relating to a former or current patient, except when otherwise required or permitted by law.

13. Knowingly engaging or assisting any person to engage in, or otherwise participating in, abusive or fraudulent billing practices, including violations of federal Medicare and Medicaid laws or state medical assistance laws.

14. Improper management of patient records, including failure to maintain adequate patient records or to furnish a patient record or report required by law; or making, causing, or permitting anyone to make false, deceptive, or misleading entry in any patient record.

15. Knowingly aiding, assisting, advising, or allowing a person without a current and appropriate state permit, license, or registration certificate or a current certificate of registration with ARRT to engage in the practice of radiologic technology, in a jurisdiction which requires a person to have such a current and appropriate state

Figure 1–1. (*Continued*).

permit, license, or registration certificate or a current and appropriate registration of certification with ARRT in order to practice radiologic technology in such jurisdiction.

16. Violating a rule adopted by any state board with competent jurisdiction, an order of such board, or state or federal law relating to the practice of radiologic technology, or any other medical or allied health professions, or a state or federal narcotics or controlled-substance law.

17. Knowingly providing false or misleading information that is directly related to the care of a former or current patient.

18. Practicing outside the scope of practice authorized by the individual's current state permit, license, or registration certificate, or the individual's current certificate of registration with ARRT.

19. Making a false statement or knowingly providing false information to ARRT or failing to cooperate with any investigation by ARRT or the Ethics Committee.

20. Engaging in false, fraudulent, deceptive, or misleading communications to any person regarding the individual's education, training, credentials, experience, or qualifications, or the status of the individual's state permit, license, or registration certificate in radiologic technology or certificate of registration with ARRT.

21. Knowing of a violation or a probable violation of any Rule of Ethics by any Registered Technologist, Registered Radiologist Assistant, or Candidate and failing to promptly report in writing the same to the ARRT.

22. Failing to immediately report to his or her supervisor information concerning an error made in connection with imaging, treating, or caring for a patient. For purposes of this rule, errors include any departure from the standard of care that reasonably may be considered to be potentially harmful, unethical, or improper (commission). Errors also include behavior that is negligent or should have occurred in connection with a patient's care, but did not (omission). The duty to report under this rule exists whether or not the patient suffered any injury.

American Registry of Radiologic Technologists®
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Figure 1–1. (*Continued*).

The student should be completely familiar with the ARRT Standards of Ethics. Situations can occur that make us wonder what is the "right" thing to do—situations that require us to make ethical decisions. The Standards of Ethics provides guidelines for making these very important decisions; the decision we make can impact our entire professional career.

The ARRT Ethics Committee provides peer review of cases to ensure adherence to standards of professional behavior. Radiographers, like all health care providers, must have the moral character required to practice in the health care professions. If their actions demonstrate that moral character is lacking, that individual can be sanctioned. The sanction can be in the form of a reprimand, a suspension of registration, revocation of registration, ineligibility for certification, or other sanctions deemed appropriate by the Ethics Committee. The student should carefully study the ARRT Rules of Ethics.

For example, if you become aware that one of your coworkers is in violation of one of the Rules of Ethics, what must you do? Your professional obligation is to report your knowledge to your supervisor, then to the ARRT (according to Rule #21, *you* are in violation if you fail to report to the ARRT), *and* you must report to the State if your State has licensing.

A radiographer (or student radiographer) convicted of a misdemeanor or felony must report that to the ARRT. The Ethics Committee will conduct a peer review of the case and make a determination regarding possible sanction. *One* important consideration will be if the actions were job related and could present a risk to the welfare of the patient.

The radiographer must remember that failure to disclose a conviction is a violation of Ethical Rules #1 and #19 and involves falsification of ARRT information. ARRT can become aware of an unreported

conviction as part of an employment background check. This could actually result in a more serious sanction than the original offense!

The ARRT Standards of Ethics provides much important information and many answers to tough questions.

■ *SUMMARY*

- Patient consent can be verbal, written, or implied; a valid patient consent includes four conditions.
- Hospital Information Systems must ensure confidentiality in compliance with Health Insurance Portability and Accountability Act (HIPAA) of 1996 regulations.
- The AHA Patient's Bill of Rights details 12 specific areas of patient rights that the health care professional is obligated to respect.
- The AHA has replaced the Patient's Bill of Rights with the six-part Patient Care Partnership.
- An Advance Health Care Directive, or Living Will, names the individual authorized to make all health care decisions and can include specifics regarding DNR, DNI, and/or other end-of-life decisions.
- The ASRT Practice Standards identifies the level of knowledge and skill required of a professional radiographer.
- Radiologic examinations may be requested by a physician or physician assistant.
- The radiographer should examine the requisition carefully prior to bringing the patient to the radiographic room.
- Most health care facilities require that examination requests include pertinent diagnostic information and any infection control or isolation information.
- A civil injustice is a *tort*; a tort can be intentional or negligent.
- Negligence litigation in radiology most frequently involves injuries from falls, positioning injuries, pregnancy, errors or delays in diagnosis.
- The ARRT Standards of Ethics has two parts: the Code of Ethics and the Rules of Ethics.
- The Code of Ethics details guidelines for the radiographer's professional conduct; it is *aspirational.* The Rules of Ethics are *mandatory and enforceable.*

Chapter Exercises

⭐ ***Congratulations!*** *You have completed this chapter. If you are able to answer the following group of comprehensive questions, you can feel confident that you have mastered this section. You are then ready to go on to the "Registry-type" questions that follow.* ***For greatest success, do not go to the multiple-choice questions without first completing the short-answer questions below.***

1. What are the two parts of the ARRT Standards of Ethics? Which part is mandatory and enforceable *(p. 7)?*

2. Discuss the AHA Patient's Bill of Rights with respect to legal considerations pertinent to radiography and relate it to the new AHA Patient Care Partnership *(p. 4).*

3. Describe an Advance Health Care Directive and possible elements that it might address; what is its purpose *(p. 4, 5)?*

4. Discuss the purpose of the ASRT Practice Standards for the radiographer *(p. 5).*

5. List the conditions necessary for valid consent *(p. 6).*

6. Discuss public versus private (civil) law *(p. 6).*

7. Differentiate between assault and battery; slander and libel *(p. 6).*

8. Give examples of intentional and unintentional torts *(p. 6).*

9. List the four elements of a negligent tort *(p. 9).*

10. Identify the areas of litigation that most frequently involve radiology *(p. 6, 7).*

11. List the patient information usually found on examination request forms *(p. 5).*

12. Describe the impact of the 1996 HIPAA regulations on radiologic patient care considerations *(p. 3).*

13. Identify the kinds of clarification that may be required prior to starting the examination *(p. 5).*

14. Review the ARRT Rules of Ethics and give an example of how one or more could impact a radiography student *(p. 8–10).*

Chapter Review Questions

1. The ASRT document that defines the radiographer's role is the:
   (A) Standards of Ethics
   (B) Practice Standards
   (C) Standard of Care
   (D) Legal Standards

2. The legislation that guarantees confidentiality of all patient information is:
   (A) HSS
   (B) HIPAA
   (C) HIPPA
   (D) MQSA

3. Violations of the ARRT Rules of Ethics include:
      1. accepting responsibility to perform a function outside the scope of practice
      2. failure to obtain pertinent information for the radiologist
      3. failure to share newly acquired knowledge with peers
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

4. The threat to do harm is referred to as:
   (A) assault
   (B) battery
   (C) slander
   (D) libel

5. A radiographer who discloses confidential information to unauthorized individuals may be found liable for:
   (A) assault
   (B) battery
   (C) intimidation
   (D) defamation

6. Patients' rights include the following:
      1. the right to refuse treatment
      2. the right to confidentiality
      3. the right to possess one's medical records
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

7. What organization has the authority to impose professional sanction on a radiographer?
   (A) ARRT
   (B) ASRT
   (C) JRCERT
   (D) TJC

8. An individual's legal document that names the person authorized to make all health care decisions, should they be unable to, is called a:
   1. Living Will
   2. Advance Health Care Directive
   3. Last Will and Testament
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

9. Which of the following refer(s) to the patient's right to privacy?
   1. patient modesty must be preserved
   2. patient dignity must be respected
   3. patient confidentiality must be respected
   (A) 1 only
   (B) 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

10. If the patient lacks decision-making capacity, their rights can be exercised on their behalf by:
    1. designated surrogate
    2. designated proxy
    3. no one
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 3 only

Answers and Explanations

1. (B) Radiographers should be familiar with their *Practice Standards* published by the American Society of Radiologic Technologists (ASRT). The Standards provide a legal role definition and identify Clinical, Quality, and Professional Standards of practice—each Standard has its own rationale and identifies general and specific criteria related to that Standard. The student radiographer can access the individual standards, their rationale, and criteria on the ASRT Web site.

The ARRT establishes principles of professional conduct to ensure the best services possible to patients entrusted to our care. These principles are detailed in the ARRT two-part *Standards of Ethics,* which includes the Code of Ethics and the Rules of Ethics. The 10-part

Code of Ethics is aspirational; the 22 *Rules* of Ethics are enforceable and violation can result in professional sanction.

2. (B) Most institutions now have computerized, paperless systems for patient information transmittal; these systems must ensure confidentiality in compliance with Health Insurance Portability and Accountability Act (HIPAA) of 1996 regulations. The health care professional generally has access to the computerized system only via personal password, thus helping ensure confidentiality of patient information. All medical records and other individually identifiable health information, whether electronic, on paper, or oral, are covered by HIPAA legislation and by subsequent Department of Health and Human Services (HHS) rules that took effect in April of 2001.

3. (A) Accepting responsibility to perform a function outside the scope of practice is a violation of Ethical *Rule* #7, which states that it is a violation to "delegate or accept delegation of a radiologic technology function or any other prescribed health care function when the delegation or acceptance could reasonably be expected to create an unnecessary danger to a patient's life, health, or safety. Actual injury to a patient need not be established under this clause." So, accepting a responsibility outside the scope of practice is a violation of an ARRT *rule*. However, choices 2 and 3 are in violation of the *aspirational Code* of Ethics.

4. (A) *Assault* is to threaten harm; *battery* is to carry out the threat. A patient may feel sufficiently intimidated to claim assault by a radiographer who threatens to repeat a difficult examination if the patient does not try to cooperate better. A radiographer who performs an examination on a patient without the patient's consent or after the patient has refused the examination may be liable for battery. A charge of battery may also be made against a radiographer who treats a patient roughly or who performs an examination on the wrong patient. A radiographer who discloses confidential information to unauthorized individuals may be found liable for *invasion of privacy* or *defamation*. A radiographer whose disclosure of confidential information is in some way detrimental to the patient may be accused of defamation. Spoken defamation is *slander;* written defamation is *libel*.

5. (D) A radiographer who discloses confidential information to unauthorized individuals may be found guilty of *invasion of privacy or defamation*. A radiographer whose disclosure of confidential information is in some way detrimental to the patient may be accused of defamation. Spoken defamation is *slander;* written defamation is *libel. Assault* is to threaten harm; *battery* is to carry out the threat.

6. (B) The AHA identifies 12 important areas in its "Patient's Bill of Rights." These include the right to refuse treatment (to the extent allowed by law), the right to confidentiality of records and communication, and the right to continuing care. Other patient rights identified are the right to informed consent, privacy, respectful care, *access* to personal medical records, refusal to participate in research projects, and an explanation of one's hospital bill.

7. (A) The ARRT establishes principles of professional conduct to ensure the best services possible to patients entrusted to our care. These principles are detailed in the ARRT two-part *Standards of Ethics*, which includes the Code of Ethics and the Rules of Ethics. The 10-part *Code* of Ethics is aspirational; the 22 *Rules* of Ethics are enforceable and violation can result in professional sanction. The ARRT Ethics Committee provides peer review of cases

(misdemeanor, felony, etc.) to ensure adherence to standards of professional behavior and possession of the moral character required to practice in the health care professions. If the violator's actions demonstrate that moral character is lacking, that individual can be sanctioned—i.e., reprimanded, suspended, revoked, ineligible for certification, etc.—or other sanctions deemed appropriate by the Ethics Committee.

8. (B) Patient rights can be exercised on the patient's behalf by a designated surrogate or proxy decision maker if the patient lacks decision-making capacity, is legally incompetent, or is a minor. Many people believe that potential legal and ethical issues can be avoided by creating an *Advance Health Care Directive* or *Living Will*. Since all persons have the right to make decisions regarding their own health care, this legal document preserves that right in the event an individual is unable to make those decisions. An Advance Health Care Directive, or Living Will, names the individual authorized to make all health care decisions and can include specifics regarding *DNR* (do not resuscitate), *DNI* (do not intubate), and/or other end-of-life decisions.

9. (D) The *Constitution of the United States* expresses the categorical laws of the country. Its impact with respect to health care and health care professionals lies, in part, in its assurance of the *right to privacy*. The right to privacy indicates that the patient's modesty and dignity will be respected. It also refers to the health care professional's obligation to respect the confidentiality of privileged information. Inappropriate communication of privileged information to anyone but the appropriate health care professionals is inexcusable.

10. (C) Patient rights can be exercised on the patient's behalf by a *designated surrogate or proxy* decision maker if the patient lacks decision-making capacity, is legally incompetent, or is a minor. Many people believe that potential legal and ethical issues can be avoided by creating an Advance Health Care Directive or Living Will. Since all persons have the right to make decisions regarding their own health care, this legal document preserves that right in the event an individual is unable to make those decisions. An Advance Health Care Directive, or Living Will, names the individual authorized to make all health care decisions and can include specifics regarding *DNR* (do not resuscitate), *DNI* (do not intubate), and/or other end-of-life decisions.

Patient Communication and Safety

2

I. COMMUNICATION WITH PATIENTS

Effective communication starts with verification of patient identity. Care must be taken when making the initial patient identification. If the radiographer calls out a name into a rather full waiting room, or asks a patient if he is Mr. so-and-so, an anxious patient might readily respond in the affirmative without actually having heard his/her name called. The radiographer must check the patient's wristband *and* ask the patient for a second verification, such as his/her birth date.

X-ray examinations may be requested by a physician or physician assistant. Request forms for radiologic examinations should be carefully reviewed by the radiographer prior to commencement of the examination; any vague or conflicting information must be clarified immediately. Many hospitals and radiology departments have specific rules about exactly what kind(s) of information must appear on the requisition.

Effective communication with patients should also begin with a review of relevant patient history. The acquisition of pertinent clinical history from the patient is one of the most valuable contributions to the diagnostic process. Because the diagnostic radiologist rarely has the opportunity to speak with the patient, this is a crucial responsibility of the radiographer. For instance, to report that your patient indicates most pain at his/her medial malleolus is far more valuable than simply saying that his/her leg hurts. Review of patient information before bringing the patient into the radiographic room also enables the radiographer to have the x-ray room prepared, with all equipment and accessories readily available.

The importance of effective patient and professional *communication* skills cannot be overstressed; the interaction between patient and radiographer generally leaves the patient with a lasting impression of their health care experience. Of course, communication refers not only to the spoken word, but also to unspoken communication. Facial expression can convey caring and reassurance or impatience and disapproval. Similarly, a radiographer's touch can convey his or her commitment to considerate care, or it can convey a rough, uncaring, hurried attitude.

A. Verbal and Nonverbal Communication

Consider the *nonverbal* messages communicated to a patient brought into a disorderly radiographic room, or by a radiographer's sloppy, poorly groomed appearance. What about the grim-faced professional who hurries the patient along to the radiographic room, gives rapid-fire instructions on what to do while searching for missing markers and cassettes, tosses the patient about on the x-ray table, and finally dismisses the patient with a curt "you can go now"?

Consider another patient, greeted by a smiling professional who introduces himself or herself and brings the patient to a neat and orderly radiographic room, where everything is in readiness for the procedure. The radiographer explains the procedure and answers the patient's questions. At the end of the examination, the patient is escorted back to the waiting area and clear instructions are given for appropriate postprocedural care.

Which patient has a more comfortable, anxiety-free examination? Which leaves the hospital or clinic environment with a more favorable impression of his or her health care experience? Which experience would *you* prefer for yourself or a loved one?

The volume of the radiographer's *voice* and his or her rate of speech are also important factors to consider in effective communication. Loud, rapid speech is particularly uncomfortable for the sick patient. A conscious effort should be made to use a well-modulated tone. The radiographer should face the patient and make *eye contact* during communication.

Gaining the patient's confidence and trust through effective communication is an essential part of the radiographic examination. Some patients present challenges and will require a greater use of the radiographer's communication skills—patients who are seriously ill or injured; traumatized patients; patients who have impaired vision, hearing, or speech; infants and children; non–English-speaking patients; the elderly and infirm; the physically or mentally impaired; alcohol and drug abusers—the radiographer must adapt his or her communication skills to meet the needs of many types of individuals.

Elderly patients, for example, dislike being pushed or hurried about. They appreciate the radiographer who is compassionate enough to take the extra few minutes necessary for comfort. Some elderly patients are easily confused; it is best to address them by their full name and to keep instructions simple and direct. The elderly deserve the same courteous, dignified care as all other patients.

Communication difficulties can often be simply and significantly improved through explanation. Many patients are anxious about their illness/condition and unfamiliar with the procedure they are about to undergo. Anxious patients require more time to think and to move. The radiographer who takes the time to explain the procedure, explain unfamiliar terminology, and answer patient questions will be long-remembered and appreciated by that patient.

B. Explanation of Procedure

It is imperative that the radiographer takes adequate time to thoroughly explain the procedure or examination to the patient. The radiographer requires the cooperation of the patient throughout the course of the

examination. A thorough explanation will alleviate the patient's anxieties and permit fuller cooperation. Layman's terms should be used, or explanation given for any medical terms employed. Patients should be clear about what will be expected of them and what they may expect from the radiographer. Effective communications skills help ensure this cooperation.

Patients often have questions about other scheduled diagnostic imaging procedures such as mammography, computed tomography, magnetic resonance imaging, sonography, or nuclear medicine studies. Patients might not be knowledgeable about the length of an examination; they often have concerns/questions about safety or contraindications for an examination. The diagnostic radiographer must be able to respond knowledgeably to questions, or know where to get information, regarding diet restrictions or other preparation that might be needed for computed tomography or sonography, concerns or contraindications for some examinations such as magnetic resonance imaging, and positioning techniques such as compression used in mammography. The radiographer should also be able to help the patient obtain information about these and other services he or she might require, for example, social services, rehabilitation, etc.

C. EXPLANATION OF AFTERCARE

Radiographers must be certain to provide patients with appropriate aftercare instructions (e.g., plenty of fluids following barium examinations).

Patients sometimes need to repeat explanations or instructions (to the radiographer) to be certain they understand; some have an additional question or two they must ask to clarify their thoughts. The radiographer's patience and understanding at these times is greatly appreciated by the anxious patient or relative.

■ SUMMARY

- **Most health care facilities require that examination requests include pertinent diagnostic information and any infection control or isolation information.**
- **It is the radiographer's responsibility to clarify any vague or conflicting information found on the requisition.**
- **Patients must be identified by checking their wristbands and requesting a second verification such as birth date.**
- **Verbal communication involves the tone and rate of speech as well as what is being said. It involves personalization and respect.**
- **Nonverbal communication involves facial expression, professional appearance, orderliness of the radiographic room, and the preparation and efficiency of the radiographer.**
- **A thorough explanation of procedures reduces the patient's anxiety, increases cooperation, and results in a better examination.**
- **The radiographer provides aftercare information and can ably address patient questions about other imaging studies.**

II. EVALUATING PATIENT CONDITION

The radiographer must *assess* a patient's condition prior to bringing the patient to the radiographic room and as the examination progresses. A good place to begin is with a review of the patient's chart. Other useful information includes the admitting diagnosis and recent nurses' notes including information regarding the patient's degree of ambulation, any preparation for the x-ray procedure and how it was tolerated, notes regarding laboratory tests, and saving the patient's urine.

As the radiographer obtains a brief pertinent clinical history, he or she also assesses the patient's condition by observing and listening. To provide safe and effective care, the radiographer must be able to assess the severity of a trauma patient's injury, the patient's degree of motor control, and the need for support equipment or radiographic accessories. Can the patient move or be moved from the stretcher? Can the part be imaged adequately and with less pain on the stretcher or in the wheelchair? Will the use of sponges and/or sandbags result in a more comfortable, safer, and better imaged examination?

A. Physical Signs

When the patient is first approached, and as the examination progresses, the radiographer should be alert to the patient's appearance and condition, and any subsequent changes in them. Notice the color, temperature, and moistness of the patient's skin. Paleness frequently indicates weakness; the *diaphoretic* patient has pale, cool skin. *Fever* is frequently accompanied by hot, dry skin. "Sweaty" palms may indicate *anxiety*. A patient who becomes *cyanotic* (bluish lips, mucous membranes, or nail beds) needs oxygen and requires immediate medical attention.

B. Vital Signs

If a medical emergency arises, the radiographer may be required to assist by obtaining the patient's vital signs. Although checking vital signs is not a routine function, the radiographer should be proficient and confident if and when the need arises. Practicing vital signs during "slow" periods will benefit the patient who needs those skills during an emergency; also, those on whom you practice will learn their vital signs—valuable information for all.

Obtaining *vital signs* involves the measurement of *body temperature, pulse* rate, *respiratory rate*, and arterial *blood pressure*.

Body temperature varies with the time of day and site of measurement. Body temperature can be measured via thermometer in the mouth, rectum, axilla, bladder, heart chamber, or external auditory canal. Increased body temperature, or *fever*, usually signifies infection. Symptoms of fever include general malaise, increased pulse and respiratory rates, flushed skin that is hot and dry to the touch, and occasional chills. Very high, prolonged fevers can cause irreparable brain damage.

Normal body temperature varies from person to person depending on several factors, including age. A normal *adult* body temperature taken orally is 98.6°F (37°C). Rectal temperature is generally 0.5° to 1.0° higher, whereas axillary temperature is usually 0.5° to 1.0° lower.

Normal Body Temperatures	
Adult	
Oral	98.6°F
Rectal	99.1°F–99.6°F
Axillary	97.6°F–98.1°F
Infant to age 4 y	99°F–99.7°F
Child aged 5–13 y	97.8°F–98.6°F

A variation of 0.5° to 1.0° is generally considered within normal limits. Body temperature is usually lowest in the early morning and highest at night. Infants and children have a wider range of body temperature than adults; the elderly have lower body temperatures than others. Infants up to 4 years of age have normal body temperatures of between 99°F and 99.7°F. *Children* aged 5 to 13 years have a normal range of 97.8°F to 98.6°F.

Body areas having superficial arteries are best suited for determination of a patient's pulse rate. The *five most readily palpated pulse points* are the radial, carotid, temporal, femoral, and popliteal pulse. Of these, the radial pulse is the most frequently used. The apical pulse, at the apex of the heart, may be readily evaluated with the use of a stethoscope.

Pulse rate depends on the person's age, sex, body exertion and position, and general state of health. The very young and the very old have higher pulse rates. The pulse rate increases in the standing position and after exertion. The pulse rate also increases with certain conditions, such as fever, organic heart disease, *shock*, and alcohol and drug use. Certain variations in the regularity and strength of the pulse are characteristic of various maladies. Pulse rates vary between men and women and among adults, children, and infants; athletes often have lower pulse rates.

The act of *respiration* serves to deliver oxygen to all the body cells and rid the body of carbon dioxide. The radiographer must be able to recognize abnormalities or changes in patient respiration. The general term used to describe difficult breathing is *dyspnea*. More specific terms used to describe abnormal respirations include *uneven, spasmodic, strident* (shrill, grating sound), *stertorous* (labored, e.g., snoring), *tachypnea* (abnormally rapid breathing), *orthopnea* (difficulty breathing while recumbent), and *oligopnea* (abnormally shallow, slow).

A patient's respirations should be counted after counting the pulse rate, while still holding the patient's wrist. Respiratory action may become more deliberate and less natural in the patient who is aware that his or her respirations are being counted. The normal *adult* respiratory rate is 12 to 18 breaths per minute. The respiratory rate of young *children* is somewhat higher, up to 30 breaths per minute. While the radiographer is counting respirations, he or she should also be assessing the respiratory pattern (even, uneven) and depth (normal, shallow, deep).

Blood encounters a degree of resistance as it travels through the peripheral vascular system; thus, a certain amount of pressure exists within the walls of the vessels. *Blood pressure* among individuals varies with age, sex, fatigue, mental or physical stress, disease, and trauma. The blood pressure within vessels is greatest during ventricular *systole* (contraction) and lowest during *diastole* (relaxation). Blood pressure measurements are recorded with the systolic pressure on top and the diastolic pressure on the bottom, as in 100/80 (read "one hundred over eighty"). Normal *adult* systolic pressure ranges between 100 and 140 mm Hg; the normal diastolic range is between 60 and 90 mm Hg. Prehypertension is present when blood pressure measurements are between 120 and 140 mm Hg systolic and/or between 80 and 90 mm Hg diastolic. Blood pressure consistently above 140/90 is considered *hypertension*. Left undiagnosed and untreated, hypertension can lead to renal, cardiac, or brain damage. Hypotension is characterized by a systolic pressure of less than 90 mm Hg. Hypotension is seen in

Common Pulse Points

Artery	Location
Radial	Wrist; at base of thumb
Carotid	Neck; just lateral to midline
Temporal	In front of upper ear
Femoral	Inguinal region; groin
Popliteal	Posterior knee

Normal Pulse Rates (beats/min)

Men	70–72
Women	78–82
Children	90–100
Infants	120

Blood Pressure Determined by:

- cardial output
- blood volume
- vascular resistance

Blood Pressure:

- measured using sphygmomanometer and stethoscope
- cuff inflation sufficient to collapse brachial a.
- first sound heard is systolic pressure

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individuals with a decreased blood volume as a result of hemorrhage, infection, fever, and anemia. *Orthostatic* hypotension occurs in some individuals when they rise quickly from a recumbent position.

Blood pressure is measured using a *sphygmomanometer* and stethoscope. The patient may be recumbent or seated with the arm supported. The cuff of the sphygmomanometer is wrapped snugly around the arm, with its lower edge just above the *antecubital fossa.* With the stethoscope earpieces in place, the brachial artery pulse is palpated in the antecubital fossa and the bell (diaphragm) of the stethoscope is placed over the brachial artery. The valve on the bulb pump is closed and the cuff inflated *enough to collapse the brachial artery* (approximately 180 mm Hg). The valve is then opened very slowly. The first sound heard is the systolic pressure; as the valve pressure is slowly released, the sound becomes louder and then suddenly gets softer— this is the diastolic pressure. After the blood pressure measurements are recorded, the stethoscope earpieces and bell should be cleaned.

■ *SUMMARY*

- ■ **Radiologic examinations can be requested by a physician or physician assistant.**
- ■ **The radiographer should examine the requisition carefully prior to bringing the patient to the radiographic room.**
- ■ **Patient condition may be assessed through chart information, observation, questioning, and vital signs.**
- ■ **A patient's vital signs are temperature, pulse and respiration rates, and blood pressure.**
- ■ **A normal adult oral body temperature is 98.6°F, axillary temperatures are 0.5° to 1° lower, and rectal temperatures are 0.5° to 1° higher.**
- ■ **The arterial pulse points include radial, carotid, temporal, femoral, and popliteal.**
- ■ **The normal adult pulse rate is 70 to 80 beats per minute; infant and children pulse rates are higher.**
- ■ **The normal adult respiratory rate is 12 to 18 breaths per minute, with children's respirations being higher (up to 30/min).**
- ■ **Dyspnea refers to difficulty breathing; other terms are used to describe specific respiratory abnormalities. Blood pressure is measured using a sphygmomanometer and stethoscope.**
- ■ **The average normal adult systolic blood pressure is <120 mm Hg; average normal adult diastolic blood pressure is <80 mm Hg; blood pressure varies with a person's age, sex, fatigue and stress level, and disease, and with trauma.**
- ■ **Systolic pressure (contraction) is the top number; diastolic pressure (relaxation) is the bottom number.**

III. BODY MECHANICS AND PATIENT TRANSFER

Radiographers work with many patients whose capacities for *ambulation* vary greatly. Outpatients are usually *ambulatory*, that is, able

to walk and not confined to bed. Ambulatory inpatients generally travel by wheelchair, whereas patients confined to bed must travel by stretcher. It is essential for the radiographer to use proper technique and body mechanics when transferring patients, for the safety of the patient and the radiographer.

To transfer the patient with maximum safety for the patient and himself or herself, the radiographer must correctly use certain concepts of body mechanics. First, *a broad base of support* lends greater stability; therefore, the radiographer should stand with his or her feet approximately 12 inches apart and with one foot slightly forward. Second, stability is achieved when the body's *center of gravity* (center of the pelvis) is positioned over its base of support. For example, leaning away from the central axis of the body makes the body more vulnerable to losing balance; if the feet are close together, balance is even more difficult to keep.

Even the ambulatory outpatient might be somewhat unsteady, so a ready, supporting hand at the elbow can be very helpful. The radiographer should keep a watchful eye on the patient and assist him or her as needed.

Not all patients need, or want, well-intentioned assistance. Many prefer to manage on their own. The radiographer should recognize this, but be ever alert and watchful should the patient need assistance. Other patients find it reassuring and feel an added sense of security with an attentive radiographer. The professional radiographer develops a sense of awareness of each patient's needs and concerns.

Before helping a patient into or out of a wheelchair, it must first be locked. Then, the footrests must be moved aside to avoid tripping over them or tilting the wheelchair forward. Once the patient is seated, the footrests should be lowered into place for the patient's comfort.

When *transferring* a patient between the x-ray table and a stretcher, the stretcher is first securely locked. Often a smooth piece of plastic, placed partially under the patient and used in conjunction with the drawsheet, is used to facilitate patient transfer. Patient transfer should involve pulling, not pushing; pushing increases friction and makes the transfer more difficult. Use the biceps muscles for pulling; do not bend at the waist and pull, as this motion increases back strain.

It is essential that someone be responsible for keeping any intravenous (IV) tubing, *catheters*, oxygen lines, or other equipment free from entanglement during wheelchair and/or stretcher transfers.

The patient may be adjusted into the Fowler position (head higher than feet) for comfort or ease of breathing. The radiographer must be certain that safety belts and/or side rails are appropriately used for any patient on a stretcher.

Other Rules of Good Body Mechanics

1. When carrying a heavy object, hold it close to the body.
2. The back should be kept straight; avoid twisting.
3. When lifting an object, bend the knees and use leg and abdominal muscles to lift (rather than the back muscles).
4. Whenever possible, push or roll heavy objects (rather than lifting or pulling).

IV. PATIENT SAFETY AND COMFORT

It is the health care practitioner's responsibility to ensure patient safety and comfort while the patient is in his or her care. The radiographer should make mental notes of what the patient has when he or she enters the department, such as glasses or a purse. Patient belongings should be properly secured according to institution or department policy. The radiographer must be certain that the radiographic room is

hazard free, that all equipment and accessories are used properly and safely, and that the patient is as comfortable as possible.

When moving to or from the wheelchair or stretcher, patients should always be assisted or, at least, given careful attention. It is exceedingly unwise to finish a radiographic examination and say "OK, you can get off the x-ray table now," or something to that effect. The x-ray tube must be moved away from the x-ray table, a footstool must be in place to assist the patient from the table, and the radiographer must be there to guide or assist the patient safely to the correct dressing room.

Should an injured patient require assistance with dressing and undressing, it is important to remember that clothing should be *removed* from the *un*injured side first and *placed* on the *injured* side first.

Special consideration must be given to each patient according to his or her condition. Elderly and very thin patients, and those who will be required to lie on the x-ray table for a lengthy period of time, benefit greatly from a foam pad between themselves and the x-ray table. Lumbar strain is relieved by a pillow or positioning sponge placed under the knees. An extra pillow for the head or cushioning under the heels or ischial tuberosities can make a big difference in patient care. Special care and attention should be given to the skin of the elderly, as it bruises and bleeds easily.

Patients who are sedated, senile, in shock, or under the influence of alcohol or drugs must never be left unattended. Patients who arrive in the radiology department with restraints in place must never be left alone on the x-ray table, since they are usually active, disoriented, and occasionally, combative. Indeed, many radiology departments have rules stating that *no* patient may *ever* be left unattended in the radiographic room.

Patients with IV *infusions* in place require added attention. The IV standard/bag should be 18 to 24 inches above the level of the vein. The infusion site should be checked periodically for any signs of tissue infiltration. Swelling around the needle site generally indicates that the needle or catheter is no longer in the vein and that the medication is infiltrating the surrounding tissues. The radiographer should turn off the IV and notify the physician or nurse.

Difficulty in communication can be encountered with a patient having a *tracheostomy* in place. These individuals are often anxious because they cannot communicate verbally and they are fearful of choking because they cannot remove the secretions that accumulate in their throats. They require careful attention. The nurse should be available to suction secretions if the patient starts to breathe noisily or with difficulty. The radiographer can relieve much patient anxiety by careful explanation of the examination. The patient can be provided with pencil and pad to communicate any questions or concerns.

Just as health care practitioners provide for patient safety and comfort, they must ensure their own safety by practicing good body mechanics, infection control, and standard precautions.

Should an accident ever occur and a patient or health care practitioner be injured, no matter how small or insignificant the injury seems, it must be reported to the supervisor and an incident report completed. The risk management team, or similar group, requires all such information for legal documentation and as a means of identifying and resolving potential hazards.

Safety/Comfort Guidelines:

- belongings secure
- hazard-free environment
- equipment used properly

To avoid unnecessary/painful movement:

- remove clothing first from uninjured side
- place clothing first on the injured side

■ *SUMMARY*

- Modes of patient transportation include ambulation, wheelchair, and stretcher.
- Patient and radiographer safety requires the use of proper and safe body mechanics.
- Wheelchairs and stretchers must be locked and wheelchair footrests positioned out of the way prior to patient transfer.
- One person should be responsible for the safe transport of IV lines, catheters, and other tubes.
- Patient transfer between the radiographic table and stretcher should involve pulling, not pushing; a smooth plastic board often helps.
- The knees should be bent when lifting heavy objects; leg and abdominal muscles are used instead of back muscles.
- Heavy objects should be carried close to the body; the back should be kept straight and twisting motions should be avoided.
- Heavy objects should be pushed or rolled (instead of pulled or lifted) whenever possible.
- Patient belongings should be properly secured according to policy while the patient is in the radiographer's care.
- The radiographer must be alert for patient safety and comfort at all times; patients should not be left unattended in the radiographic room.
- Should an accident occur involving the patient and/or radiographer, an incident report should be completed regardless of how minor the incident.

Chapter Exercises

☆ ***Congratulations!*** *You have completed your review of this chapter. If you are able to answer the following group of comprehensive questions, you can feel confident that you have mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to these multiple-choice questions without first completing the short-answer questions below.*

1. Explain the importance of reviewing the examination request and other patient information prior to bringing the patient to the radiographic room *(p. 17).*

2. Discuss the best way(s) to ensure correct identification of a patient *(p. 17).*

3. Explain the importance of obtaining patient history *(p. 17, 20).*

4. Discuss the importance of explaining the procedure to the patient *(p. 18, 19).*

5. Discuss five ways the radiographer communicates verbal messages to the patient *(p. 18).*

6. Discuss five ways the radiographer communicates nonverbal messages to the patient *(p. 18).*

7. Discuss some qualities of verbal communication likely to evoke a *positive* response from the patient; a *negative* response *(p. 18).*

8. Explain the value of making as many preparations as possible prior to bringing the patient into the radiographic room *(p. 18, 20).*

9. Discuss five types of patients who might require special communication efforts on the part of the radiographer *(p. 18, 19).*

10. List five benefits of effective communication skills *(p. 17–19).*

11. Discuss the importance of being alert to initial patient condition and any subsequent changes in condition *(p. 20).*

12. Identify the following with respect to body temperature *(p. 20, 21).*
    A. normal adult, infant, and child temperature
    B. the significance of fever, that is, what it usually indicates
    C. symptoms usually associated with fever
    D. difference among oral, rectal, and axillary temperatures

13. Identify the following with respect to pulse rate *(p. 21)*.
    A. the normal, average adult pulse rate for men and women
    B. normal and abnormal conditions under which pulse rate will vary/change
    C. the usual site of pulse determination; other possible sites/any special equipment needed

14. Identify the following with respect to respiration *(p. 21)*.
    A. its function
    B. the ideal time to determine patient respiration rate; why?
    C. the normal, average adult respiratory rate

15. Identify the following with respect to blood pressure *(p. 21, 22)*.
    A. equipment necessary
    B. position of patient
    C. position of cuff and bell
    D. first and second sounds heard
    E. maximum norms for systolic and diastolic pressures
    F. prehypertensive and hypertensive pressures

16. Discuss three modes of patient transport *(p. 22, 23)*.

17. Discuss some specials needs that a tracheostomy patient might have *(p. 24)*.

18. Identify, with respect to body mechanics and patient transfer *(p. 23, 24)*.
    A. position of radiographer's feet (as base of support)
    B. the body's center of gravity (vis-à-vis stability) and when moving heavy objects: push versus pull; use of knees, legs, and back; proximity of object to body
    C. position of footrests and locks during wheelchair transfers
    D. position of locks, use of drawsheet and plastic mover, push versus pull in stretcher transfer
    E. care of IV lines, catheters, O_2, safety belts, and side rails

19. Identify the manner in which patients should be directed onto, and removed from, the x-ray table *(p. 23)*.

20. Explain how clothing should be removed from a patient with unilateral injury *(p. 24)*.

21. Identify techniques used to reduce discomfort of elderly and/or thin patients recumbent on the radiographic table *(p. 24)*.

22. Discuss the types of patients likely to be at greater risk left unattended on the radiographic table *(p. 24)*.

Chapter Review Questions

1. Which of the following communicate(s) messages to the patient?
    1. rate of speech
    2. eye contact
    3. readiness of radiographic room
    (A) 1 only
    (B) 1 and 2 only
    (C) 3 only
    (D) 1, 2, and 3

2. When an injured patient requires assistance with dressing or undressing, the radiographer must remember to:
    1. place clothing on the injured side first
    2. remove clothing from the injured side first
    3. always start with the injured side
    (A) 1 only
    (B) 1 and 2 only
    (C) 3 only
    (D) 1, 2, and 3

3. To reduce the back strain associated with transferring patients from stretcher to x-ray table, you should:
    (A) pull the patient
    (B) push the patient
    (C) hold the patient away from your body and lift
    (D) bend at the waist and pull

4. The normal adult axillary temperature is:
    (A) higher than rectal temperature
    (B) lower than rectal temperature
    (C) the same as rectal temperature
    (D) the same as oral temperature

5. The period of relaxation of the heart is termed:
    (A) systole
    (B) diastole
    (C) hypertension
    (D) dyspnea

6. A patient who is diaphoretic has:
    (A) pale, cool, clammy skin
    (B) hot, dry skin
    (C) dilated pupils
    (D) warm, moist skin

7. A pulse can be detected only by the use of a stethoscope in which of the following locations?
   - (A) wrist
   - (B) neck
   - (C) groin
   - (D) apex of the heart

8. Prehypertension is present when:
   1. systolic pressure is between 120 and 140 mm Hg
   2. diastolic pressure is between 80 and 90 mm Hg
   3. diastolic pressure is consistently 90 mm Hg
   - (A) 1 only
   - (B) 2 only
   - (C) 1 and 2 only
   - (D) 1 and 3 only

9. What number of breaths per minute represents the average rate of respiration for a normal adult?
   - (A) 8 to 15
   - (B) 10 to 20
   - (C) 30 to 60
   - (D) 60 to 90

10. Instruments needed to assess vital signs include:
    1. tongue blade
    2. watch with a second hand
    3. thermometer
    - (A) 1 only
    - (B) 1 and 2 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

Answers and Explanations

1. (D) The interaction between patient and radiographer generally leaves a lasting impression of the patient's health care experience. Communication may be verbal or nonverbal. *Verbal communication* involves tone and rate of speech as well as what is being said. It involves personalization and respect. *Nonverbal communication* involves facial expression, professional appearance, orderliness of radiographic room, and preparation and efficiency of the radiographer.

2. (A) Special consideration must be given to each patient according to his or her condition. Elderly and very thin patients, and those who will be required to lie on the x-ray table for a lengthy period of time, benefit greatly from a foam pad between themselves and the x-ray table. Should an injured patient require assistance with dressing and undressing, it is important to remember that clothing should be *removed from* the *un*injured side first and *placed on* the *injured* side first.

3. (A) When transferring a patient from stretcher *to x-ray table, several rules apply that will help reduce back strain. Pull*, do not push the patient; pushing increases friction and makes the transfer more difficult. *Use the biceps* muscles for pulling; do not bend at the waist and pull, as this motion *increases back strain.*

4. (B) Normal body temperature varies from person to person depending on several factors, including age. Normal adult body temperature taken orally is 98.6°F (37°C). Rectal temperature is generally 0.5° to 1.0° higher, whereas axillary temperature is usually 0.5° to 1.0° lower. Variation of 0.5° to 1.0° is generally considered within normal limits. Body temperature is usually lowest in the early morning and highest at night. Infants up to 4 years of age have normal body temperatures of between 99°F and 99.7°F. Children aged 5 to 13 years have a normal range of 97.8°F to 98.6°F.

Obtaining *vital signs* involves the measurement of *body temperature, pulse rate, respiratory rate, and arterial blood pressure.* Increased body temperature, or fever, usually signifies infection. Symptoms of fever include general malaise, increased pulse and respiratory rates, flushed skin that is hot and dry to the touch, and occasional chills. Very high, prolonged fevers can cause irreparable brain damage.

5. (B) Blood pressure within vessels is greatest during ventricular *systole* (contraction) and lowest during *diastole* (relaxation). Blood pressure measurements are recorded with the systolic pressure on top and the diastolic pressure on the bottom, as in 100/75 (read "one hundred over seventy-five"). Normal *adult* systolic pressure ranges between 100 and 140 mm Hg; the normal diastolic range is between 60 and 90 mm Hg. *Prehypertension* is present when blood pressure measurements are between 120 and 140 mm Hg systolic and/or between 80 and 90 mm Hg diastolic. Blood pressure consistently above 140/90 is considered *hypertension.* Left undiagnosed and untreated, hypertension can lead to renal, cardiac, or brain damage. Hypotension is characterized by a systolic pressure of less than 90 mm Hg. Hypotension is seen in individuals with a decreased blood volume as a result of hemorrhage, infection, fever, and anemia. *Orthostatic* hypotension occurs in some individuals when they rise quickly from a recumbent position. *Dyspnea* is the medical term used to describe difficulty in breathing.

6. (A) The radiographer must be alert to the patient's appearance and condition, and any subsequent changes in them. Notice the color, temperature, and moistness of the patient's skin: paleness frequently indicates weakness; the *diaphoretic* patient has pale, cool skin; *fever* is frequently accompanied by hot, dry skin; "sweaty" palms may indicate *anxiety*, a patient who becomes *cyanotic* (bluish lips, mucous membranes, nail beds) needs oxygen and requires immediate medical attention.

7. (D) Body areas having superficial arteries are best suited for determination of a patient's pulse rate. The five most readily palpated pulse points are the radial, carotid, temporal, femoral, and popliteal pulse. Of these, the radial pulse is the most frequently used. *The apical pulse, at the apex of the heart, may be readily evaluated with the use of a stethoscope.*

8. (C) Blood pressure among individuals varies with age, sex, fatigue, mental or physical stress, disease, and trauma. The blood pressure within vessels is greatest during ventricular contraction/*systole* and lowest during ventricular relaxation/*diastole.* Blood pressure measurements are recorded with the systolic pressure on top and the diastolic pressure on the bottom.

Normal *adult* systolic pressure ranges between 100 and 140 mm Hg; the normal diastolic range is between 60 and 90 mm Hg. *Prehypertension* is present when blood pressure measurements are between 120 and 140 mm Hg systolic and/or between 80 and 90 mm Hg diastolic. Blood pressure consistently above 140/90 is considered *hypertension.* Left undiagnosed and untreated, hypertension can lead to renal, cardiac, or brain damage. Hypotension is characterized by a systolic pressure of less than 90 mm Hg. Hypotension is seen in individuals with a decreased blood volume as a result of hemorrhage, infection, fever, and anemia.

9. (B) A patient's respirations should be counted after counting the pulse rate, while still holding the patient's wrist. Respiratory action may become more deliberate, or less natural, in the patient who is aware that his or her respirations are being counted. *The normal respiratory rate is 12 to 18 breaths per minute.* The respiratory rate of young *children* is somewhat *higher*, up to 30 breaths per minute. While the radiographer is counting respirations, he or she should be assessing the respiratory pattern (even, uneven) and depth (normal, shallow, deep) as well.

10. (C) Obtaining vital signs involves the measurement of *body temperature,* pulse rate, *respiratory rate,* and *arterial blood pressure.* A *thermometer* is used to take the patient's temperature. A *watch* with a second hand is required to time the patient's pulse rate and respirations. To measure blood pressure, a *sphygmomanometer* and *stethoscope* are required. A tongue blade is used to depress the tongue for inspection of the throat and is not part of vital sign assessment.

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Infection Control

I. TERMINOLOGY AND BASIC CONCEPTS

A. MEDICAL AND SURGICAL ASEPSIS

Antisepsis is a practice that retards the growth of pathogenic bacteria. *Medical asepsis* refers to the destruction of pathogenic microorganisms (bacteria) through the process of *disinfection*. Examples of disinfectants are hydrogen peroxide, chlorine, iodine, boric acid, and formaldehyde. *Surgical asepsis* (*sterilization*) refers to the removal of all microorganisms *and* their spores (reproductive cells) and is practiced in the surgical suite. Health care practitioners must practice medical asepsis at all times.

B. HANDWASHING

As early as 1843, Dr. Oliver Wendell Holmes advocated handwashing to prevent childbed fever. Holmes's ideas were greeted with disdain by many physicians of his time. Today we know that *the most important precaution in the practice of aseptic technique is proper handwashing*. The radiographer's hands should be thoroughly washed with soap and warm, running water for at least 10 seconds after each patient examination. If the faucet cannot be operated with the knee, it should be opened and closed using paper towels (to avoid contamination of or by the faucet). The radiographer's uniform should not touch the sink. The hands and forearms should always be kept lower than the elbows; care should be taken to wash all surfaces and between fingers. Hand lotions should be used to prevent hands from chapping; broken skin permits the entry of microorganisms. *Disinfectants, antiseptics, and germicides are substances used to kill pathogenic bacteria*; they are frequently used in handwashing substances. Alcohol-based hand sanitizers have been recommended as an alternative to handwashing with soap and water.

C. PERSONAL CARE

Uniforms are recommended because clothing worn in patient areas should not be worn elsewhere. Because clothing becomes

contaminated in the patient area, a clean uniform should be worn daily. Microorganisms can find safe harbor in jewelry, especially in rings with stones and other crevices; many facilities do not permit health care workers to wear artificial nails, for they can harbor fungi and microbes. It is recommended that the only jewelry a health care practitioner wear is a wristwatch and unadorned wedding band. *Remember that many microorganisms can remain infectious while awaiting transmission to another host.*

Sterile technique is employed during invasive procedures, such as biopsies, and for the administration of contrast media via the intravenous (IV) and *intrathecal* routes (e.g., IV urography and myelography). When radiography is required in the surgical suite, every precaution must be made to maintain the surgical asepsis required in surgical procedures. This requires proper dress, cleanliness of equipment, and restricted access to certain areas. One example of a restricted area is the "sterile corridor," the area between the draped patient and the instrument table. This area is occupied only by the surgeon and the instrument nurse.

II. CYCLE OF INFECTION

A. PATHOGENS

Pathogens are causative agents—microorganisms capable of producing disease. Pathogens termed *opportunistic* are usually harmless, but can become harmful if introduced into a part of the body where they do not normally reside, or when introduced into an immunocompromised host. *Bloodborne* pathogens reside in blood and can be transmitted to an individual exposed to that blood or body fluids of the exposed individual. Common bloodborne pathogens include hepatitis C, hepatitis B, and human immunodeficiency virus (HIV).

The control and prevention of infection must be a hospital-wide effort; each department is required to have its own infection-control protocol, designed according to the risks unique to the services provided. Because radiography often involves exposure to sickness and disease, the radiographer must be aware of, and conscientiously practice, infection control and effective preventive measures.

B. CONTACT: DIRECT AND INDIRECT

Infectious microorganisms can be transmitted from patients to other patients or to health care workers, and from health care workers to patients. They are transmitted by means of either direct or indirect contact. *Direct contact* involves *touch*. The courteous act of handshaking is a simple way of transmitting infection from one individual to another. Diseases transmitted by direct contact include skin infections such as boils, and sexually transmitted diseases such as syphilis and acquired immunodeficiency syndrome (AIDS). Direct contact with droplets of nasal or oral secretions from a sneeze or cough is referred to as *droplet* contact.

Indirect contact involves transmission of microorganisms via *airborne* contamination, *fomites*, and *vectors*. *Pathogenic microorganisms* expelled from the respiratory tract through the mouth or nose can be carried as evaporated droplets through the air or on dust and settle

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Factors in Infection Transmission/Cycle of Infection

1. An infectious agent
2. Reservoir or environment for agent to live and multiply
3. A portal of exit from the reservoir
4. A means of transmission
5. A portal of entry into a susceptible new host

on clothing, utensils, or food. Patients with respiratory tract infections or disease transported to the radiology department, therefore, should wear a mask to prevent such transmission during a cough or sneeze; it is not necessary for the health care worker to wear a mask (as long as the patient does). Many microorganisms can remain infectious while awaiting transmission to another host. A contaminated inanimate object such as a food utensil, doorknob, or IV pole is referred to as a *fomite*. A *vector* is an insect or animal carrier of infectious organisms, such as a rabid animal, a mosquito that carries malaria, or a tick that carries Lyme disease. They can transmit disease through either direct or indirect contact.

Direct contact

- touch
- droplet

Indirect contact

- airborne
- fomites
- vectors

C. NOSOCOMIAL

Nosocomial infections are infections acquired by patients while they are in the hospital—these infections are unrelated to the condition for which the patients were hospitalized. The Centers for Disease Control and Prevention estimates that from 5% to 15% of all hospital patients acquire some type of nosocomial infection. Hospital personnel can also become infected. It is somewhat surprising, yet understandable, that many infections can be acquired in the hospital; surprising because hospitals are places where people go to regain their health, yet understandable because individuals weakened by illness or disease are more susceptible to infection than are healthy individuals. Infections acquired in hospitals, especially by patients whose resistance to infection has been diminished by their illness, are termed *nosocomial*. The most common nosocomial infection is the *urinary tract infection*, often related to the use of urinary catheters that can allow passage of pathogens into the patient's body. Other types of nosocomial infections include sepsis, wound infection, and respiratory tract infection.

Health care practitioners must exercise strict infection-control precautions so that their *equipment* and/or technique will not be the source of nosocomial infection. *Contaminated* waste products, soiled linen, and improperly sterilized equipment are all means by which microorganisms can travel. Not every patient will come in contact with these items; however, the health care professional is in constant contact with patients and is therefore a constant threat to spread infection. Microorganisms are most commonly spread by way of the hands; spread of infection can be effectively reduced by proper disposal of contaminated objects and proper handwashing before and after each patient. *Disinfectants, antiseptics*, and *germicides* are used in many handwashing liquids to kill microorganisms.

■ SUMMARY

- ■ **Antiseptics retard the growth of bacteria.**
- ■ **Medical asepsis refers to the destruction of bacteria through the use of disinfectants/antiseptics.**
- ■ **Surgical asepsis refers to the destruction of all microorganisms and their spores through sterilization.**
- ■ **The practice of medical asepsis is required at all times, whereas surgical asepsis is required for invasive procedures.**

- **The single most important component of medical asepsis is proper and timely handwashing.**
- **A clean uniform must be worn daily; uniforms become contaminated and should not be worn elsewhere; pathogenic microorganisms thrive in jewelry crevices and cracked nail polish.**
- **Infectious microorganisms are transmitted by either direct or indirect contact. Direct contact involves touch. Indirect contact includes airborne contamination, fomites, and vectors.**
- **Infections acquired in hospitals are called nosocomial infections; the most common nosocomial infection is urinary tract infection.**
- **Disinfectants (germicides) are used in handwashing liquids to kill microorganisms.**

III. STANDARD PRECAUTIONS

The Centers for Disease Control and Prevention (*CDC*) and the Hospital Infection Control Practices Advisory Committee (*HICPAC*) have revised and simplified infection control guidelines for hospitals and other health care facilities. The various types of isolation techniques, disease-specific precautions, and varied terminology have been reviewed, revised, and updated. All these considerations are now incorporated into *standard precautions* and *transmission-based precautions*.

Exposure to infectious microorganisms is a daily concern for health care professionals, especially with the rapid spread of *HIV*, *AIDS*, and the hepatitis B virus (*HBV*) infection. HIV-infected individuals may be symptomless and go undiagnosed for 10 years or more, yet they are carriers of the infection and have the potential to spread the disease. *Epidemiologic* studies indicate that HIV infection can be transmitted only by intimate contact with blood or body fluids of an infected individual. This can occur through the sharing of contaminated needles, through sexual contact, from mother to baby at childbirth, and from transfusion of contaminated blood. HIV *cannot* be transmitted by inanimate objects such as water fountains, telephone surfaces, or toilet seats. *Hepatitis B* is another bloodborne infection; it affects the liver. It is thought that more than 1 million people in the United States have chronic hepatitis B and, as such, can transmit the disease to others.

Because no symptoms may be evident in patients infected with particular diseases, such as HIV, AIDS, and HBV, all patients must be treated as potential sources of infection from blood and other body fluids. The practices associated with this concept are called *standard precautions*. This rationale treats *all* body fluids and substances as infectious and serves to prevent the spread of microorganisms to other patients by the radiographer, as well as to protect the radiographer from contamination. Body fluids and substances that may be considered infectious include blood, breast milk, vaginal secretions, amniotic fluid, semen, peritoneal fluid, synovial fluid, cerebrospinal fluid, feces, urine, secretions from the nasal and oral cavities, and secretions from the lacrimal and sweat glands.

It is essential, then, that the radiographer makes the practice of blood and body fluid precautions *standard*; that is, they must be

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Guidelines for Standard Precautions

The radiographer is now legally, as well as ethically, responsible for strict adherence to standard precaution principles identified in the following guidelines:

- Shielding for the face and eyes must be in place whenever the possibility of blood or body fluid splashes may occur near the face.
- Plastic aprons must be worn whenever the possibility of blood or body fluid splashes may occur on the clothing.
- Gloves must be worn whenever touching blood or body fluids is possible, and whenever handling equipment or touching surfaces contaminated with blood or body fluids is possible.
- Gloves must be changed and the hands washed after every patient contact.
- Blood and body fluid spills should be carefully cleaned and disinfected using a solution of 1 part bleach to 10 parts water.
- Used needles must not be separated from the syringe and must be placed in designed puncture-proof containers.
- Prescribed procedures must be followed and sufficient care and attention given to risky tasks to avoid needle sticks and other skin penetrations from cutting instruments ("sharps").
- Emergency cardiopulmonary resuscitation (CPR) equipment must include resuscitation bags and mouthpieces.

practiced on all patients without exception. This involves the use of barriers, such as gloves, to provide a separation between a patient's blood and body fluids and the radiographer or other health care worker. *Special precautions must also be taken with the disposal of biomedical waste*, such as laboratory and pathology waste, all sharp objects, and liquid waste from suction, bladder catheters, chest tubes, and IV tubes, as well as drainage containers.

Biomedical waste is generally packaged in easily identifiable impermeable bags and removed from the premises by an approved biomedical waste hauler.

IV. TRANSMISSION-BASED PRECAUTIONS

Adherence to standard blood, body fluids, and substances precautions in the care of all patients will minimize the risk of transmission of HIV and other blood and body substance-borne pathogens from the patient to the radiographer and from the radiographer to patient. The use of standard precautions also minimizes the need for category-specific isolation. These have been replaced by *transmission-based precautions: airborne*, *droplet*, and *contact* (Table 3–1). Under these guidelines, some conditions/diseases can fall into more than one category.

A. AIRBORNE

Medical asepsis and blood and body fluids precautions are used when performing radiographic examinations on *all* patients, but additional precautions may be required when a patient is suspected or known to have a *particular communicable disease*. For example, *airborne precaution* is employed with patients suspected or known to be infected with the *tubercle bacillus* (*TB*)*, chickenpox* (*varicella*), and *measles* (*rubeola*). Airborne precaution *requires the patient to wear a mask* to avoid the spread of acid-fast bacilli (in bronchial secretions) or other pathogens during coughing. If the patient is unable or unwilling to wear a mask, the radiographer must wear one. An N95 Particulate Respirator mask, which requires fit-testing, is the mask to be worn

TABLE 3–1. TRANSMISSION-BASED PRECAUTIONS

EXAMPLES	PROTECTION
Airborne TB Varicella Rubeola	Patient: wears mask, private, negative-pressure room Radiographer: wears gloves; gown for blatant contamination
Droplet Rubella Mumps Influenza	Patient: wears mask, private room Radiographer: gown and gloves as indicated
Contact MRSA* C *difficile** Some wounds	Patient: private room, wears mask if required by your facility Radiographer: gloves and gown, mask for MRSA if required by facility

C difficile: Clostridium difficile; MRSA: methicillin-resistant *Staphylococcus aureus*.

by health care workers. The radiographer should wear gloves, but a gown is required only if flagrant contamination is likely. Patients infected with *airborne diseases* require a *private, specially ventilated (negative pressure) room* (Table 3–1).

B. DROPLET

A private room is indicated for all patients on *droplet precaution*; that is, diseases transmitted via large droplets expelled from the patient while speaking, sneezing, or coughing. The pathogenic droplets can infect others when they come in contact with mouth or nasal mucosa or conjunctiva. *Rubella* ("German measles"), *mumps*, and *influenza* are among the diseases spread by droplet contact; *a private room is required* for the patient, and health care practitioners must wear a regular (string) *mask* to enter a droplet-precautions isolation room.

C. CONTACT

Any disease spread by direct or close *contact*, such as *MRSA* (methicillin-resistant *Staphylococcus aureus*), *Clostridium difficile (C difficile)*, and *some wounds*, requires *contact precautions. Contact precaution* procedures require a *private patient room*, and the use of *gloves and gown* for anyone coming in direct contact with the infected individual or the infected person's environment. Some facilities require health care workers to wear a mask when caring for a patient with MRSA.

Patients in *contact isolation* occasionally have to be transported to the radiology department for examination. When this is the case, the department should be notified first in order to prepare properly. The patient should wear a mask and gown. The wheelchair or stretcher should first be covered with a clean sheet, followed by a second sheet or thin blanket. After transferring the patient to the wheelchair or stretcher, the inner sheet is wrapped around the patient, and the outer sheet over it (thus, the inner sheet is the contaminated one). The radiographic room should be available and ready for the patient to be taken in directly. The x-ray table should be covered with a clean sheet before the patient is transferred to it. One radiographer (wearing gloves) must be responsible for patient positioning and the other for equipment controls and operation (to avoid contamination of equipment and possible transmission of disease to others via indirect contact or fomites).

After the examination is completed, the patient is transferred to the wheelchair or stretcher and wrapped in the same way. Any contaminated *linens* should be placed in a plastic bag and contaminated disposables such as tissues are placed in a separate bag; both are returned with the patient to his private room.

The radiographic table and other equipment should be cleaned with a disinfectant and hands should be washed carefully when the task is completed.

Mobile radiography performed on patients on *contact isolation* generally requires special precautions and the teamwork of *two* radiographers. The first (or "dirty") radiographer dons gown, gloves (gloves must cover gown cuffs), and mask, usually available just outside the patient's room. The necessary cassette(s) must be placed in a plastic bag or pillowcase to protect them from contamination. This radiographer must remember to bring an extra pair of gloves into the patient room.

The mobile x-ray unit is brought into the room, and all possible adjustments must be made before the radiographer touches anything else.

The equipment and cassette are positioned, and the patient is adjusted properly. *At this point, the mobile x-ray unit must not be touched* until the radiographer disposes of the gloves he or she has on and replaces them with the clean extra pair.

The exposure is then made; the covered cassette is removed from behind/under the patient and brought to the door. The "dirty" radiographer slides the pillowcase or plastic cover away from the cassette and the second member of the team (the "clean" radiographer) grasps the uncovered cassette. Just inside the patient room door, the contaminated gloves should be removed properly and the hands washed thoroughly. The mask and gown ties are then untied with clean hands; the gown is removed by placing a clean hand under the cuff and pulling the arm down from underneath. The other sleeve is also removed *by touching only the inside of the gown*. The gown is slipped off and folded forward with the contaminated surfaces touching.

The discarded garments must be placed in the container provided. The radiographer should then carefully rewash his or her hands, dry them with paper towels, and take care not to touch the faucets. After leaving the room, *the mobile unit must be thoroughly cleaned* with a disinfectant and the hands carefully washed once again.

It should be noted that these patients may feel ostracized and relegated to a kind of solitary confinement. The radiographer must remember that these patients have the same needs as other patients (indeed, perhaps greater needs) and be certain to treat them with dignity and care.

Protective, or reverse, isolation is used to keep the susceptible patient from becoming infected. Burn patients who have lost their means of protection, their skin, have increased susceptibility to bacterial invasion. Patients whose immune systems are compromised (e.g., transplant recipients, leukemia) are unable to combat infection and are more susceptible to infection. These patients are treated with strict isolation technique, taking care to protect the *patient* from contamination.

■ *SUMMARY*

- ■ **Because no symptoms may be evident in patients afflicted with certain diseases such as HIV, AIDS, and hepatitis B, all patients must be treated as potential sources of infection from blood and other body fluids; this is the standard precautions concept.**
- ■ **The practice of standard precautions helps prevent transmission of infection to the health care professional and to other patients.**
- ■ **The health care professional is legally and ethically responsible for adhering to standard precautions principles; they must be practiced on all patients at all times without exception.**
- ■ **Biomedical waste (body substances and their containers) must be disposed of in carefully controlled circumstances.**
- ■ **Transmission-based precautions include airborne, droplet, and contact.**

- Airborne precaution requires that the patient wear a mask and be admitted to a private, specially ventilated room.
- Droplet precaution and a private room are required for measles, mumps, and influenza; the radiographer requires a mask (if the patient is not wearing one) and may also need to wear gown and gloves.
- Contact precaution (*C difficile*, MRSA, some wounds) requires that the radiographer use mask, gown, and gloves when in direct contact with the patient.
- Mobile radiography on a patient with contact precaution requires the teamwork of two radiographers.
- Protective, or reverse, isolation is used to keep the susceptible patient from being infected.

Chapter Exercises

⭐ ***Congratulations!*** *You have completed your review of this chapter. If you are able to answer the following group of comprehensive questions, you can feel confident that you have mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to these multiple-choice questions without first completing the short-answer questions below.*

1. List three disinfectant agents ***(p. 33).***

2. Describe the correct method of handwashing, including *when* hands should be washed, opening/closing faucets, position of hands and forearms ***(p. 33).***

3. Define *pathogen*; describe types ***(p. 34).***

4. Describe the importance of the radiographer's personal care, related to disease control ***(p. 34).***

5. Identify and differentiate between the two basic means of transmitting infectious microorganisms ***(p. 34, 35).***

6. List three means of indirect transmission of pathogenic microorganisms ***(p. 34, 35).***

7. Identify the most common type of hospital-acquired infection ***(p. 35).***

8. List five possible sources of nosocomial infection in the radiology department ***(p. 35).***

9. Describe the type of protection required for patients with respiratory infections ***(p. 35).***

10. Identify the means by which microorganisms are spread ***(p. 33, 34).***

11. What substances are added to handwashing liquids to kill microorganisms ***(p. 33)*** ?

12. Discuss the rationale of body fluid and substance (standard) precautions ***(p. 36).***

13. Discuss each of the following with respect to standard precautions ***(p. 36, 37)*** :
    A. when a face shield should be used
    B. when a plastic apron should be used
    C. when hands should be washed
    D. when gloves should be used
    E. how body fluid and substance spills should be cleaned
    F. care of used needles

G. special devices available for CPR

H. on whom standard precautions should be practiced

14. Differentiate between medical and surgical asepsis *(p. 33).*

15. Identify and explain the most important practice in good aseptic technique *(p. 33).*

16. Discuss the function of uniforms worn by health care practitioners; the hazards of jewelry and nail polish *(p. 34).*

17. List the three types of transmission-based precautions *(p. 34).*

18. Explain the precautionary measures taken in airborne precaution, regarding apparel (and for whom), and patient room *(p. 37).*

19. List three communicable diseases spread by droplet contact that require droplet precaution *(p. 37, 38).*

20. Describe the method of performing mobile chest radiography on patients with contact precaution, to include *(p. 38)* :
A. number of persons needed
B. radiographer's apparel
C. how to protect cassettes from contamination
D. why an extra pair of gloves is needed in the patient room
E. role played by the second individual
F. how protective clothing should be removed
G. care of x-ray machine at completion of examination

21. Describe the proper method of transporting a contact precaution patient to the radiology department *(p. 38).*

22. Describe the purpose of reverse isolation *(p. 39).*

23. Discuss any special needs the isolation patient may have *(p. 39).*

Chapter Review Questions

1. Pathogens are:
    1. always harmful
    2. sometimes harmful
    3. capable of producing disease
    (A) 1 only
    (B) 2 only
    (C) 1 and 3 only
    (D) 2 and 3 only

2. Diseases that can be transmitted by direct contact include:
    1. skin infections
    2. syphilis
    3. malaria
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

3. In which of the following conditions is protective or reverse isolation indicated?
    1. transplant recipient
    2. burns
    3. leukemia
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

4. Which of the following are means of indirect transmission of microorganisms?
    1. vector
    2. fomite
    3. airborne
   (A) 1 only
   (B) 1 and 2 only
   (C) 3 only
   (D) 1, 2, and 3

5. What is the single most effective means of controlling the spread of infectious microorganisms?
   (A) wearing gloves
   (B) wearing masks
   (C) handwashing
   (D) sterilization

6. What is the name of the practice that serves to retard the growth of pathogenic bacteria?
   (A) antisepsis
   (B) bacteriogenesis
   (C) sterilization
   (D) disinfection

7. Which of the following diseases require(s) airborne precaution?
    1. TB
    2. varicella
    3. rubella
   (A) 1 only
   (B) 1 and 2 only
   (C) 3 only
   (D) 1, 2, and 3

8. The radiographer must perform the following procedure(s) prior to entering an isolation room with a mobile x-ray unit:
   1. wear gown and gloves
   2. wear gown, mask, and gloves
   3. clean the mobile x-ray unit
   (A) 1 only
   (B) 2 only
   (C) 1 and 3 only
   (D) 2 and 3 only

9. Lyme disease is a condition caused by bacteria carried by deer ticks. The tick bite may cause fever, fatigue, and other associated symptoms. This is an example of transmission of an infection by:
   (A) droplet contact
   (B) the airborne route
   (C) a vector
   (D) a vehicle

10. Which of the following can be transmitted via infected blood?
    1. TB
    2. AIDS
    3. HBV
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

Answers and Explanations

1. (D) *Pathogens* are causative agents—microorganisms capable of producing disease. Pathogens termed *opportunistic* are usually harmless, but can become harmful if introduced into a part of the body where they do not normally reside, or when introduced into an immunocompromised host. *Bloodborne* pathogens reside in blood and can be transmitted to an individual exposed to that blood or body fluids of the exposed individual. Common bloodborne pathogens include hepatitis C, hepatitis B, and human immunodeficiency virus (HIV). Because radiography often involves exposure to sickness and disease, the radiographer must be aware of, and conscientiously practice, infection control and effective preventive measures.

2. (B) Infectious microorganisms can be transmitted from one patient to other patients or to health care workers, and from health care workers to patients. They are transmitted by means of either direct or indirect contact. *Direct contact* involves touch. Diseases transmitted by direct contact include skin infections such as boils and sexually transmitted diseases such as syphilis.

   Indirect contact involves transmission of microorganisms via airborne contamination, fomites, and vectors. Pathogenic microorganisms expelled from the respiratory tract through the mouth or nose can be carried as evaporated droplets through the air or on dust and settle on clothing, utensils, or food. Patients with respiratory tract infections and disease transported to the radiology department, therefore, should wear a mask to prevent such transmission

during a cough or sneeze; it is not necessary for the health care professional or transporter to wear a mask (as long as the patient does). Many such microorganisms can remain infectious while awaiting transmission to another host. A contaminated inanimate object such as a food utensil, doorknob, or IV pole is referred to as a fomite. A vector is an insect or animal carrier of infectious organisms, such as a rabid animal (e.g., rabies; although the rabid animal is the vector, rabies is contracted by contact), a mosquito that carries malaria, or a tick that carries Lyme disease.

3. (D) *Protective, or reverse, isolation is used to keep the susceptible patient from becoming infected.* Burn patients who have lost their means of protection (their skin) have increased susceptibility to bacterial invasion. Patients whose immune systems are compromised (e.g., transplant recipients, leukemia) are unable to combat infection and are more susceptible to infection. These patients are treated with strict isolation technique, taking care to protect the *patient* from contamination.

4. (D) *Indirect* contact involves transmission of microorganisms via *airborne* contamination, *fomites*, and *vectors*. Pathogenic microorganisms expelled from the respiratory tract through the mouth or nose can be carried as evaporated droplets through the air or on dust and settle on clothing, utensils, or food. A contaminated inanimate object such as a pillowcase, x-ray table, or IV pole is referred to as a *fomite.* A *vector* is an insect or animal carrier of infectious organisms, such as a rabid animal (rabies), a mosquito that carries malaria, or a tick that carries Lyme disease.

5. (C) Health care practitioners must exercise strict infection-control precautions so that they or their equipment will not be the source of nosocomial infection. Contaminated waste products, soiled linen, and improperly sterilized equipment are all means by which microorganisms can travel. Not every patient will come in contact with these items; however, the health care professional is in constant contact with patients and is therefore a constant threat to spread infection. *Microorganisms are most commonly spread by way of the hands; therefore, handwashing before and after each patient is the most effective means of controlling the spread of microorganisms.* Disinfectants, antiseptics, and germicides are used in many handwashing liquids to kill microorganisms.

6. (A) *Antisepsis* retards the growth of pathogenic bacteria. Alcohol is an example of an antiseptic. *Medical asepsis* refers to the destruction of pathogenic microorganisms through the process of *disinfection.* Examples of disinfectants are hydrogen peroxide, chlorine, and boric acid. *Surgical asepsis* (*sterilization*) refers to the removal of all microorganisms and their spores (reproductive cells) and is practiced in the surgical suite. *Bacteriogenesis* refers to the formation of bacteria.

7. (B) *Airborne precaution* is employed with patients suspected or known to be infected with the tubercle bacillus (TB), chickenpox (varicella), and measles (rubeola). Airborne precaution requires the patient to wear a mask to avoid the spread of acid-fast bacilli (in bronchial secretions) and other pathogens during coughing. If the patient is unable or unwilling to wear a mask, the radiographer must wear one. An N95 Particulate Respirator is the mask required for health care workers. The radiographer should wear gloves, but a gown is required only if flagrant contamination is likely. Patients with airborne precautions require a private, specially ventilated (negative pressure) room (Table 3–1).

A private room is indicated for all patients on *droplet precaution*, that is, diseases transmitted via large droplets expelled from the patient while speaking, sneezing, or coughing. The pathogenic droplets can infect others when they come in contact with mouth or nasal mucosa or conjunctiva. Rubella ("German measles"), mumps, and influenza are among the diseases spread by *droplet* contact; a private room is required for the patient, and health care practitioners must wear a mask.

8. (B)   When performing bedside radiography in an isolation room, the radiographer should wear a gown, gloves, and mask. The cassettes are prepared for the examination by placing a pillowcase over them to protect them from contamination. Whenever possible, one person should manipulate the mobile unit and remain "clean," while the other handles the patient. The mobile unit should be cleaned with a disinfectant before *exiting* the patient's room.

9. (C)   Lyme disease is a condition that results from transmission of an infection by a vector ("deer" tick). *Vectors* are insects and animals carrying disease. *Droplet contact* involves contact with secretions (from the nose, mouth) that travel via a sneeze or cough. *Airborne* route involves evaporated droplets in the air that transfer disease.

10. (C)   Epidemiologic studies indicate that HIV and AIDS can be transmitted only by intimate contact with blood or body fluids of an infected individual. This can occur through the sharing of contaminated needles, through sexual contact, from mother to baby at childbirth, and from transfusion of contaminated blood. HIV and AIDS cannot be transmitted by inanimate objects. HBV is another bloodborne infection and affects the liver. It is thought that more than one million people in the United States have chronic hepatitis B and, as such, can transmit the disease to others. Acid-fast bacillus isolation is employed with patients suspected or known to be infected with the TB. Acid-fast bacillus isolation requires that the patient wear a mask to avoid the spread of acid-fast bacilli (in bronchial secretions) during *coughing*.

Medical Emergencies and Contrast Media

4
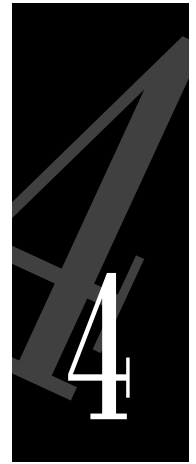
I. ROUTINE MONITORING

Routine monitoring of patient condition, physical signs, and *vital signs* was discussed in Chapter 2. Routine and continuous monitoring of patient condition is essential, so that any change in condition can be addressed *before* it becomes a medical emergency.

In review, obtaining *vital signs* involves the measurement of *body temperature, pulse rate, respiratory rate*, and *arterial blood pressure*. Elevated body temperature, or *fever*, often signifies infection. Symptoms include malaise; increased pulse and respiratory rates; flushed, hot, and dry skin; and occasional chills.

Normal body temperature varies from person to person depending on several factors, including age. Normal adult body temperature taken orally is 98.6°F (37°C). *Rectal* temperature is generally 0.5° to 1.0° *higher*, whereas *axillary* temperature is usually 0.5° to 1.0° *lower*. Slight variation of 0.5° to 1.0° is generally considered within normal limits. Body temperature is usually lowest in the early morning and highest at night. Infants and children have a wider range of body temperature than adults; the elderly have lower body temperatures than others.

Superficial arteries are best suited for determination of *pulse rate*. The five most easily palpated pulse points are the radial, carotid, temporal, femoral, and popliteal pulse. The radial pulse is the most frequently used. The apical pulse, at the apex of the heart, can be evaluated with the use of a stethoscope.

Respirations should be counted after counting the pulse rate, while still holding the patient's wrist. *The normal respiratory rate is 12 to 18 breaths per minute*. The respiratory rate of young children is higher, up to 30 breaths per minute. While the radiographer is counting respirations, he or she should be assessing the respiratory pattern (even, uneven) and depth (normal, shallow, deep) as well.

Blood pressure within vessels is greatest during ventricular *systole* (contraction) and lowest during *diastole* (relaxation). Blood pressure is recorded with the systolic pressure on top and the diastolic pressure on the bottom, as in 100/70 (read, "one hundred over seventy"). Normal

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Vital Signs

- temperature
- pulse
- respiration
- blood pressure

Normal Body Temperatures	
Adult	
Oral	98.6°F
Rectal	99.1°F–99.6°F
Axillary	97.6°F–98.1°F
Infant to age 4 y	99°F–99.7°F
Child aged 5–13 y	97.8°F–98.6°F

Common Pulse Points	
Artery	**Location**
Radial	Wrist; at base of thumb
Carotid	Neck; just lateral to midline
Temporal	In front of upper ear
Femoral	Inguinal region; groin
Popliteal	Posterior knee

Normal Pulse Rates (beats/min)	
Men	70–72
Women	78–82
Children	90–100
Infants	120

adult systolic pressure ranges between 100 and 140 mm Hg; the normal diastolic range is between 60 and 90 mm Hg. Blood pressure consistently above 140/90 is considered *hypertension.*

The radiographer should be alert to the patient's appearance and condition, and any sudden changes in them, such as changes in the color, temperature, and moistness of the patient's skin. Paleness can indicate weakness; the *diaphoretic* patient has pale, cool skin; *fever* is frequently accompanied by hot, dry skin; "sweaty" palms might indicate *anxiety*, a patient who is *cyanotic* (bluish lips, mucous membranes, nail beds) needs oxygen and requires immediate attention.

II. PATIENT SUPPORT EQUIPMENT

A. OXYGEN

One of a human being's most basic physiologic needs is an adequate supply of oxygen. Diminished oxygen supply (*hypoxia*) can result from an airway obstructed by *aspirated* material, laryngeal edema as a result of *anaphylaxis*, or a pathologic process such as *emphysema.* The radiographer must be knowledgeable enough to recognize symptoms and respond appropriately. The proper response to respiratory distress might be to perform the *Heimlich maneuver*, to summon the code team, or to check the flow of oxygen already in place.

Oxygen is taken into the body and supplied to the blood to be delivered to all body tissues. Any tissue(s) lacking in, or devoid of, an adequate blood supply can suffer permanent damage or die. Oxygen may be required in cases of severe anemia, pneumonia, pulmonary edema, and shock.

Symptoms of inadequate oxygen supply include *dyspnea*, *cyanosis, diaphoresis*, and distention of the veins of the neck. The patient who experiences any of these symptoms will be very anxious and must not be left unattended. The radiographer must *call* for help, assist the patient to a sitting or semi-*Fowler position* (the recumbent position makes breathing more difficult), and have oxygen and emergency drugs available.

In areas that patients will occupy for extended periods (e.g., patient department, operating room, emergency department, and radiology department), oxygen is available through wall outlets at a pressure of 60 to 80 psi (pounds per square inch) equipped with an easily adjustable flowmeter to regulate the administration of oxygen. It is important to administer *humidified* oxygen to avoid drying and irritation of the respiratory mucosa. In other areas, oxygen will be available in tanks having one valve to regulate its flow and another to indicate the amount of oxygen remaining in the tank.

There are various devices available to deliver oxygen to the patient. Their use is determined by the amount of oxygen required by the patient. They are frequently classified as *low* or *high flow.*

The *nasal cannula* is the most frequently used device and is used to supplement the oxygen in room air. The nasal cannula is a low-flow oxygen device. It is convenient and fairly comfortable for the patient, although it can be somewhat easily moved out of position, during sleep, for example.

There are various types of oxygen *masks* available for delivery of oxygen. The *simple face mask* (low flow) is best suited for short-term oxygen therapy. With extended use, the plastic becomes warm and sticky. Communication is difficult, the mask is easily displaced, and it must be removed at mealtime. The *partial rebreathing mask* (low flow) and *nonrebreathing mask* (low flow) deliver more precise concentrations of oxygen to the patient.

Mechanical ventilators (high flow) are most frequently encountered in a hospital critical care unit. Patients on ventilators have an artificial airway in place, while the ventilator controls the respiratory rate and volume.

Although oxygen is not a flammable substance, it does support combustion, so care must be taken to avoid spark or flame where oxygen is in use.

B. Suction

The use of a *suction* device is occasionally required to maintain a patient's airway by *aspirating* secretions, blood, or other fluids when the patient is unconscious or otherwise unable to do so. Suction is available from a wall outlet, similar to oxygen, or as a mobile apparatus. It is unlikely that the radiographer would be required to suction a patient, but he or she might be needed to assist with the procedure. Suction tubing must have a disposable catheter attached to its end for collection of airway secretions. The radiographer should be familiar with the location of suction equipment and replacement disposable catheters.

C. Intravenous Equipment and Venipuncture

Intravenous fluids and/or medication are administered to meet specific patient needs. Medications administered intravenously result in rapid patient response; medications are delivered in this fashion in emergency and critical situations. Patients who are dehydrated and require fluid and electrolyte replacement will have these (normal saline or D5W) administered intravenously. *Intravenous (IV) equipment* includes needles, syringes, fluids such as normal saline or D5W (a solution of 5% dextrose in water), IV catheters, heparin locks, IV poles, and infusion sets.

The diameter of a needle is identified as its *gauge*. As the gauge increases, the *bore* becomes smaller. Hence, an 18-gauge needle has a larger diameter bore than a 23-gauge needle. Hypodermic needles are generally used for phlebotomy, while butterflies and IV catheters are used more frequently for injections such as contrast media. If an *infusion* injection is required, an IV catheter is generally preferred. The *hub* of the hypodermic needle is attached to a syringe, whereas the hub of the butterfly tubing or IV catheter may be attached to a syringe or an IV bottle or bag via an IV infusion set.

Medication or contrast material is often mixed with normal saline or D5W. Some IV medications are given at intervals through an established heparin lock. A heparin lock consists of a venous catheter established for a certain length of time to make a vein available for medications that have to be administered at frequent intervals. This helps prevent the formation of scarred, sclerotic veins as a result of frequent injections at the same site. When repeated administrations of

Needles:
gauge: identifies diameter of needle bore/lumen
larger gauge: smaller bore diameter
smaller gauge: larger bore diameter
hub: part of needle attached to syringe or IV tube

medication are needed, an IV catheter is often used. This is a two-part device consisting of a solid (without a bore) needle and a flexible plastic catheter. After the needle is introduced into the vein, the catheter is advanced over the needle, secured with tape, and the needle removed.

The IV bottle or bag should be hung 18 to 24 inches *above the level of the vein*. If placed lower than the vein, the solution will stop flowing and blood will return into the tubing. If hung too high, the solution can run too fast. Occasionally, the position of the needle or catheter in the vein will affect the flow rate. If the bevel is adjacent to the vessel wall, flow may decrease or stop altogether. Often, just changing the position of the patient's arm will remedy the situation.

Extravasation occurs when medication or contrast medium is introduced into the tissues surrounding a vein rather than into the vein itself. It can occur when the patient's veins are particularly deep or small. The needle should be removed, pressure applied to prevent formation of a *hematoma*, and *warm moist heat* applied to relieve pain.

The *antecubital* vein is the most commonly used *venipuncture* site for contrast medium administration. It is not used for infusions that take longer than 1 hour because of its location at the bend of the elbow. The *basilic* vein, located on the dorsal surface of the hand, is used when the antecubital vein is inaccessible. The *cephalic* vein may also be used. A *warm compress* can be applied to the area of intended injection to *increase area blood circulation* and improve access to the intended vein. The needle is inserted into the vein at a 15-degree angle; blood will flow back into the tubing when the needle is correctly positioned. Strict aseptic technique must be used for all IV injections.

D. TUBES

Following thoracotomy or other thoracic surgery, a *chest tube* may be put in place for the purpose of treating pneumothorax or hemothorax (removing air and/or fluid from the pleural space). The chest drainage system usually has three compartments: one is the suction control chamber, another is the collection chamber, and the third is the water seal chamber, which prevents atmospheric air from entering the chest cavity. The drainage system must always be kept below the level of the patient's chest.

Radiographers might encounter chest drainage systems when performing mobile radiographic examinations on postsurgical patients. The radiographer must be careful not to disturb chest tubes during patient or equipment manipulation, and to immediately report any sudden change in patient condition and/or patient complaint of chest pain or discomfort.

Gastrointestinal tubes can be *nasogastric* (NG), *nasointestinal* (NI), or *nasoenteric* (NE). NG tubes, such as the Dobbhoff tube, are used as feeding tubes for patients whose condition prevents normal swallowing. NI/NE *tubes* can be used following digestive tract surgery to remove gastric fluids and/or air (decompression). NG and NI/NE tubes may be single or double *lumen* and can sometimes be temporarily disconnected for radiographic examinations. The *single*-lumen NG or NI/NE tube can be clamped, but the *double*-lumen tube must *never* be clamped. If clamped, the walls of the double-lumen tube could adhere permanently. Instead, the tip of a syringe is inserted into the

lumen and the syringe and tube then pinned (open side up) to the patient's gown. Care must be taken not to disturb the placement of the gastrointestinal tube.

Urinary catheterization may be employed postsurgically to assist in the healing of tissues or to assist the incontinent patient in the elimination of urine. It is essential that equipment used for the catheterization procedure is sterile, and that subsequent care is given to the catheterized patient to prevent infection, as *urinary tract infections (UTIs) account for the greatest number of nosocomial infections*. Urinary catheters are made of plastic, rubber, PVC (polyvinylchloride), and silicone. The type selected is dependent on how long it is expected to remain in the bladder. Plastic and rubber are generally employed for short-term use, while PVC or silicone catheters can be in place for up to 3 months. The urine collection bag must be *kept below the level of the bladder*; backflow of urine into the bladder can lead to infection. When transporting or transferring the catheterized patient, care must be taken that the catheter does not become entangled or dislodged.

III. ALLERGIC REACTIONS

A. ALLERGY

Medications are administered to meet specific patient needs; medications can have harmless side effects in some individuals. If the *side effect* offsets the benefit, the medication might be discontinued. Medications can also have a *toxic effect*. Toxic effects can occur because of sensitivity, overdose, or poor metabolism. An *antidote* is used to treat a toxic effect.

An *allergy* is an abnormal, acquired immune response to a substance (i.e., *allergen*) that would not usually trigger a reaction. An initial exposure to the allergen (i.e., *sensitization*) is required. Subsequent contact with the allergen then results in an *inflammatory response*. Examples of such responses include hay fever, urticaria, allergic rhinitis, eczema, and bronchial asthma. Allergens can be introduced into the body via contact, ingestion (e.g., food), inhalation (e.g., dust, pollen), or injection (e.g., medication, drugs). Allergic reactions of particular importance to the radiographer involve the use of *latex* products and *contrast media*.

B. LATEX

Latex products are manufactured from a milky fluid derived from the rubber tree and several chemicals are added to the fluid during the manufacture of commercial latex. Some proteins in latex can produce mild to severe allergic reactions. Additionally, chemicals added during processing can also cause skin rashes. When *powdered* latex gloves are worn, more latex proteins reach the skin. Also, when gloves are changed, latex protein/powder particles get into the air, where they can be inhaled and come in contact with body membranes. Studies have indicated that when unpowdered gloves are worn, there are extremely low levels of the allergy-producing proteins present.

A wide variety of products contain latex: medical supplies, personal protective equipment, and many household items. The intermittent use of latex products generally causes no health problems.

Medical Equipment That Could Contain Latex

Disposable gloves
Tourniquets
Blood pressure cuffs
Stethoscopes
Intravenous tubing
Oral and nasal airways
Enema tips
Endotracheal tubes
Syringes
Electrode pads
Catheters
Wound drains
Injection ports

However, workers in the health care industry (physicians, technologists, nurses, dentists, etc.) are at risk for developing *latex allergy* because they use latex gloves frequently. Also at risk are other workers with frequent glove use (hairdressers, housekeepers, food service workers, etc.) and those involved in the manufacture of latex products.

1. Irritant Contact Dermatitis. The most common reaction to latex products is *irritant contact dermatitis.* It is characterized by development of irritated dry, itchy areas on the skin, usually the hands. Irritant contact dermatitis is a skin irritation resulting from the use of gloves and/or from exposure to other workplace products and chemicals. Irritant contact dermatitis can also be caused by repeated handwashing, incomplete drying, use of sanitizers, and exposure to glove powder. *Irritant contact dermatitis* is not defined as a true allergy.

2. Allergic Contact Dermatitis. Allergic contact dermatitis (*delayed hypersensitivity*) results from exposure to the chemicals added to latex during its manufacture. These chemicals can cause skin reactions like those produced by poison ivy, that is, the rash usually begins 24 to 48 hours following contact and can lead to oozing skin blisters and/or spread to areas away from the area of initial contact. Wearing latex gloves during episodes of hand dermatitis may increase skin exposure and the risk of developing latex allergy.

3. Latex Allergy. Latex allergy (*immediate hypersensitivity*) can be a much more serious reaction to latex. Certain proteins in latex can cause sensitization and, although the amount of exposure needed to cause this sensitization is unknown, even very low-level exposure can trigger allergic reaction in some sensitized individuals.

Reactions usually begin within minutes of exposure to the latex, but can occur hours later. *Mild* reactions involve skin redness, hives, or itching. *More severe* reactions are respiratory, for example, itchy eyes, runny nose, sneezing, difficulty breathing, and wheezing. A *life-threatening reaction* such as shock is rarely the first sign of latex allergy. Such reactions are similar to those seen in some allergic persons after a bee sting.

Health care professionals should help educate latex-sensitized persons about the latex content of common objects.

Types of Reactions to Latex

- Irritant contact dermatitis
- Allergic contact dermatitis (delayed hypersensitivity)
- Latex allergy (immediate hypersensitivity)

■ *SUMMARY*

- ■ **Obtaining vital signs involves the measurement of body temperature, pulse rate, respiratory rate, and arterial blood pressure.**
- ■ **Symptoms of inadequate oxygen supply include dyspnea, cyanosis, diaphoresis, and neck vein distention; seated and semi-Fowler positions are helpful for the dyspneic patient.**
- ■ **Oxygen is usually available through wall outlets with adjustable flowmeters, or in tanks having a flow-regulation valve and an indicator showing the quantity of oxygen left in the tank.**

- Oxygen can be administered via nasal cannula, masks, or mechanical ventilators; oxygen supports combustion so it must be used away from flame.
- Suction devices are used for aspiration of secretions; suction is available from wall outlets or portable suction mechanisms.
- Needle size is indicated by gauge; larger gauge = smaller needle bore.
- Butterfly sets or IV catheters are generally used for IV injection of a contrast medium; the antecubital vein is generally used for injection of contrast material.
- A heparin lock makes a vein accessible for medications administered at frequent intervals.
- IV solutions should be elevated 18 to 24 inches above the injection site.
- Chest tubes function to remove fluids or air from the thoracic cavity.
- NG and NI/NE tubes assist in the removal of gastric secretions or air and/or are used for the administration of water-soluble contrast material.
- Urinary collection bags must be kept below the level of the bladder; to prevent UTIs, catheterization procedures must be sterile.
- The radiographer must be alert for any sudden changes in patient condition.
- An *allergy* is an abnormal, acquired immune response.
- Allergens can be introduced into the body via contact, ingestion, inhalation, or injection.
- Initial *sensitization* to the allergen is required; subsequent contact results in an *inflammatory response.*
- Proteins in *latex* can produce mild-to-severe allergic reactions.
- Types of reactions to latex include irritant contact and delayed or immediate hypersensitivity.

IV. CONTRAST MEDIA

A. *TERMINOLOGY AND BASIC CONCEPTS*

1. Patient History. It is important that the radiographer obtain a short but adequate, pertinent patient history of why the examination has been requested. Because patients are rarely examined or interviewed by the radiologist, observations and information obtained by the radiographer can be a significant help in making an accurate diagnosis.

2. Routes of Administration. Although radiographic contrast media are usually administered orally or intravenously, there are a number of *routes* and methods of drug administration. Drugs and medications may be administered either *orally* or *parenterally. Parenteral* refers to any route other than via the digestive tract and includes *topical, subcutaneous, intradermal, intramuscular, intravenous,* and *intrathecal.*

3. Purpose. The purpose of a *contrast medium* is to artificially increase subject contrast in body tissues and areas where there is little

Methods of Administration
Oral
PO (by mouth), through digestive system
Parenteral
Topical
Subcutaneous
Intradermal
Intramuscular
Intravenous
Intrathecal

natural subject contrast. The abdominal viscera, for example, have very little subject contrast; that is, it is very difficult to identify specific organs or distinguish one organ from another. However, if a contrast agent is introduced into a particular organ such as the kidney or stomach, or into a vessel such as the aorta or one of its branches, we may more readily visualize these anatomic structures and/or evaluate physiologic activity.

4. **Types of Agents.** *Contrast media* or *contrast agents* can be described as either positive (radiopaque) or negative (radiolucent). *Positive*, or *radiopaque*, contrast agents have a higher atomic number than the surrounding soft tissue, resulting in a greater attenuation or absorption of x-ray photons. They, therefore, produce higher radiographic contrast. Examples of positive contrast media are *iodinated agents* (both water and oil based) and *barium sulfate* suspensions. The inert characteristics of barium sulfate render it the least *toxic* contrast medium. On the other hand, iodinated contrast media have characteristics that increase their likelihood of producing *side effects* and reactions.

Negative, or radiolucent, contrast agents used are *air* and various *gases*. Because the atomic number of air is also quite different from that of soft tissue, high subject contrast is produced. Carbon dioxide is absorbed more rapidly by the body than air.

Negative contrast is often used *with* positive contrast in examinations termed *double-contrast studies*. The function of the positive agent is usually to *coat* the various parts under study, while the air *fills* the space and permits visualization through the gaseous medium. Examinations that frequently use double-contrast technique are barium enema (BE), upper gastrointestinal (UGI) series, and arthrography.

B. Scheduling and Preparation Considerations

1. Multiple Examinations. When the patient must be scheduled for multiple x-ray examinations, each requiring the use of a contrast medium, the examinations must be scheduled in the correct sequence. For example, if a particular patient must be scheduled for a UGI series, BE, and intravenous urogram (IVU), what sequence will permit optimal visualization of the required structures? Remember that it is important that residual barium not overlie structures of interest. Radiographic examinations of the gallbladder (GB) are rarely requested today, but should that examination be requested, the accompanying chart indicates when that examination would be scheduled among the others.

Generally speaking, the examinations with a contrast medium that is excreted quickly and completely should be scheduled first. Therefore, the IVU should be scheduled first, and then the GB, if requested. If the UGI series were scheduled next, residual barium would be in the large bowel the next day, thus preventing adequate investigation. So the BE should be scheduled third; any residual barium should not interfere with a UGI examination, although a preliminary scout image should first be taken in each case.

If it is desired to expedite the studies, perhaps to reduce the length of hospital stay, some examinations, for example, GB and IVU, can be performed on the same day. If the patient's GB is studied first and a *fatty meal* is used to evaluate its emptying function, there should be little contrast medium left to obscure the right urinary collecting

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Contrast Media

Positive (radiopaque)
- barium sulfate
- iodinated

Negative (radiolucent)
- air
- other gases

Sequencing and Combining Contrast Examinations

Sequence
IVU
GB
BE
GI

Examinations that can be combined
GB and IVU
IVU and BE
GB and GI

system. Another example of paired examinations is the IVU and BE. IVU contrast medium is excreted rapidly by the kidneys and should not interfere with visualization of the barium- and air-filled large bowel.

2. Patient Preparation. Patient preparation is somewhat different for each of these examinations. An iodinated contrast agent, usually in the form of several pills, is taken by the patient the evening before a scheduled *GB* examination and only water is allowed the morning of the examination. The patient scheduled for an *UGI* series must receive NPO (nothing by mouth) after midnight. A BE (*lower GI*) requires that the large bowel be very clean prior to the administration of barium; this requires the administration of *cathartics* (laxatives) and cleansing enemas. Preparation for an *IVU* requires that the patient be NPO after midnight; some institutions also require that the large bowel be cleansed of gas and fecal material. Aftercare for barium examinations is very important. Patients are typically instructed to take milk of magnesia, increase their intake of fiber, drink plenty of water, to expect change in stool color until all barium is evacuated, and to call their physician if they do not have a bowel movement within 24 hours. Because water is removed from the barium sulfate suspension in the large bowel, it is essential to make patients understand the importance of these instructions to avoid barium impaction in the large bowel.

Patient Preparation

GB
Iodinated contrast evening before examination; water only in AM
UGI
NPO after midnight
BE
Cathartics, cleansing enemas
IVU
NPO after midnight, cleansing enemas, empty bladder before scout film

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C. CONTRAINDICATIONS AND PATIENT EDUCATION

Radiopaque contrast media are most frequently employed for radiographic procedures. *Barium sulfate* is one type of radiopaque contrast agent that is used to visualize the GI tract. Mixed with water, it forms a suspension that is usually administered orally for demonstration of the upper GI tract (esophagus, stomach, and progression through the small intestine), and rectally for demonstration of the lower GI tract (large intestine).

Barium sulfate is *contraindicated* if a *perforation* is suspected somewhere along the course of the GI tract (e.g., a perforated diverticulum or gastric ulcer). Barium could escape into the peritoneal cavity and result in peritonitis. A water-soluble (absorbable) iodinated contrast medium is generally used instead of barium in these cases. The water-soluble preparations are available as ready-mixed liquid or as powder requiring appropriate dilution with water. A patient with an NG tube can have the contrast medium administered through it for the purpose of locating and studying any site of obstruction. This procedure is called *enteroclysis*.

Patients can experience constipation following a GI or BE examination unless proper *aftercare instructions* are given to the patient upon completion of the examination. Barium preparations in the large bowel become thickened as a result of absorption of their fluid content, a process called *inspissation*, causing symptoms from mild constipation to bowel obstruction. Constipation can be a serious problem, particularly in the elderly, and fecal impaction or obstruction can result. It is essential that the radiographer provide clear instructions for follow-up care, especially to outpatients. Patients are usually advised to expect light-colored stools for the next few days, to drink plenty of fluids, to increase their intake of fiber, and to take a mild laxative such as milk of magnesia following a barium study.

Qualities of Iodinated Contrast Agents That Contribute to Discomfort, Side Effects, and Reactions

Viscosity. More viscid (thick, sticky) agents are more difficult to inject and produce more heat and vessel irritation; the higher the concentration, the greater the viscosity; viscosity also increases as room temperature decreases.
Toxicity. Potential toxicity is greater with higher-concentration agents and ionic agents.
Miscibility. Contrast agents should be readily miscible (able to mix) with blood.
Osmolality. Low-osmolality agents have fewer particles in a given amount of solution and are less likely to provoke an allergic reaction.

Iodinated contrast agents are another type of radiopaque contrast medium. They may be *oil base or water base.* Oil-base contrast media are infrequently used today. They are not water soluble, not readily absorbed by the body, and remain in body tissues for lengthy periods of time. Examinations that can employ the use of oil-base contrast agents, though infrequently performed, are lymphangiograms, sialograms, and bronchograms. Water-base contrast media may be *ionic* or *nonionic.* These agents are principally used to delineate the urinary and vascular systems, the GB, and the GI tract when barium sulfate is contraindicated.

Ionic contrast media have a *higher osmolality*, that is, a greater number of particles in a given amount of solution. *Nonionic*, or *low osmolality*, contrast agents are used especially with children, the elderly, patients with renal disease, patients having a history of *allergic* reaction to contrast media, or patients having multiple allergies. Side effects and allergic reactions are less likely and less severe with these media. Nonionic contrast agents are associated with less injection discomfort, and a lower incidence of *nausea*, vomiting, and cardiovascular complications. Their only disadvantage is their cost, which is far greater than that of ionic contrast agents.

Iodinated contrast agents can become more *viscous* at normal room temperature, making injection more difficult. Warming the contrast to body temperature, in a special warming oven, reduces *viscosity*, permitting an easier and more comfortable injection.

Diabetic patients who are scheduled for a UGI series are generally instructed to withhold their morning insulin until the meal following the examination. Should the patient take insulin before the examination and remain NPO, a reaction might occur, especially if the examinations were delayed for any reason. UGI examinations on diabetic patients should be among the first examinations scheduled each day and priority should be given to these patients.

Reactions can Result from:
• ingestion, • injection, or • absorption....   of the sensitizing agent

D. REACTIONS AND EMERGENCY SITUATIONS

Anaphylaxis is a life-threatening allergic reaction that affects millions of Americans every year and can be caused by a variety of allergens. *Anaphylaxis* can result from the body's sensitivity and allergic reaction to certain foods, insect venom, medications, anesthetics, and latex. The reaction can be the result of *ingestion, injection*, or *absorption* of the sensitizing agent.

Because iodinated contrast media are potentially toxic, the radiographer must be knowledgeable and alert to the possible adverse effects of their use (although the risk of a life-threatening reaction is relatively rare). Reactions to contrast media generally occur within 2 to 10 minutes following injection and can affect all body systems.

The body's response to the introduction of contrast material is the production of histamines, which brings about various symptoms. Symptoms of a *mild* reaction include a flushed appearance, nausea, a metallic taste in the mouth, nasal congestion, a few hives (*urticaria*), and, occasionally, vomiting. Treatment of these minor symptoms generally consists of administration of either an *antihistamine* such as diphenhydramine (Benadryl), which blocks the action of the histamine and reduces the body's inflammatory response, or an epinephrine to raise the blood pressure and relax the bronchioles (see Table 4–1).

TABLE 4–1. COMMON MEDICATIONS AND THEIR APPLICATION

TYPE	EFFECT	EXAMPLE
Adrenergic	Vasopressor, stimulates sympathetic nervous system: increases BP, relaxes smooth muscle of respiratory system	Epinephrine (Adrenalin)
Analgesic	Relieves pain	Aspirin, acetaminophen (Tylenol), codeine, meperidine (Demerol)
Antiarrhythmic	Relieves cardiac arrhythmia	Quinidine sulfate, lidocaine (Xylocaine)
Antibacterial	Stops growth of bacteria	Penicillin, tetracycline, erythromycin
Anticholinergic	Depresses parasympathetic system	Atropine, scopolamine, belladonna
Anticoagulant	Inhibits blood clotting; keeps IV lines and catheters free of clots	Heparin, warfarin
Anticonvulsant	Prevents/relieves convulsions	Carbamazepine (Tegretol) Phenytoin (Dilantin)
Antidepressant	Prevents/alleviates mental depression	Fluoxetine (Prozac) Paroxetine (Paxil) Sertraline (Zoloft) Nortriptyline (Pamelor, Aventyl)
Antihistamine	Relieves allergic symptoms	Diphenhydramine hydrochloride (Benadryl)
Antipyretic	Reduces fever	Aspirin, acetaminophen
Antitussive	Reduces coughing	Dextromethorphan (Romilar)
Barbiturate	Depresses CNS, decreases BP and respiration, and induces sleep	Phenobarbital sodium (Nembutal), secobarbital sodium (Seconal)
Cardiac stimulant	Increases cardiac output	Digitalis
Cathartic	Laxative, relieves constipation, prepares colon for diagnostic tests	Bisacodyl (Dulcolax), castor oil
Diuretic	Stimulates urine	Furosemide (Lasix)
Emetic	Stimulates vomiting	Ipecac
Hypoglycemic	Lowers blood glucose	Insulin, chlorpropamide (Diabinese), metformin (Glucophage)
Narcotic (opioid)	Sedative/analgesic; potentially addictive	Morphine, codeine, meperidine (Demerol)
NSAID	Nonsteroidal pain relief	Aspirin (Bayer, and others) Ibuprofen (Motrin, and others) Naproxen (Aleve, and others)
Stimulant	Stimulates the CNS	Caffeine, amphetamines
Tranquilizer	Reduces anxiety	Diazepam (Valium)
Vasodilator	Relaxes and dilates blood vessels, decreases BP	Nitroglycerine, verapamil

Potentially life-threatening responses include respiratory failure, shock, and death within minutes. A very serious and life-threatening response is an anaphylactic reaction. *Early* symptoms of an anaphylactic reaction include itching of the palms and soles, wheezing, constriction of the throat (possibly caused by laryngeal edema), *dyspnea, dysphagia, hypotension*, and *cardiopulmonary arrest.* The radiographer must maintain the patient's airway, summon the radiologist, and call a "code." The radiographer should then be prepared to stay with the patient and assist until the arrival of the code team.

The diabetic patient requires different and special attention. Metformin (Glucophage) is an antidiabetic agent indicated for the treatment of type 2 diabetes mellitus. Radiologic examinations requiring the use of intravascular iodinated contrast agents can lead to acute alteration of renal function and have been associated with lactic acidosis in patients taking metformin. The manufacturer recommends that patients taking metformin discontinue it at the time of or prior to the x-ray examination and withhold it for 48 more hours following the examination. The medication should be continued only after *adequate renal function* has been indicated by blood test (blood urea nitrogen [BUN], creatinine).

■ *SUMMARY*

- Multiple radiologic examinations must be scheduled in a sequence that will allow prompt and adequate visualization of structures of interest.
- Patients must be appropriately prepared for the contrast examination(s) for which they are scheduled.
- Drugs and medications may be administered orally or parenterally.
- *Parenteral* administration includes topical, oral, subcutaneous, intradermal, IM, IV, and intrathecal.
- Artificial contrast media function to increase insufficient subject contrast; artificial contrast media can be positive (radiopaque) or negative (radiolucent).
- Positive contrast media include barium sulfate and iodinated (oil- or water-based) agents.
- Qualities of iodinated contrast media that contribute to their risk include viscosity, toxicity, and miscibility.
- Negative and positive contrast agents are often used together in "double-contrast" studies.
- Water-soluble (absorbable) contrast agents are used in place of barium sulfate when visceral *perforation* is suspected.
- Patients require clear and complete postprocedural instructions, particularly following barium examinations.
- Nonionic iodinated contrast agents produce far fewer side effects than do their ionic counterparts; nonionic contrast agents are more expensive.
- Reactions to ionic agents usually occur within 2 to 10 minutes following injection.
- Symptoms of a mild reaction include mild urticaria, flushing, nausea, nasal congestion, metallic taste; an antihistamine is usually given to the patient.

■ **To avoid renal dysfunction, diabetic patients taking metformin must discontinue its use for 48 hours after administration of an intravascular contrast agent.**

V. OTHER MEDICAL EMERGENCIES

The importance of the radiographer's careful evaluation of his or her patient is never more obvious than when an emergency arises. An emergency is defined as *a sudden change in a patient's condition requiring immediate medical intervention*. Most patients arrive in the radiology department in a stable condition; a few arrive for diagnostic evaluation of a medical crisis. The radiographer must note the patient's condition on arrival and be alert to any subsequent sudden change in that condition. The value of continual review of the knowledge and skills required for emergency situations cannot be overemphasized. Many of these emergencies can occur with little or no warning. Many can be life threatening if not dealt with immediately and correctly.

A. VOMITING

Vomiting patients who are seated or standing should be provided with a basin, tissues, and water for rinsing their mouths. It is essential that the recumbent patient have his or her head turned to the side to prevent choking from aspiration of vomitus. A patient who reports feeling nauseous is often apprehensive and may get some relief by breathing slowly and deeply through his or her mouth.

B. FRACTURES

An *unsplinted* fracture must be moved with great care, with *areas proximal and distal to the fracture site adequately supported*. Any motion is very painful and can result in further injury to tissues surrounding the fracture. Muscle spasm can cause additional pain and can interfere with proper reduction of the fracture. A *splint* should never be removed from an extremity except by or under the direct supervision of the physician. Some splinting devices are not radiolucent and removal may be required before the radiographic examination.

    Rib fractures may be associated with lung trauma, and sternum fractures with heart lacerations. Rib fractures can be very painful—the patient experiences pain just from breathing. *Pelvic* fractures are often associated with injuries to pelvic and abdominal viscera, and extreme care must be taken to avoid *hemorrhage*.

C. SPINAL INJURIES

Patients arriving for radiographic evaluation with possible spinal injuries must not be moved. The position of any sandbags or other supportive mechanisms must not be changed. A *horizontal (cross-table) lateral projection* should be evaluated by the physician first to determine the extent of injury and necessity for further radiographs. If the patient must be placed in a lateral position, the logrolling method is usually advised. *A physician must be present whenever the patient's position is changed.*

D. EPISTAXIS

A nosebleed (*epistaxis*) may be a result of any one of many causes, including *hypertension*, dry nasal mucous membranes, sinusitis, or trauma. The patient should be seated or in a Fowler position. The radiographer should place cold cloths over the patient's nose and back of the neck. Compressing the sides of the nose against the nasal septum for 6 to 8 minutes is also helpful. Continued hemorrhage should be brought to the attention of the physician because cautery or nasal packs might be required.

E. POSTURAL HYPOTENSION

Orthostatic, or postural, *hypotension* is a decrease in blood pressure that occurs on rising to the erect position. It can be severe enough to cause fainting in individuals who have been confined to bed for several days. The radiographer should assist patients slowly and be watchful for signs of weakness.

F. VERTIGO

Objective vertigo is the sensation of having *objects* (or "the room") spinning about the person; *subjective* vertigo is the sensation of the *person* spinning about. It is usually associated with an inner-ear disturbance. Patients experiencing true vertigo (as opposed to dizziness or lightheadedness) are often very nauseous and must be protected from falls by the use of side rails and/or safety belts.

G. SYNCOPE

A patient who reports feeling dizzy or faint should be immediately assisted to a chair. Bending forward and placing the head between the knees will often help relieve the lightheadedness as blood flow to the brain increases. In more severe cases, a patient who cannot be assisted to a chair should be *lowered to a recumbent position*. Elevation of the lower legs or use of the Trendelenburg position is helpful. If the patient loses consciousness, the radiographer should make certain that the airway is open and that clothing, especially at the collar, is loose. Once the patient is recumbent, recovery is usually swift; however, a physician should be notified and the cause of *syncope* identified.

H. CONVULSION

Involuntary muscular contractions and relaxations, often associated with epilepsy, characterize a *convulsion*. *Febrile* convulsions are associated with fever, especially in children. During convulsion, no attempt must be made to restrain the patient's movements. The radiographer's responsibility is to keep the patient from injuring himself or herself. Tight clothing can be loosened and objects that could harm the patient should be moved out of the way. A padded tongue blade or other suitable object should be placed between the patient's teeth to prevent biting the tongue.

I. UNCONSCIOUSNESS

The unconscious patient is unaware of, and unresponsive to, his or her surroundings. Unconsciousness can be caused by a wide variety of conditions including insulin overdose, uremia, concussion, heat *stroke*, and intoxication.

There are various levels of consciousness and the condition of an acutely ill patient can rapidly deteriorate from being fully aware and responsive to diminished or inappropriate responsiveness, to complete unresponsiveness. The unconscious patient must never be left unattended. The radiographer must be alert to changes in the patient's level of consciousness and notify the physician immediately of any deterioration.

J. ACUTE ABDOMEN

Patients arriving for radiographic evaluation having a diagnosis of "acute abdomen" are usually suffering severe abdominal pain, are nauseous and vomiting, and are frequently close to being in shock. These are indeed very sick patients. The radiographer must perform the examination swiftly and efficiently and remain alert for any sudden changes in patient condition.

K. SHOCK

Shock is a general term and is characterized by diminished peripheral blood flow and insufficient oxygen supply to body tissues. Shock can be caused by a number of conditions including allergic reaction, trauma, hemorrhage, myocardial infarction, and infection. The patient is pale and may become cyanotic; the pulse is rapid and weak, breathing is shallow and rapid, and blood pressure drops sharply. The radiographer should keep the patient warm and flat, or in the Trendelenburg position, and be prepared to assist with emergency procedures.

L. SEIZURE

The type of *seizure* known as *petit mal* is so subtle as to go unnoticed by the patient and observer. It is characterized by brief loss of consciousness (10 to 30 seconds) and accompanied by eye or muscle fluttering. A *grand mal* seizure is characterized by loss of consciousness and falling, followed by generalized muscle spasms. The radiographer should remove any objects in the area that could harm the patient and loosen any tight clothing. The patient's head should be turned to the side to allow any secretions to flow from the mouth. A padded tongue blade should be placed between the patient's teeth to help avoid biting the tongue.

M. RESPIRATORY FAILURE

The inability of the lungs to perform ventilating functions is respiratory distress and may be described as *acute* or *chronic*. Acute respiratory distress can be caused by impaired gas exchange processes (requiring positive-pressure ventilation) or airway obstruction (requiring the Heimlich maneuver). Chronic respiratory failure is a result of a disease process that impairs breathing, such as emphysema, bronchitis, *asthma*, or cystic fibrosis.

The radiographer should be able to distinguish between respiratory arrest (absence of chest movement and breathing sounds) and cardiopulmonary arrest (absence of pulse and respiration with loss of consciousness) and be able to initiate life-saving actions.

N. CARDIOPULMONARY ARREST

The *sudden cessation of productive ventilation and circulation* is called cardiopulmonary arrest. The radiographer should be trained in the ABCs (airway, breathing, and circulation) of cardiopulmonary resuscitation and be able to initiate the appropriate care until the arrival of the emergency team.

Many health care facilities require their employees to be certified in basic life-saving skills. It is wise for radiographers to be familiar with skills such as the Heimlich maneuver (abdominal thrust) and cardiopulmonary resuscitation should the need arise.

O. STROKE

A *stroke*, or cerebrovascular accident, is an interference with blood supplied to the brain as a result of occlusion or rupture of a cerebral vessel. If the condition results from a partial vessel occlusion, the interference is usually mild and temporary and is referred to as a *transient ischemic attack*. The patient may experience temporary blindness in one eye, *dysphasia* or *aphasia, hemiparesis* or hemiplegia, or anesthesia.

If the cerebral vessel is totally occluded or ruptures into the brain or subarachnoid space, a much more serious event has occurred. The patient frequently experiences sudden loss of consciousness and one-sided paralysis (*hemiparesis*), although the onset can be slower if the *occlusion* is caused by *thrombus* formation. Other symptoms include speech disturbances and cool, sweaty skin. The patient should have his or her head and shoulders elevated or be in the lateral recumbent position; an open airway must be maintained. Because a stroke can occur without warning at any time, the radiographer should be familiar with the signs of an impending stroke and be able to provide appropriate immediate care.

■ SUMMARY

■ **It is essential that the radiographer be alert for *any* sudden changes in patient condition; how well the radiographer recognizes and is prepared to meet the challenges of emergency situations can largely determine the outcome of the emergency.**

Chapter Exercises

⭐ ***Congratulations!*** *You have completed your review of this chapter. If you are able to answer the following group of comprehensive questions, you can feel confident that you have mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to these multiple-choice questions without first completing the short-answer questions below.*

1. Identify illnesses and conditions that might require supplemental oxygen ***(p. 48).***

2. List the subjective symptoms of inadequate oxygen; identify the body position frequently helpful for the dyspneic patient ***(p. 48).***

3. Describe four methods of oxygen therapy and identify when each might be indicated ***(p. 48, 49).***

4. Identify any hazards involved in the use of oxygen ***(p. 49).***

5. Describe the circumstance(s) in which suction might be required; identify types of suction devices available ***(p. 49).***

6. Identify how needle bore changes with increasing gauge ***(p. 49).***

7. Describe the function and uses of a heparin lock ***(p. 49).***

8. Identify the height at which IV bottles and bags should be hung ***(p. 50).***

9. Explain how contrast medium extravasation should be treated ***(p. 50).***

10. Identify the vein(s) frequently used for introduction of contrast medium ***(p. 50).***

11. Explain the function of chest tubes and precautions that should be taken by the radiographer ***(p. 50).***

12. Describe the function of NG and NI tubes and any precautions that should be taken by the radiographer ***(p. 50).***

13. Describe the function of urinary catheters and any precautions that should be taken by the radiographer ***(p. 51).***

14. Identify the level at which urinary collection bags should be kept ***(p. 51).***

15. Define *allergy*; discuss *sensitization* and *inflammatory response* ***(p. 51).***

16. Distinguish between *side effect* and *toxic effect* *(p. 51)*.

17. List the three types of latex reactions; discuss the effect *powder* can have in latex gloves *(p. 51, 52)*.

18. Discuss the difference between *delayed* and *immediate* hypersensitivity *(p. 52)*.

19. Discuss the importance of observing initial patient condition and any subsequent changes *(p. 53)*.

20. Describe the difference between oral and parenteral drug administration; list five types of parenteral administration *(p. 53)*.

21. Explain the purpose of contrast medium *(p. 53, 54)*.

22. Identify the two types of contrast media, describe their characteristics, and give examples of each *(p. 54)*.

23. Explain how best to correctly schedule multiple contrast examinations on the same patient; identify which examinations can be performed together *(p. 54)*.

24. Explain the appropriate patient preparation for GB, UGI, BE, and IVU/IVP *(p. 55)*.

25. Explain why a diabetic patient who is required to receive nothing by mouth beginning the preceding midnight should be scheduled as the first AM appointment *(p. 56)*.

26. Describe the risks associated with iodinated contrast media and identify the type of iodinated media associated with less risk *(p. 56)*.

27. Describe three qualities of iodinated contrast media that contribute to the production of side effects *(p. 56)*.

28. Explain how double-contrast examinations can serve to better demonstrate certain anatomic parts *(p. 54)*.

29. Describe contraindications to the use of barium sulfate; identify the alternative contrast medium *(p. 55)*.

30. Explain the importance of aftercare explanations, especially following barium examinations *(p. 55)*.

31. Distinguish between oil- and water-based iodinated contrast media, their uses, and their characteristics *(p. 56)*.

32. Identify the basic difference between ionic and nonionic contrast media and identify when use of nonionic agents is indicated *(p. 56)*.

33. Identify the major disadvantage of nonionic contrast media *(p. 56)*.

34. Describe symptoms a patient having a mild reaction to iodinated contrast media might experience and their usual treatment *(p. 56)*.

35. Describe the symptoms of a possible impending anaphylactic reaction and the radiographer's responsibilities *(p. 58)*.

36. Describe care provided to the nauseous or vomiting patient; identify the body position required for the recumbent patient *(p. 59)*.

37. Describe precautions the radiographer should take when examining a patient with a fracture *(p. 59)*.

38. Discuss precautions that should be taken with patients having suspected spinal injuries *(p. 59)*.

39. Describe first aid for epistaxis *(p. 60)*.

40. Distinguish between postural hypotension, vertigo, and syncope; discuss precautions taken and care given by the radiographer *(p. 60)*.

41. Describe any precautions that should be taken with the unconscious patient *(p. 61)*.

42. Describe symptoms of acute abdomen and shock; indicate any precautions that should be taken by the radiographer *(p. 61)*.

43. Distinguish between grand mal and petit mal seizures; discuss the care appropriate for a patient experiencing a grand mal seizure *(p. 61)*.

44. Distinguish between respiratory arrest and cardiopulmonary arrest; discuss the responses appropriate to the radiographer *(p. 61, 62)*.

45. Describe "stroke," to include some symptoms and responses appropriate for the radiographer *(p. 62)*.

Chapter Review Questions

1. Which of the following is/are symptom(s) of inadequate oxygen supply?
   1. diaphoresis
   2. cyanosis
   3. dyspnea
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

2. The usual patient preparation for an upper GI examination is:
    (A) NPO 8 hours before the examination
    (B) light breakfast only the morning of the examination
    (C) clear fluids only the morning of the examination
    (D) 2 ounces of castor oil and enemas until clear

3. Before performing which of the following examinations is a cathartic almost always required?
    1. lower GI
    2. upper GI
    3. IVU
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

4. Which of the following gauge needles has the largest bore?
    (A) 12
    (B) 18
    (C) 20
    (D) 23

5. Proper treatment for contrast media extravasation into tissues around a vein includes:
    1. application of cold wet towel to affected area
    2. application of moist heat to affected area
    3. application of pressure to injection site
    (A) 1 only
    (B) 2 only
    (C) 1 and 3 only
    (D) 2 and 3 only

6. Parenteral administration of drugs may be performed:
    1. intrathecally
    2. intravenously
    3. orally
    (A) 1 only
    (B) 1 and 2 only
    (C) 3 only
    (D) 1, 2, and 3

7. What is the most frequently used site for intravenous injection of contrast agents?
    (A) basilic vein
    (B) cephalic vein
    (C) antecubital vein
    (D) femoral vein

8. In what order should the following examinations be performed?
   1. UGI
   2. IVU
   3. barium enema
   (A) 3, 1, 2
   (B) 1, 3, 2
   (C) 2, 1, 3
   (D) 2, 3, 1

9. A patient's IV bottle or bag should be hung:
   (A) 18 to 24 inches above the vein
   (B) 18 to 24 inches below the vein
   (C) 18 to 24 inches above the heart
   (D) 18 to 24 inches below the heart

10. A patient's feeling of spinning, or the room spinning about him, is called:
    (A) orthostatic hypotension
    (B) epistaxis
    (C) vertigo
    (D) syncope

Answers and Explanations

1. (D) Symptoms of inadequate oxygen supply include *dyspnea, cyanosis, diaphoresis*, and distention of the veins of the neck. The patient who experiences some or all of these symptoms will be very anxious and must not be left unattended. The radiographer must call for help, assist the patient to a sitting or semi-Fowler position (the recumbent position makes breathing more difficult), and have oxygen and emergency drugs available.

2. (A) Patient preparation differs for various contrast examinations. To obtain a diagnostic examination of the stomach, it must first be empty. The usual *UGI* preparation is NPO (nothing by mouth) after midnight (approximately 8 hours before the examination). Any material in the stomach can simulate the appearance of disease. An iodinated contrast agent, usually in the form of several pills, is taken by the patient the evening before a scheduled *GB* examination and only water is allowed the morning of the examination. The patient scheduled for a *BE* (lower GI) requires a large bowel that is very clean prior to the administration of barium; this requires the administration of cathartics (laxatives) and cleansing enemas. Preparation for an *IVU* requires that the patient be NPO after midnight; some institutions may require that the large bowel be cleansed of gas and fecal material. *Aftercare* for barium examinations is also very important. Patients are typically instructed to take milk of magnesia and to drink plenty of water. Because water is removed from the barium sulfate suspension in the large bowel, it is essential to make patients understand the importance of these instructions to avoid barium impaction in the large bowel.

3. (A) Patient preparation varies among contrast examinations. A patient scheduled for a UGI series must be NPO (receive nothing by mouth) after midnight. A BE (lower GI) requires that the large bowel be very clean prior to the administration of barium; this requires the administration

of *cathartics* (laxatives) and *cleansing enemas.* Preparation for an IVU/IVP requires that the patient be NPO after midnight; some institutions also require that the large bowel be cleansed of gas and fecal material.

4. (A) The diameter of a needle is identified as its *gauge.* As the diameter of its *bore* decreases, the *gauge* increases. Hence, a 23-gauge needle has a smaller diameter bore than an 18-gauge needle. Hypodermic needles are generally used for phlebotomy (i.e., blood samples), while butterflies and IV catheters are used more frequently for injections such as contrast media. If an infusion injection is required, an IV catheter is generally preferred. The hub of the hypodermic needle is attached to a syringe, while the hub of the butterfly tubing or IV catheter may be attached to a syringe or an IV bottle or bag via an IV infusion set.

5. (D) *Extravasation* occurs when medication or contrast medium is introduced into the tissues surrounding a vein rather than into the vein itself. It can occur when the patient's veins are particularly deep or small. The needle should be removed, pressure applied to prevent formation of a hematoma, and warm *moist heat* applied to relieve pain.

6. (B) Although radiographic contrast media are usually administered orally or intravenously, there are a number of routes or methods of drug administration. Drugs and medications may be administered either *orally* or *parenterally. Parenteral* refers to any route other than the digestive tract (orally) and includes *topical, subcutaneous, intradermal, intramuscular, intravenous,* and *intrathecal.*

7. (C) The *antecubital* vein is the most commonly used injection site for contrast medium administration. It is not used for infusions that take longer than 1 hour because of its location at the bend of the elbow. The basilic vein, located on the dorsal surface of the hand, is used when the antecubital vein is inaccessible. The cephalic vein may also be used. Strict aseptic technique must be used for all intravenous injections.

8. (D) When scheduling patient examinations, it is important to avoid the possibility of residual contrast medium overlying areas of interest of later examinations. The IVU should be scheduled first because the contrast medium used is excreted very rapidly. The BE should be scheduled next. The UGI is scheduled last. Any barium remaining from the previous BE is unlikely to interfere with the stomach or duodenum, although a preliminary scout image should be taken in each case.

9. (A) The IV bottle or bag should be hung 18 to 24 inches *above the level of the vein.* If placed lower than the vein, solution will stop flowing and blood will return into the tubing. If hung too high, solution can run too fast. Occasionally, the position of the needle or catheter in the vein will affect the flow rate. If the bevel is adjacent to the vessel wall, flow may decrease or stop altogether. Often, just changing the position of the patient's arm will remedy the situation.

10. (C) *Objective vertigo* is the sensation of having *objects* (or "the room") spinning about the person; *subjective vertigo* is the sensation of the *person* spinning about. It is often associated with an inner-ear disturbance. Patients experiencing true vertigo (as opposed to dizziness or lightheadedness) are often very nauseous and must be protected from falls. A patient who reports feeling dizzy or faint (*syncope*) should be immediately assisted to a chair. Bending forward and placing the head between the knees will often help relieve the lightheadedness

as blood flow to the brain increases. In more severe cases, *a patient who cannot be assisted to a chair should be lowered to a recumbent position.* Elevation of the lower legs, or use of the Trendelenburg position, is helpful. *Orthostatic, or postural, hypotension* is a decrease in blood pressure that occurs on rising to the erect position. It can be severe enough to cause fainting in individuals who have been confined to bed for several days. A nosebleed (epistaxis) may be a result of any one of many causes, including hypertension, dry nasal mucous membranes, sinusitis, or trauma. The patient should be seated or placed in a Fowler position. The radiographer should place cold cloths over the patient's nose and back of the neck.

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part

II

Radiographic Procedures

General Procedural Considerations
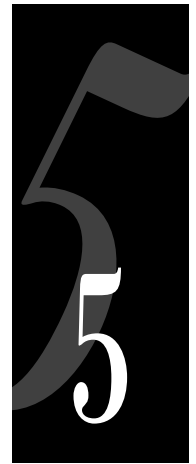
The development of positioning skills requires a thorough knowledge of normal *anatomy,* an awareness of *pathologic conditions* and their impact on positioning limitations, and selection of *technical factors*.

A review of basic positioning principles and terminology is essential to an overview of radiographic procedures. Several tables and figures in this chapter summarize body *planes* (Fig. 5–1), body *habitus* (Fig. 5–2), the *four quadrants* and *nine regions* of the abdomen (Fig. 5–3), *body surface landmarks* and localization points (Fig. 5–4), and *standard terminology* (Fig. 5–5). The student should be thoroughly acquainted with these before approaching the study of specific positioning skills.

It must be emphasized that a patient's condition very often impacts his or her ability to move readily on the x-ray table or maintain positions for lengthy periods of time. Many of the descriptions of *Position of Part* in chapter 6 are most easily used on patients who are not severely injured or afflicted with debilitating pathology; in many instances, modifications for the *trauma* patient are included. One measure of a good radiographer is his or her ability to be cautious and resourceful when examining injured or debilitated patients having pathologic or traumatic conditions such as metastatic bone disease, arthritis, or bone fractures.

The use of *body surface landmarks* and localization points (Fig. 5–5) as external indicators of anatomic structures can increase the ease and accuracy of positioning.

Thoughtful placement of a cushioning sponge, the use of a horizontal beam ("cross-table") for *lateral* projections instead of moving the patient (Fig. 5–6), and performing the examination *erect* if the *recumbent* position is uncomfortable are examples of modifications that the considerate radiographer can make that will result in an appreciative patient, as well as a diagnostic examination. The radiographer must also be alert to the changes in technical factors that may be necessitated by various pathologic processes.

I. BODY PLANES (Fig. 5–1)

- ***Midsagittal*** or *Median Sagittal Plane* (MSP): divides body into left and right halves.
- ***Sagittal Plane:*** any plane parallel to the MSP.
- ***Midcoronal Plane*** (MCP): divides body into anterior and posterior halves.
- ***Coronal Plane:*** any plane parallel to the MCP.
- ***Transverse/Horizontal* Plane:** perpendicular to MSP and MCP, divides body axially into superior and inferior portions.

Body Habitus

Hypersthenic and asthenic characterize the extremes in body types:

Hypersthenic
- Body is large and heavy
- Bony framework is thick, short, and wide
- Lungs and heart are high
- Transverse stomach
- Gallbladder high and lateral
- Peripheral colon

Asthenic
- Body is slender and light
- Bony framework is delicate
- Long, narrow thorax
- Very low, long ("fish hook") stomach
- Gallbladder low and medial
- Low, medial, and redundant colon

Sthenic and hyposthenic types characterize the more average body types:

Sthenic
- Average, athletic build
- Similar to hypersthenic, but modified by elongation of abdomen and thorax

Hyposthenic
- Somewhat slighter, less robust
- Similar to asthenic, but stomach, intestines, and gallbladder situated higher in abdomen

Figure 5–1. Body planes.

II. BODY HABITUS (Fig. 5–2)

Patients come in all shapes and sizes. The term *body habitus* refers to the body's physical appearance. Variations in body habitus have a significant effect on the *shape* and *location* of organs, and can affect their function. It is essential that radiographers are knowledgeable about the characteristics of each body habitus, and how to use that knowledge when imaging patients of varying habitus.

The *hypersthenic* habitus is the largest of the four types. This type is large and heavy; the chest area is short, with a high diaphragm. The viscera (stomach, gallbladder, colon) are usually high and lateral.

The *sthenic* habitus is defined as an average athletic build. Compared to the hypersthenic, it is characterized by a longer chest and abdomen, with viscera located more medially.

The *hyposthenic* habitus is a slighter version of the sthenic—less athletic/strong. The *asthenic* habitus is the smallest/slightest of the four types. This habitus can be frail-looking, slender, and slight. The chest is long and the abdominal viscera are located quite low and medial.
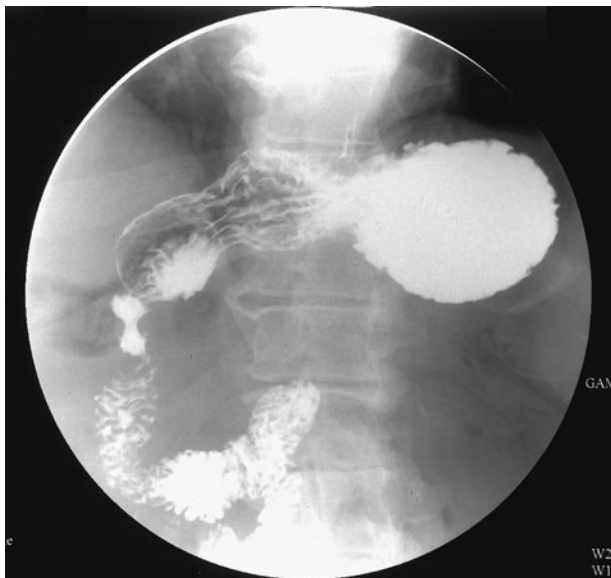
A
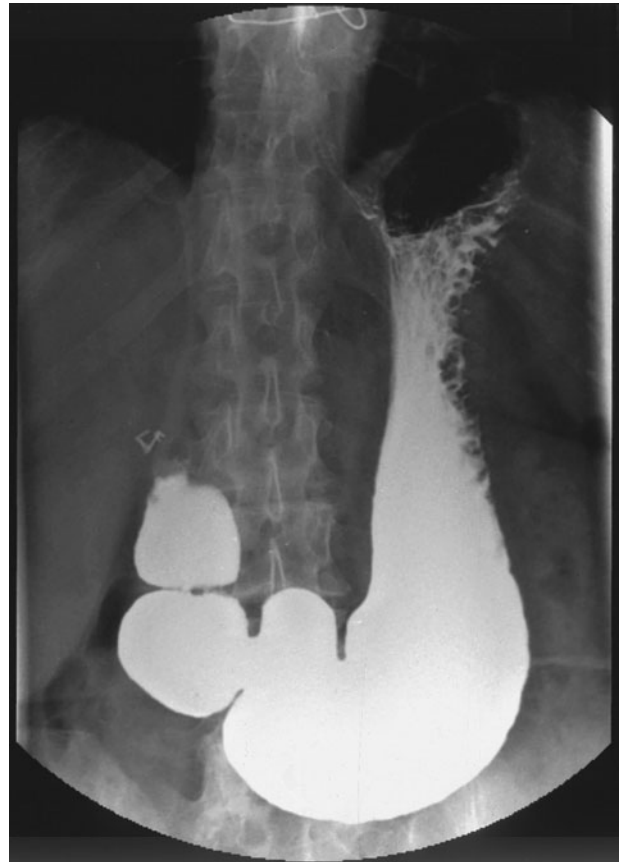
B

Figure 5–2. The *position, shape*, and *motility* of various organs can differ greatly from one *body habitus* to another. Each of the body habitus types is shown and the characteristic variations in shape and position of the diaphragm, lungs, and stomach are illustrated. The radiographer must consider these characteristic differences while performing radiographic examinations on individuals of various body habitus.
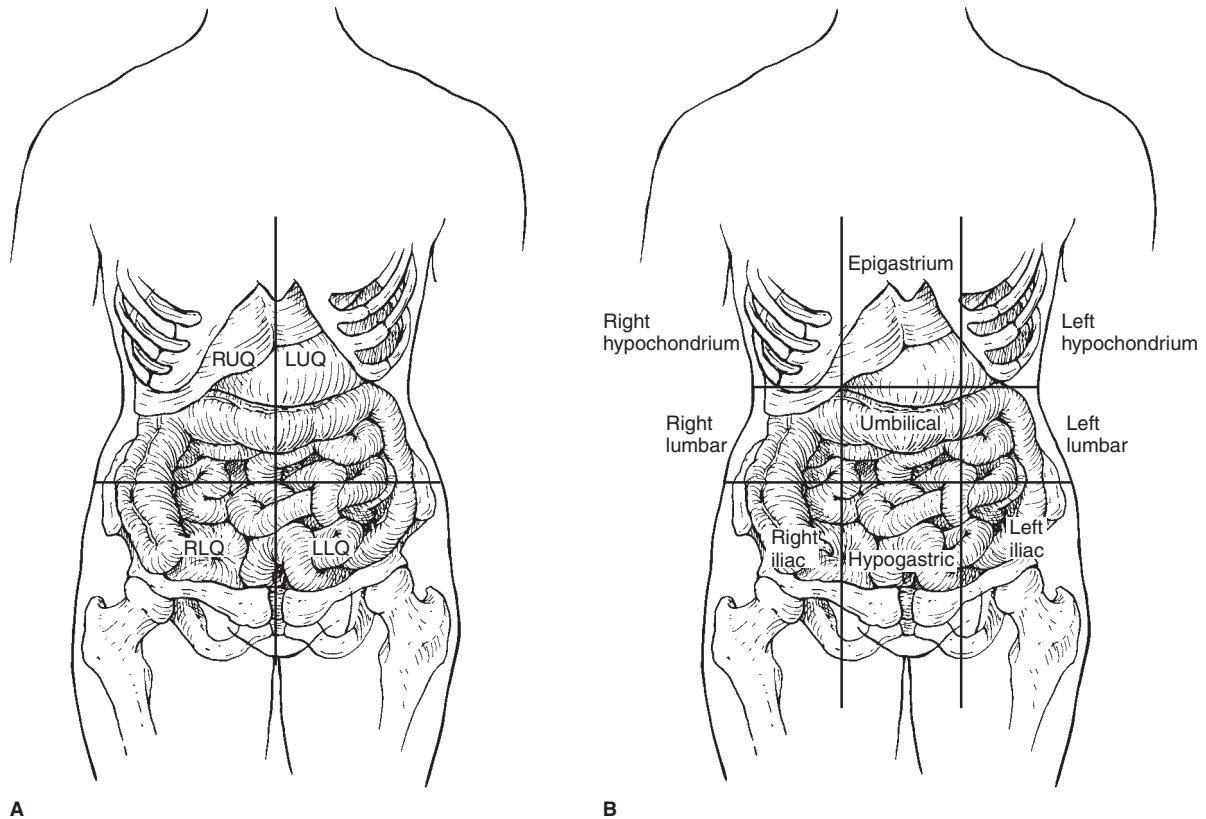
Figure 5–3. **(A)** Four quadrants of the abdomen, illustrating position of major organs. **(B)** Nine regions of the abdomen, illustrating position of major organs.

III. SURFACE LANDMARKS AND LOCALIZATION POINTS (Fig. 5–4)

Vertebra(e)		Localization Point
Cervical region	C1	Mastoid process
	C5	Thyroid cartilage (Adam's apple)
	C7	Vertebra prominens
Thoracic region	T2–3	Suprasternal (jugular) notch
	T4–5	Sternal angle
	T7–8	Inferior angle of scapula
	T9	Xiphoid (ensiform) process
	T10	Xiphoid tip
Lumbar region	T12–L3	Kidneys
	L1	Transpyloric plane
	L3	Inferior costal margin
	L3–L4	Umbilicus
	L4	Iliac crest
Sacral and coccygeal regions	S1–2	Anterosuperior iliac spine (ASIS)
	Coccyx	Symphysis pubis and greater trochanter
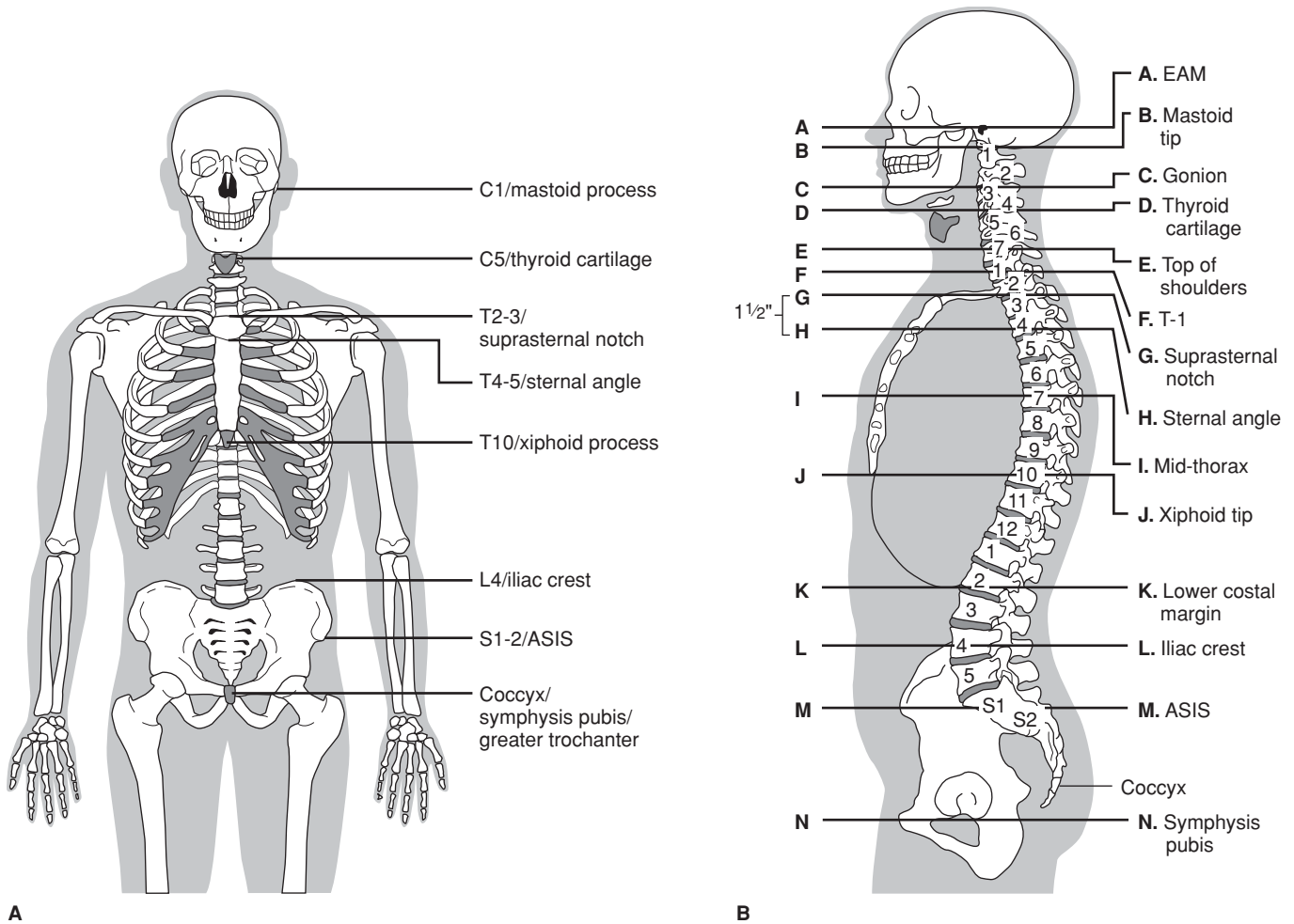
Figure 5–4. Body surface landmarks and localization points.

IV. SKELETAL MOTION TERMINOLOGY

- **Supination:** turns the body or arm so that the palm faces forward, with thumb away from midline of body.
- **Pronation:** turns the body or arm so that the palm faces backward, with thumb toward midline of body.
- **Abduction:** movement of a part away from the body's MSP.
- **Adduction:** movement of a part toward the body's MSP.
- **Flexion:** bending motion of an articulation, decreasing the angle between associated bones.
- **Extension:** bending motion of an articulation, increasing the angle between associated bones.
- **Eversion:** a turning outward or lateral motion of an articulation, sometimes with external tension or stress applied.
- **Inversion:** a turning inward or medial motion of an articulation, sometimes with external tension or stress applied.
- **Rotation:** movement of a part about its central or long axis.
- **Circumduction:** movement of a limb that produces circular motion; circumscribes a small area at its proximal end and a wide area at the distal end.

V. PRELIMINARY STEPS AND PROCEDURAL GUIDELINES

The following are steps and procedures that help ensure high-quality patient care and diagnostic radiographs:

1. *Read the request carefully*, noting the type of examination, patient condition, and mode of travel (make mental notes of any modifications or accessory equipment that may be required).
2. *Prepare the radiographic room.* Be certain that the x-ray room is neat and orderly with a clean x-ray table and a fresh pillowcase. All accessories needed for the examination should be in the room before bringing in the patient.
3. *Identify* the correct patient, quickly evaluating any special needs; *introduce* yourself and establish rapport en route to the radiographic room, *being careful not to discuss confidential issues within earshot of others.*
4. *Instruct* the patient to change into a dressing gown (if necessary), removing appropriate clothing and objects (e.g., jewelry, dentures, braided hair) that may cast *artifacts* within the area of interest (Figs. 5–7 and 5–8).
5. Speak in a well-modulated voice, give a clear and succinct *explanation* of the procedure, and address any patient questions or concerns. Obtain a short pertinent *patient history* of why the examination has been requested. The radiographer should explain that a number of different positions may be needed to evaluate the area of interest and may require *palpation* of bony landmarks and instructions to turn into various positions.

Positioning Terminology

Radiographic position
Refers to body's physical position, e.g., recumbent, erect, prone, supine, Trendelenburg, etc.

Radiographic projection
Describes the path of the CR, e.g., PA (CR enters posteriorly, exits anteriorly)

Radiographic view
Describes the body part as seen by the IR, e.g., palmar view of the hand infrequently used

General Terminology
1. Recumbent/lying down
   - lying on back, face up = supine
   - lying on abdomen, face down = prone
   - supine, prone, or lateral, using horizontal CR = decubitus
2. Erect/upright/standing or sitting up
   - facing the IR = anterior position
   - with back toward IR = posterior position
3. Oblique position—erect or recumbent
   - RAO/Right Anterior Oblique: body rotated, with right anterior aspect nearest the IR
   - LAO/Left Anterior Oblique: body rotated, with left anterior aspect nearest the IR
   - RPO/Right Posterior Oblique: body rotated, with right posterior aspect nearest the IR
   - LPO/Left Posterior Oblique: body rotated, with left posterior aspect nearest the IR

Figure 5–5. Standard terminology provides descriptions and interpretation of accepted radiologic positioning language.
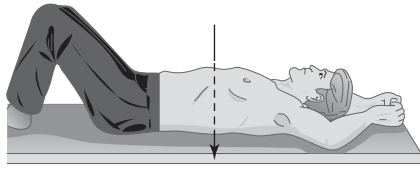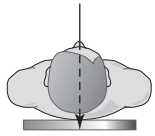
Anteroposterior projection
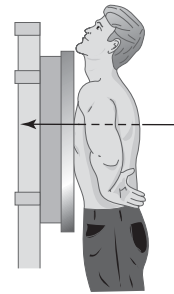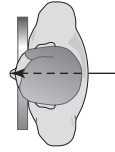
Posteroanterior projection
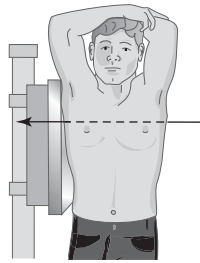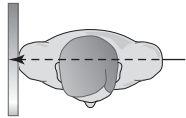
Right lateral position
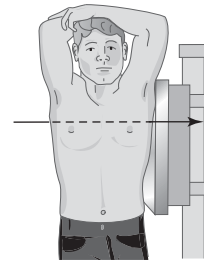
Left lateral position
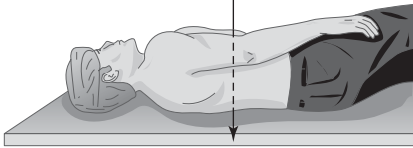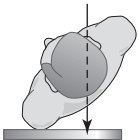
Left posterior oblique position
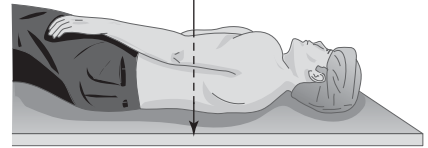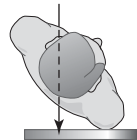
Right posterior oblique position
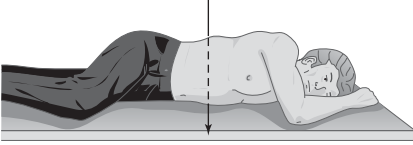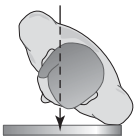
Left anterior oblique position
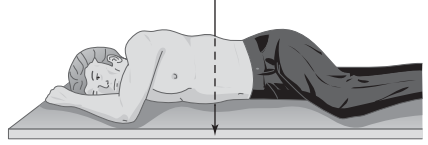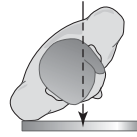
Right anterior oblique position

Figure 5–5. (*Continued*)
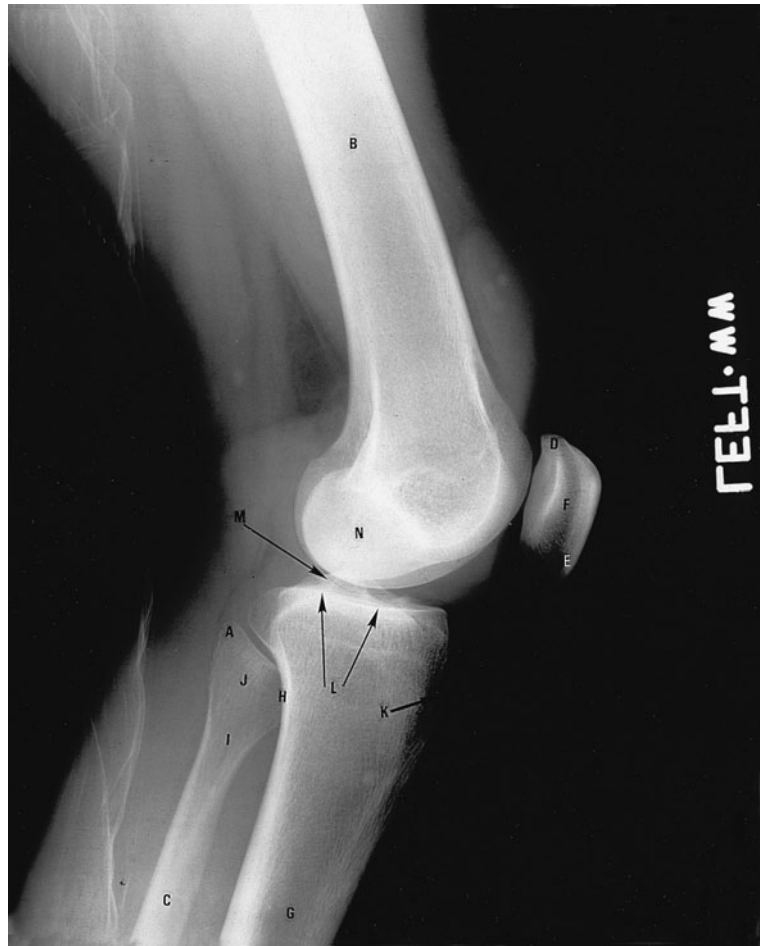
Figure 5–6. *Horizontal beam lateral* projection of knee performed in supine position on a patient with multiple injuries. A horizontal (cross-table) x-ray beam was used to reduce discomfort and risk of further injury. Observe the bedsheet artifact from the mattress pad beneath the patient. Use this radiograph to *review the skeletal anatomy* of the knee and correctly identify the lettered parts. (Courtesy of Stamford Hospital, Department of Radiology.)

6. Radiography of most structures *usually requires a minimum of two projections*, usually at right angles to each other. Side-to-side (left/right) relationships are demonstrated in the *frontal* projection (Fig. 5–9A), whereas anterior/posterior relationships are seen in the *lateral* projection (Fig. 5–9B). This is especially important in localizing foreign bodies and tumors, and demonstrating fracture displacement or alignment.

7. It is customary and economical to use the smallest size film or image receptor that will include all necessary information. Therefore, the smallest possible anatomic area (consistent with a diagnostic examination) will be irradiated to keep patient dose to a minimum.
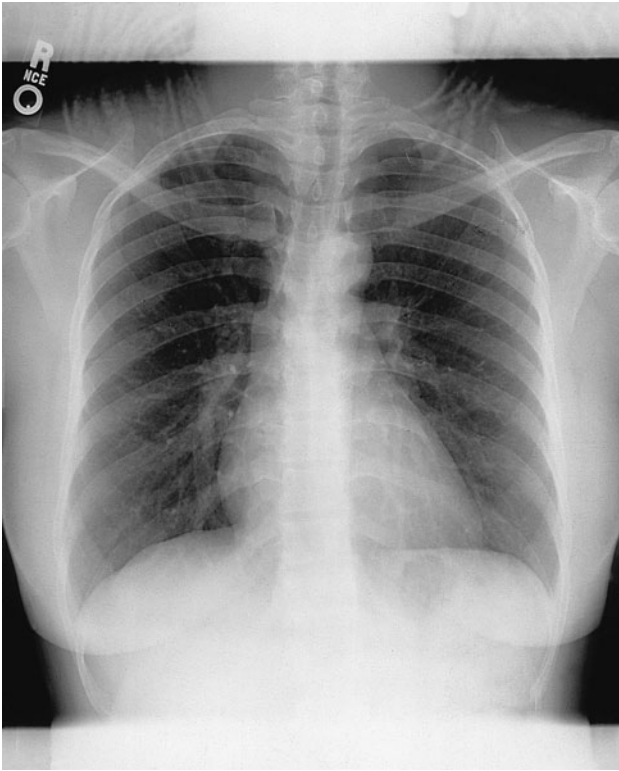
Figure 5–7. The posteroanterior chest is well positioned and exposed, but observe the braids of hair that extend past the neck and superimpose on the pulmonary apices. Braided hair should be pinned up or otherwise removed from superimposition on thoracic structures. (Courtesy of Stamford Hospital, Department of Radiology.)
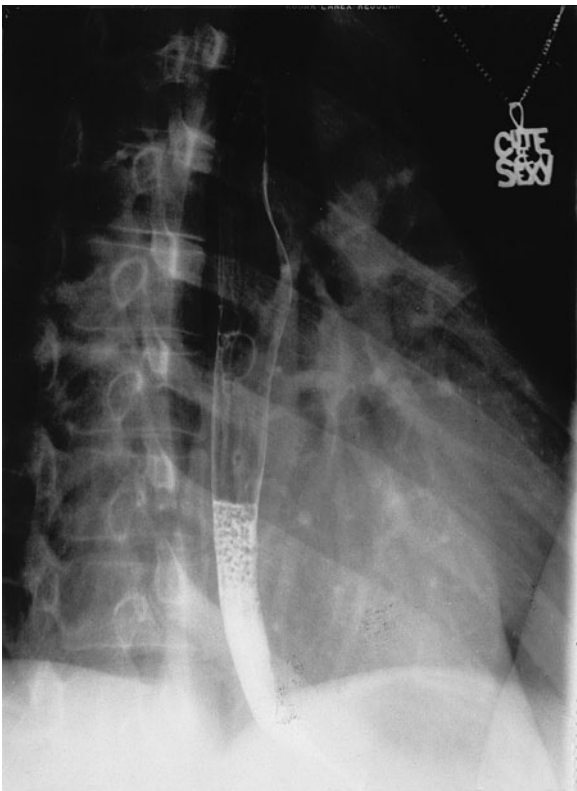
Figure 5–8. Left posterior oblique image of the esophagus with a jewelry artifact near the area of interest. The patient must remove clothing and other objects, such as jewelry, from the area to be examined before donning the dressing gown. (Courtesy of Stamford Hospital, Department of Radiology.)

A   **B**
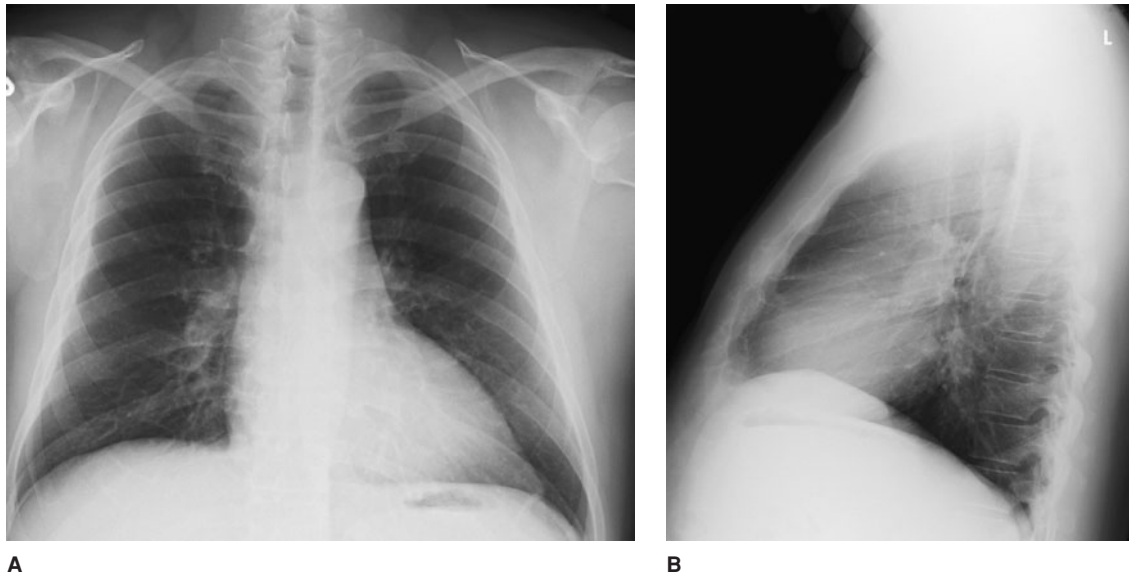
Figure 5–9. A & B. A *minimum of two projections*, at right angles to each other, is the usual minimum requirement for radiographic studies. Side-to-side (left/right) relationships are demonstrated in the *frontal* projection **(A)**, whereas anterior/posterior relationships are seen in the *lateral* projection **(B)**. This is especially important in localizing foreign bodies and tumors, and demonstrating fracture displacement or alignment. (Courtesy of Conrad P. Ehrlich, MD.)

8. In radiography of the long bones, every effort should be made to *include both articulations* associated with the injured bone, but it is essential to include at least the articulation nearest the injury.
9. So that an accurate diagnosis can be made, supplemental radiographs of any anatomic part may be required; for example, *oblique, axial, tangential, erect,* or *decubitus.* Exposure factors must be correctly adjusted for each change of position.
10. Each image must be accurately *labeled* with patient information such as *name or identification number, institution name, date of examination*, and *side marker*. Other information may be included according to institution policy.

VI. IMMOBILIZATION AND RESPIRATION

Motion obliterates recorded detail; thus, it is essential that the radiographer be able to reduce patient motion as much as possible. Several means can be employed to reduce motion unsharpness, but good *patient communication* is the most important because it is required before any other means can be effective.

The single most important way to reduce *involuntary* motion is to use the *shortest possible exposure time.* Various types of *immobilization devices* can also be used to effectively reduce motion. Motion from muscular tremors as a result of anxiety or pain is involuntary and can be greatly minimized with good communication, a carefully placed

positioning sponge or sandbag, and the use of the shortest exposure time possible.

Suspension of patient respiration for parts other than the extremities is an effective means of reducing *voluntary* motion; patient understanding and cooperation is required, thus making good *communication* the *most effective means of reducing voluntary motion*. The phase of respiration on which the exposure is made can be essential to the diagnostic quality of the radiographic image. Chest radiography, for example, normally requires that the exposure be made on inspiration (the second inspiration if the patient is of the hypersthenic type). Most abdominal examinations are exposed on expiration. The phase of respiration on which the exposure is made can also make a significant difference in the resulting radiographic density (discussed in Part IV).

VII. MODIFIED AND ADDITIONAL PROJECTIONS

Additional projections are often required in order to demonstrate the structure(s) of interest. Since human bodies are not identical, and pathological processes often unpredictable, routine projections occasionally require supplemental images.

If a patient is unable to assume or maintain the routine position used for a particular examination, the radiographer should be capable of modifying the projection to provide the required information. This is often a good measure of the radiographer's skill. Skillful maneuvering of the x-ray tube and correct placement of the image receptor can often yield excellent images of an anatomical part difficult or impossible to manipulate.

It is not within the radiographer's scope of practice to supply additional, unrequested projections, but the radiographer should advise the physician of other projections or modifications that might enable him or her to better visualize the affected area.

Chapter Exercises

⭐ ***Congratulations!*** *You have completed your review of this chapter. If you are able to answer the following group of comprehensive questions, you can feel confident that you have mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to these multiple-choice questions without first completing the short-answer questions below.*

1. Discuss how knowledge of anatomy and pathologic conditions relates to positioning skills *(p. 73).*

2. Identify the sagittal and midsagittal, coronal and midcoronal, and transverse (horizontal) planes *(p. 74).*

3. List the four types of body habitus and provide physical characteristics of each *(p. 74, 75).*

4. Name, identify, and describe the quadrants and nine regions of the abdomen *(p. 76).*

5. Identify anatomic localization points and their corresponding vertebrae *(p. 76, 77).*

6. Define and identify various skeletal movement terms *(p. 77).*

7. Discuss the importance of establishing an orderly sequence of preparation for performing radiologic examinations *(p. 78, 80, 82).*

8. Explain the importance of obtaining two views at right angles to each other for most radiologic examinations *(p. 80).*

9. Discuss the inclusion of articulations in radiography of the extremities *(p. 82).*

10. List the information that must be included on the radiographic image *(p. 82).*

11. What is the most effective means of reducing *voluntary* motion; of reducing *involuntary* motion? *(p. 82, 83).*

Chapter Review Questions

1. The plane that passes vertically through the body dividing it into anterior and posterior halves is termed the:
   (A) midsagittal plane
   (B) midcoronal plane
   (C) sagittal plane
   (D) transverse plane

2. The position of the hypersthenic gallbladder, as compared to the position of the asthenic gallbladder, is more:
   (A) superior and lateral
   (B) superior and medial
   (C) inferior and lateral
   (D) inferior and medial

3. What is the relationship between the midsagittal and transverse planes?
   (A) parallel
   (B) perpendicular
   (C) 45 degree
   (D) 70 degree

4. The best way to control voluntary motion is:
   (A) immobilization
   (B) careful explanation
   (C) short exposure time
   (D) physical restraint

5. Prior to x-ray examinations of the skull and cervical spine, the patient should remove:
   1. dentures
   2. earrings
   3. necklaces
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

6. Image identification markers should include:
   1. patient's name and/or ID number
   2. date
   3. a right or left marker
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

7. The radiographer should be able to:
    1. take a short patient history prior to the examination
    2. modify routine positions to obtain similar images in patients unable to move
    3. evaluate patient condition and needs
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

8. With the patient recumbent and head positioned at a lower level than the feet, the patient is said to be in the:
   (A) Trendelenburg position
   (B) Fowler position
   (C) decubitus position
   (D) Sims position

9. Before bringing the patient into the radiographic room, the radiographer should:
    1. be certain that the x-ray room is clean and orderly
    2. check that all necessary accessories are available in room
    3. check for clean x-ray table and fresh pillowcases
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

10. The lower portion of the costal margin is approximately at the same level as the:
   (A) mid-thorax
   (B) umbilicus
   (C) xiphoid tip
   (D) third lumbar vertebra

Answers and Explanations

1. (B) *The midcoronal plane is perpendicular to the MSP* and divides the body into anterior and posterior halves. The *midsagittal* (or median sagittal) plane passes vertically through the midline of the body, dividing it into left and right halves. Any plane parallel to the MSP is termed a sagittal plane. A *transverse* plane passes across the body, also perpendicular to a sagittal plane. These planes, especially the MSP, are very important reference points in radiographic positioning.

2. (A) The position, shape, and motility of various organs can differ greatly from one body habitus to another. The position of the diaphragm, lungs, stomach, gallbladder, and large and small intestines vary greatly with body habitus. The large extreme (*hypersthenic*) will have structures *higher and more lateral*, whereas these structures in individuals of the small extreme habitus (*asthenic*) have structures *low and medial* (Fig. 5–3).

3. (B) The *midsagittal* plane passes vertically through the midline of the body, dividing it into left and right halves. Any plane parallel to the MSP is termed a sagittal plane. The *midcoronal*

plane is perpendicular to the MSP and divides the body into anterior and posterior halves. The *transverse* plane passes across the body, also perpendicular to a sagittal plane. These planes, especially the MSP, are very important reference points in radiographic positioning.

4. (B)   Motion obliterates recorded detail; it is therefore essential that the radiographer be able to reduce patient motion as much as possible. Even the slightest movement can cause severe degradation of the radiographic image. Suspension of patient respiration for parts other than the extremities is an effective means of reducing *voluntary* motion; patient understanding and cooperation is required, thus making good *communication* the most effective means of reducing *voluntary* motion. The single most important way to reduce *involuntary* motion is to use the *shortest possible exposure time.*

5. (D)   The patient must remove any metallic objects if they are within the area(s) of interest. Dentures, earrings, necklaces, and braided hair can obscure bony details in the skull or cervical spine. The radiographer must be certain that the patient's belongings are cared for properly and returned following the examination (Figs. 5–7 and 5–8).

6. (D)   Correct and complete patient information on every radiograph is of paramount importance. Each radiographic image must be accurately labeled with such patient information as *name or identification number, institution name, date of examination,* and *side marker.* Other information may be included according to institution policy.

7. (D)   The acquisition of pertinent *clinical history* is one of the most valuable contributions to the diagnostic process. Because the diagnostic radiologist rarely has the opportunity to speak with the patient, this is a crucial responsibility of the radiographer. As the radiographer obtains a brief pertinent clinical history, the radiographer also *assesses the patient's condition* by observing and listening. To provide safe and effective care, the radiographer must be able to assess the severity of a trauma patient's injury, their degree of motor control, the need for support equipment, or radiographic accessories. In patients too injured or ill to move, the radiographer should be capable of modifying routine positions to obtain images with the required anatomic part/information.

8. (A)   When the patient is recumbent with his or her head *lower* than his or her feet, the patient is said to be in the *Trendelenburg* position. In the *Fowler* position, the patient's head is positioned *higher* than his or her feet. The *decubitus* position is used to describe the patient as recumbent (prone, supine, or lateral) with the central ray directed horizontally. The *Sims* position is the left anterior oblique position assumed for enema tip insertion.

9. (D)   A patient will naturally feel more comfortable and confident if brought into a clean, orderly x-ray room that has been prepared appropriately for the examination to be performed. A disorderly, untidy room and a disorganized radiographer hardly inspire confidence; more likely, they will increase anxiety and apprehension.

10. (D)   Surface landmarks, prominences, and depressions are very useful to the radiographer in locating anatomic structures not visible externally. The *lower costal margin* is about the same level as L3. The *umbilicus* is the same approximate level as the L3 to L4 interspace. The *xiphoid* tip is about the same level as T10. The fourth lumbar vertebra is at the same approximate level as the *iliac crest.*

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Imaging Procedures: Anatomy, Positioning, and Pathology

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I. THE SKELETAL SYSTEM

Radiographers frequently deal with bone imaging and are required to have a good knowledge of osteology. *Osteology* is the study of bones; there are usually 206 bones in the adult skeleton. The skeletal system of bones serves many functions. Bones form the *supporting* framework of the body. Bones serve as a *reservoir for minerals* such as calcium and phosphorus, storing them until the body requires them. The design of the skeletal framework is such that it provides *protection* to underlying critical and delicate structures. Many bones have prominences that serve as *attachment for muscles*, providing leverage for *movement*. Bone marrow, particularly red, is important in the production of blood cells—a process called *hematopoiesis.*

Bone tissue, or *osseous* (os = bone) tissue, is a specialized type of dense connective tissue. This tissue consists of bone cells (*osteocytes*) embedded in a nonliving matrix composed of calcium and collagen fibers. There are two types of osseous tissue: *cancellous* (spongy) and *compact* (hard, cortical) (Fig. 6–1A).

The structural unit of *compact* bone tissue is the haversian (osteon) system. A haversian system, or osteon, consists of a central haversian canal surrounded by concentric cylinders of osteocytes within the calcium matrix.

Cancellous, or spongy, bone tissue has a reticular or latticework type structure. This network of lattice-like bone is referred to as trabeculae. These trabeculae form little spaces/septa filled with red bone marrow.

The site of close approximation of two or more bones is an *articulation*, or *joint*. The study of bony articulations is termed *arthrology.* There are three classifications of bony articulations. *Synarthrotic* joints, also described as fibrous, are immovable. The sutures of the cranium are examples of synarthrotic joints. *Amphiarthrotic* joints, also described as *cartilaginous*, are partially movable. The intervertebral joints (between vertebral bodies) and the symphysis pubis are examples of amphiarthrotic joints. *Diarthrotic* joints, also described as

Functions of Skeletal System

- Support
- Reservoir for minerals
- Muscle attachment/movement
- Protection
- Hematopoiesis

Bone Tissue Types

- Cortical (hard, compact)
- Cancellous (spongy)

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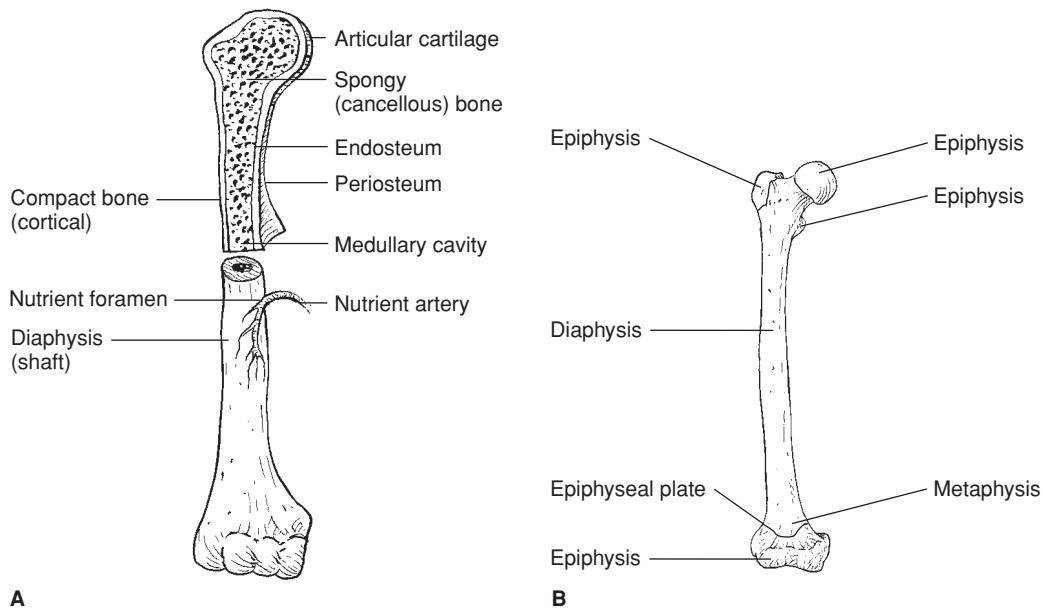
Figure 6–1. Characteristics and ossification centers of long bones.

synovial, are freely movable. The majority of human articulations are the diarthrotic/synovial type, and there are several types of diarthrotic articulations (their names describe their movements). The following list identifies the types of diarthrotic joints, describes their movement(s), and gives examples of each:

Gliding (plane)
- the simplest motion, least movement, smooth/sliding motion
- intercarpal and intertarsal joints, acromioclavicular, and costovertebral joints

Pivot (trochoid)
- permits rotation around a single axis
- proximal radioulnar joint, atlantoaxial joint

Hinge (ginglymus)
- permits flexion and extension
- elbow, interphalangeal joints, knee, ankle

Ball and socket (spheroid)
- permits flexion, extension, adduction, abduction, rotation, circumduction with more motion distally and less proximally
- shoulder, hip

Condyloid (ellipsoid)
- permits flexion, extension, abduction, adduction, circumduction (no rotation)
- radiocarpal joint, metacarpophalangeal joints (2–5)

Saddle (sellar)
- permits flexion, extension, adduction, adduction, circumduction (no rotation)
- first carpometacarpal joint (thumb)

II. THE APPENDICULAR SKELETON

The *appendicular* skeleton (Fig. 6–2) consists of the *extremities* (appendages or limbs), the arms, legs, shoulder, and the pelvic girdles. Most of these bones serve as *attachment* for muscles, thereby creating leverage for movement.

Bones are classified as *long*, *short*, *flat*, and *irregular*. Many of the bones comprising the extremities are long bones. Long bones have a *shaft* and *two extremities* (ends). The shaft (or *diaphysis*) (Fig. 6–1B) of long bones is the *primary ossification center* during bone development. It is composed of compact tissue and covered with a membrane called *periosteum*.
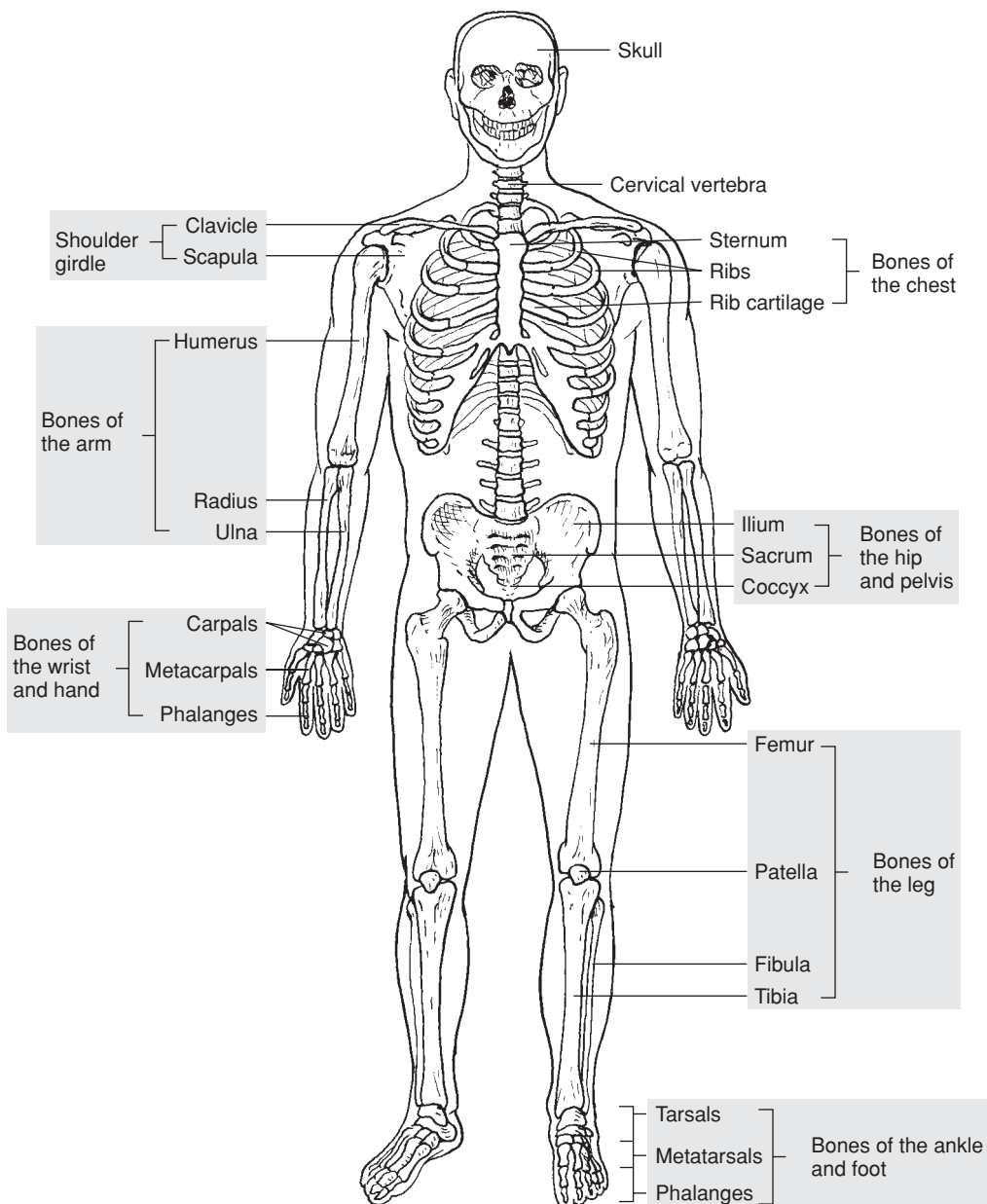
Figure 6–2. The *appendicular* skeleton (shaded); the *axial* skeleton (unshaded).

Within the shaft of a long bone is the *medullary cavity*, containing *bone marrow* and lined by a membrane called *endosteum*. In adults, yellow marrow occupies the shaft and red marrow is found within the *proximal* and *distal* extremities of long bones.

The *secondary ossification center*, the *epiphysis* (Fig. 6–1B), is separated from the diaphysis in early life by a layer of cartilage, the *epiphyseal plate*. As bone growth takes place, the epiphysis becomes part of the larger portion of bone. The epiphyseal plate disappears but a characteristic line remains and is thereafter recognizable as the *epiphyseal line*. The articular ends of bones are covered with *articular (hyaline) cartilage*.

A. UPPER EXTREMITY AND SHOULDER GIRDLE

1. Hand, Fingers, and Thumb. The hand (Fig. 6–3A and B) is composed of five *metacarpal* bones, corresponding to the palm of the
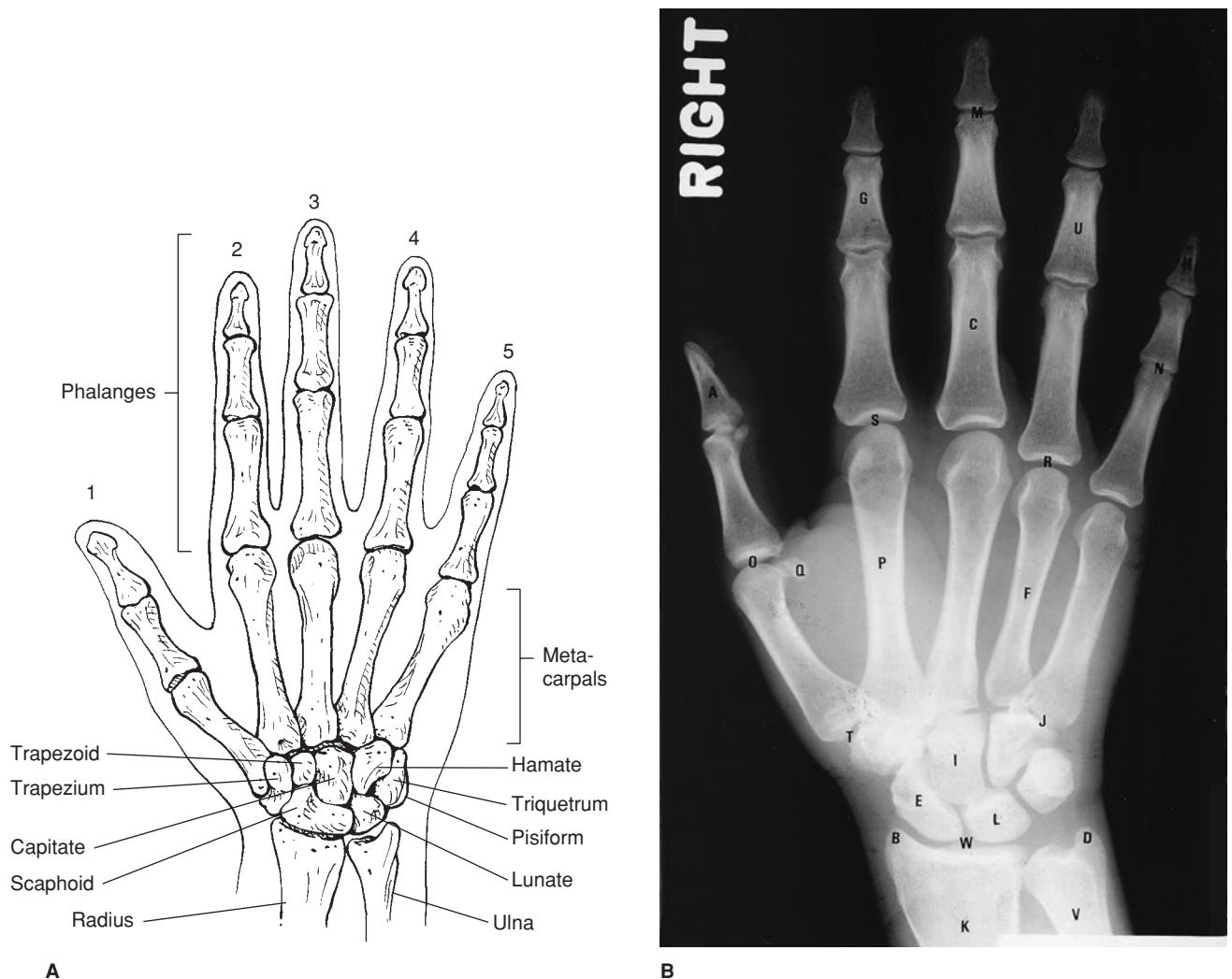
Figure 6–3. **(A)** Posterior aspect of the right hand and wrist. **(B)** PA projection of the hand; note that an oblique projection of the first metacarpal and phalanges is obtained. Review the skeletal anatomy of the hand and correctly identify each of the lettered structures. (Courtesy of Bob Wong, RT.)

hand, and 14 *phalanges*, the fingers. The second through fifth fingers have three phalanges each (proximal, middle, and distal rows) and the first finger or thumb has two phalanges (proximal and distal). The rows of phalanges articulate with each other forming proximal and distal *interphalangeal joints* (hinge/ginglymus joints), permitting flexion and extension motion.

The *bases* of the proximal row of phalanges articulate with the heads of the metacarpals to form the (condyloid/ellipsoid) *metacarpophalangeal joints* (MCP), which permit flexion and extension, abduction and adduction, and circumduction. The bases of the metacarpals articulate with each other and the distal row of carpals at the *carpometacarpal joints*. The first carpometacarpal joint (thumb) is a saddle/sellar joint, permitting flexion and extension, abduction and adduction, and circumduction.

2. Wrist. The wrist (Fig. 6–3A and B) is composed of eight carpal bones arranged in two rows (proximal and distal). The proximal row consists of, from lateral to medial, the *scaphoid*, the *lunate/semilunar*, the *triangular/triquetrum*, and the *pisiform*. The distal row, from lateral to medial, consists of the *trapezium/greater multangular*, the *trapezoid/lesser multangular*, the *capitate/os magnum* (the largest carpal), and the *hamate/unciform* (which has a hook-like process, the hamulus).

The joints of the wrist include the articulations between the carpals (*intercarpal joints*), which provide a gliding motion, and the *radiocarpal joint* (between the distal radius and scaphoid), which provides flexion and extension as well as abduction and adduction.

Traumatic *fractures* of the hand and wrist are common. Fractures of the distal (ungual) phalangeal tufts usually occur from crushing injuries, such as being closed in car doors or struck with a hammer. Metacarpal and phalangeal fractures are common fractures and are often accompanied by dislocations of the metacarpophalangeal and interphalangeal joints. In fractures of the metacarpal shafts, the bony fragments are usually displaced posteriorly and can be rotated as well.

Scaphoid fractures are common and often result from a fall onto an outstretched hand. Symptoms include tenderness and swelling over the "anatomic snuff box." Delayed or nonunion of these fractures occurs due to damage to the nutrient artery during the initial trauma event. Special projections can be used to detect scaphoid fractures.

Carpal tunnel syndrome is a painful condition of the wrist. If the anteroposterior (AP) diameter of the tunnel is diminished, the median nerve, which passes through the tunnel, is impinged upon thus causing severe pain and disability in the affected hand and wrist. Surgical decompression of the carpal tunnel can provide significant relief.

3. Forearm. The bones of the forearm, or antebrachium (Fig. 6–4), consist of the *radius* (laterally) and *ulna* (medially), which participate in the formation of the elbow joint proximally and the wrist distally.

The distal ulna presents a *head* and *styloid process* and articulates with the distal radius to form the *distal radioulnar joint*. The ulna is slender distally but enlarges proximally and becomes the larger of the two bones of the forearm. At its proximal end, the ulna presents the *olecranon process* (posteriorly) and *coronoid process* (anteriorly) that are joined by a large articular cavity, the *semilunar*, or *trochlear*, *notch*. The coronoid process fits into the humeral *coronoid fossa* during

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Articulations May Be Classified As

Diarthrotic: freely movable
Amphiarthrotic: partially movable
Synarthrotic: immovable
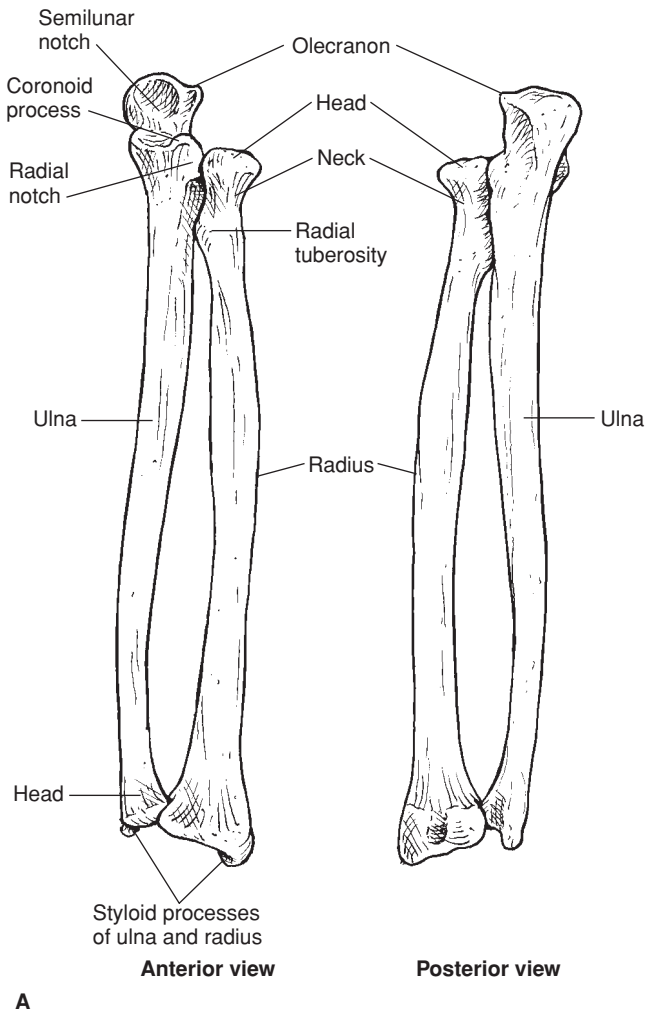
Figure 6–4. **(A)** Bones of the left forearm. **(B)** AP projection right forearm. Arm in extension with *hand supinated* to avoid overlap of radius and ulna. **(C)** Lateral projection right forearm. Elbow flexed 90° with hand and wrist in lateral position; humeral epicondyles are superimposed.

Carpal Bones

Proximal Row, Lateral to Medial
Scaphoid
Lunate/semilunar
Triangular/triquetrum
Pisiform
Distal Row, Lateral to Medial
Trapezium/Greater multangular
Trapezoid/Lesser multangular
Capitate/os magnum
Hamate/unciform

flexion and the olecranon process fits into the humeral *olecranon fossa* during extension. Just distal and lateral to the semilunar notch is the *radial notch*, which provides articulation for the radial head to form the *proximal radioulnar articulation*. Just as the ulna is the principal bone associated with the elbow joint, the radius is the principal bone associated with the wrist joint. Fracture of the distal radius is one of the most common skeletal fractures.

The distal radius presents a *styloid process* laterally; the *ulnar notch* is located medially, helping form the *distal radioulnar articulation*. The distal surface of the radius (carpal articular surface) is smooth for accommodating the scaphoid and lunate in the formation of the *radiocarpal joint*. The proximal radius has a cylindrical *head* with a medial surface that participates in the *proximal radioulnar joint*; its superior surface articulates with the capitulum of the humerus.

Fractures of the radial head and neck frequently result from a fall onto an outstretched hand with the elbow *partially flexed*. Severe
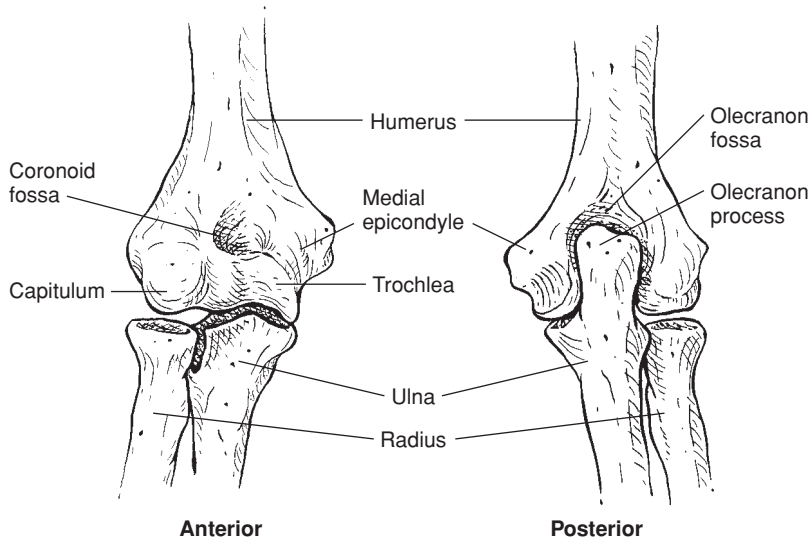
Figure 6–5. Anterior and posterior aspects of the bony articulation of the right elbow joint.

fractures are often accompanied by posterior dislocation of the elbow joint. *Colles' fractures* of the distal radius usually result from a fall onto an outstretched hand with the arm *extended*. Fractures of the ulnar styloid occur usually due to hyperabduction of the hand.

4. Elbow. The distal *humerus* articulates with the radius and ulna to form the elbow joint (Figs. 6–5 and 6–6). The lateral aspect of the distal humerus presents a raised, smooth, rounded surface, the *capitulum*, which articulates with the superior surface of the *radial head* (Fig. 6–4). The *trochlea* is on the medial aspect of the distal humerus and articulates with the semilunar notch of the ulna. Just proximal to the capitulum and trochlea are the *lateral* and *medial epicondyles*; the medial is more prominent and palpable. The *olecranon fossa* is found on the posterior distal humerus and functions to accommodate the olecranon process with the elbow in extension (Fig. 6–7).
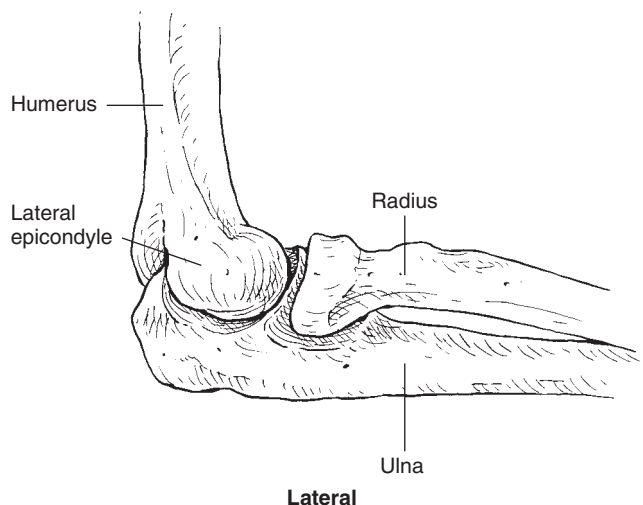
Figure 6–6. Medial and lateral aspects of the bony articulation of the right elbow joint.
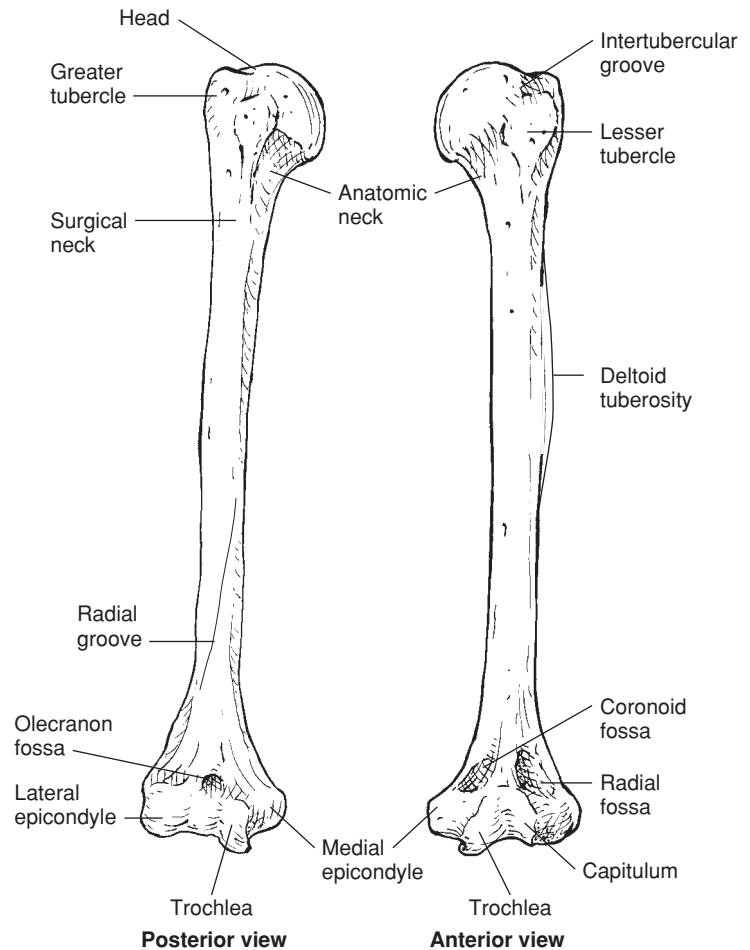
Figure 6–7. The humerus.

Lateral epicondylitis ("tennis elbow") is a painful condition caused by prolonged rotary motion of the forearm. *Dislocations* of the elbow can also occur from a fall onto an outstretched hand. One or both bones of the forearm can be involved; a posterior dislocation is the most common and is frequently accompanied by a radial head fracture. Rotation of the radial head can be palpated on the posterior lateral surface of the elbow, with elbow in extension.

There are three important *fat pads* associated with the elbow. The anterior fat pad is located just anterior to the distal humerus. The posterior fat pad is located within the olecranon fossa at the distal posterior humerus. The supinator fat pad/stripe is located at the proximal radius just anterior to the head, neck, and tuberosity. *The posterior fat pad is not visible radiographically in the normal elbow.* These fat pads can be demonstrated only in the lateral projection of the elbow.

5. Humerus. The *deltoid tuberosity* is found on the anterolateral surface of the humeral shaft. The large, round *humeral head* is covered with hyaline cartilage and articulates with the scapula's glenoid fossa. The *anatomical neck* marks the location of the fused epiphyseal plate in the adult and separates the head and metaphysis. The proximal humerus presents two protuberances on its anterior surface; the
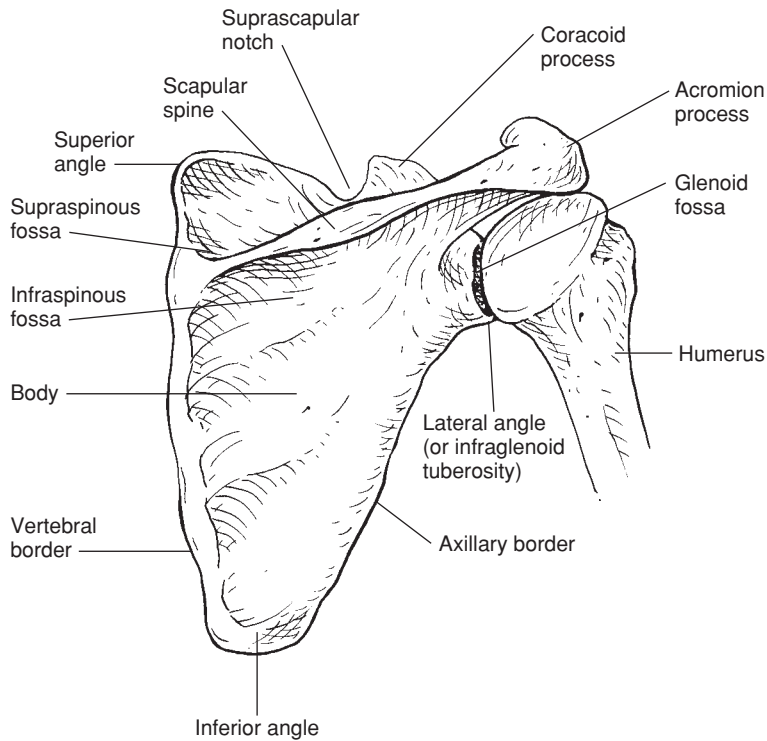
Figure 6–8. Posterior aspect of the right scapula.

greater tubercle is lateral and the *lesser tubercle* is medial. Between the tubercles is the *bicipital*, or *intertubercular*, *groove.* The humeral shaft narrows just distal to the tubercles at the point of the *surgical neck.*

Humeral *fractures* usually involve the surgical neck or the distal end of the bone. Fractures of the proximal humerus usually find the shaft impacted into the head. Fractures of the greater tubercle can result from a direct blow or as a consequence of pull from the associated muscles.

6. Shoulder. The shoulder (pectoral) girdle consists of the scapulae (Fig. 6–8) and clavicles (Fig. 6–9). The S-shaped *clavicle* ("collar
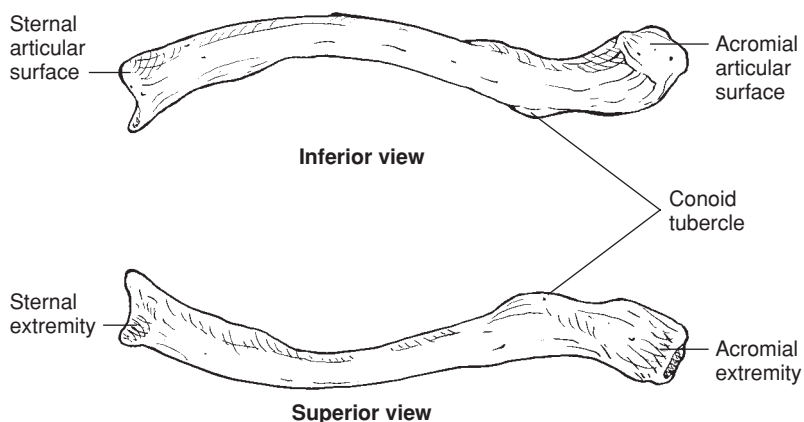
Figure 6–9. The right clavicle.

Articulation Summary: Upper Extremity and Shoulder Girdle

- Acromioclavicular
- Sternoclavicular
- Shoulder (glenohumeral)
- Elbow—three articulations:
  1. b/w humeral trochlea and semi-lunar/trochlear notch
  2. b/w capitulum and radial head
  3. proximal radioulnar joint
- Distal radioulnar
- Radiocarpal (distal radius w/scaphoid and lunate)
- Intercarpal
- Carpometacarpal
- Metacarpophalangeal
- Interphalangeal

bone") is usually the last bone to completely ossify, at about age 21, and is one of the most commonly fractured bones in young people. Its medial end articulates with the sternum to form the *sternoclavicular joint*; the clavicle articulates laterally with the scapula's acromion process, forming the *acromioclavicular joint*. Superior *dislocation* of the *acromioclavicular joint* is a common athletic injury.

The *scapula* is a flat bone, shaped like an inverted triangle, with a *costal surface* that lies against the upper posterior rib cage. The scapula has a *superior border*, a *medial* (or *vertebral*) *border*, a *lateral* (or *axillary*) *border*, and an *inferior angle*, or *apex*. Its superior border presents a *scapular notch* and, projecting anteriorly just medial to the humeral head is the palpable *coracoid process*. The *scapular spine* divides the posterior surface into a *supraspinatus fossa* and *infraspinatus fossa*; the *acromion process* is the lateral extension of the scapular spine. The *glenoid fossa* is on the lateral aspect of the scapula and, with its articulation with the humeral head, forms the (ball and socket) *shoulder joint*.

The *rotator cuff* is largely responsible for abduction and internal rotation movements, and is composed of the supraspinatus, infraspinatus, teres minor, deltoid, and subscapularis muscles. Rotator cuff injuries are a result of acute injury or chronic wear and tear. The articular capsule of the shoulder is loose, permitting a great range of movement but also making it susceptible to dislocation.

7. Positioning. Positioning of the upper extremity and shoulder girdle requires a thorough knowledge of the anatomy concerned as well as an awareness of possible pathologic conditions and their impact on positioning limitations and technical factors.

Radiopaque objects such as watches, bracelets, and rings should be removed whenever possible because they can obscure important anatomic information. The patient must be instructed regarding the importance of remaining still, and immobilization devices such as sandbags or sponges should be used as required. The shortest possible exposure time should be employed, especially when involuntary motion can be a problem, as with trauma, pediatric, or geriatric patients.

Most upper extremity examinations are more comfortably and accurately positioned with the patient seated at the end of the x-ray table, with the forearm and elbow resting on the table. Most can be performed tabletop (i.e., without a Bucky grid); the humerus sometimes requires a grid, while the shoulder, clavicle, and scapula usually do. *Suspended respiration* is suggested for radiography of the proximal portion of the upper extremity and shoulder girdle. Patients must be adequately shielded.

The use of just a few important bony landmarks and their correct placement with respect to the IR are the basis for accurate positioning. Rotation of the arm and placing the humeral epicondyles in correct relationship to the IR are the foundation of forearm, elbow, and shoulder positioning. Positioning of the wrist and hand uses the radial and ulnar styloid processes, bending maneuvers (i.e., radial and ulnar flexion), metacarpophalangeal joints (MCP), and interphalangeal joints (IPJ).

The following tables provide a summary of routine and frequently performed special projections of the upper extremity and shoulder girdle:

HAND	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	pronated, elbow flexed 90°, fingers extended and slightly spread	⊥ 3rd MCP	PA carpals, metacarpals, phalanges, and their articulations (Fig. 6–10A); provides obl proj of thumb

This position is often performed to include the wrist for *bone age* studies; 30″ SID is sometimes recommended, with the CR entering the head of the third metacarpal.

HAND	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
obl	prone, elbow flexed 90°, hand and forearm obliqued 45°	⊥ 3rd MCP	obl proj carpals, metacarpals, phalanges, and their articulations; use of a "finger sponge" places jts ‖ IR and opens jt spaces (Fig. 6–10B)
lat *in extension*	elbow flexed 90° fingers extended, wrist, lateral, ulnar surface down	⊥ MCPs	*superimposed* carpals, metacarpals, phalanges, and their articulations; decrease 10 kV for foreign body
lat *in flexion*	elbow flexed 90°, fingers slightly flexed and superimposed	⊥ MCPs	superimposed carpals, metacarpals, phalanges, and their articulations; *shows ant*/post fx displacement

A *fan lateral* with the fingers separated is often performed to better visualize each phalange.

FINGERS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	hand pronated and fingers extended, elbow flexed 90°	⊥ proximal IPJ	PA proximal, middle, and dist phalanges (usually entire hand examined in this position)
lat	elbow flexed 90°, forearm lat, finger(s) extended and ‖ IR	⊥ proximal IPJ	lat of proximal, middle, and dist phalanges; second and third digits are done *radial side down*; fourth and fifth digits are done *ulnar side down*

THUMB	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	dorsal surface adjacent and ‖ IR	⊥ MCP	
PA	palmar surface ‖ IR, *OID is increased*	⊥ MCP	
lat	lat surface adjacent to IR, fingers elevated and resting on sponge	⊥ MCP	AP, PA, or lat projection of first digit; *three articulations should be seen:* CMC, MCP, and IPJ

List of Abbreviations and Symbols Used in the Tables

AC	acromioclavicular
∠	angle
ASIS	anterior superior iliac spine
AP	anteroposterior
≈	approximately (about)
b/w	between
CMC	carpometacarpal joint
CR	central ray
°	degrees
dist	distal
EAM	external auditory meatus
fx	fracture
>	greater than
″	inches
IOML	infraorbitomeatal line
IPJ	interphalangeal joint
IR	image receptor
jt	joint
kV	kilovoltage
lat	lateral
LAO	left anterior oblique
LPO	left posterior oblique
<	less than
MCP	metacarpophalangeal joint
MTP	metatarsophalangeal joint
MSP	midsagittal plane
m/w	midway
OID	object-to-image receptor distance
obl	oblique
OML	orbitomeatal line
‖	parallel to
⊥	perpendicular to
PA	posteroanterior
proj	projection
prox	proximal
RAO	right anterior oblique
RPO	right posterior oblique
SID	source-to-image receptor distance
w/	with
w/o	without

A   B
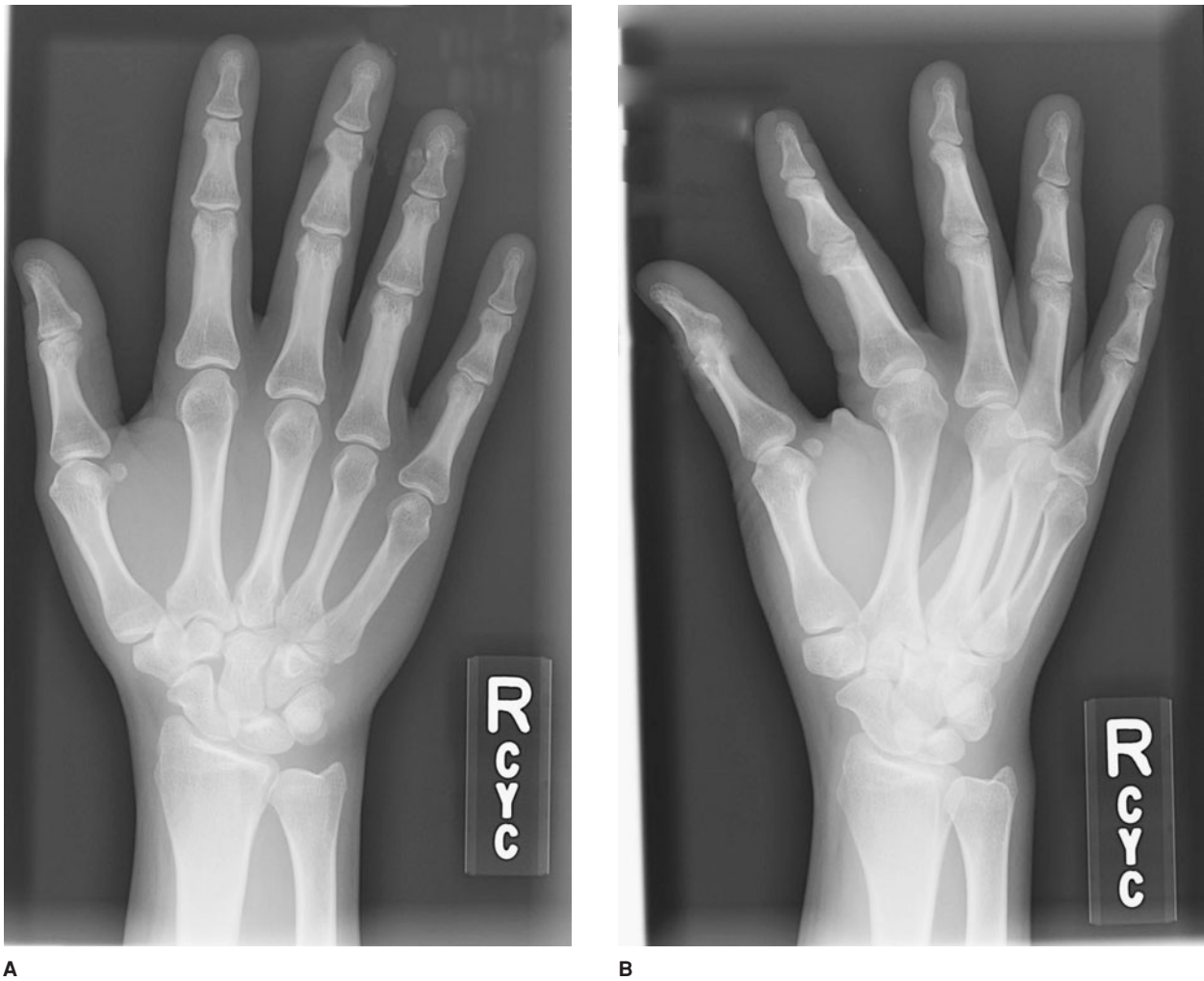
Figure 6–10. PA and oblique projections of the hand. (Courtesy of Stamford Hospital, Department of Radiology.)

WRIST	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	hand pronated w/MCPs slightly flexed and elbow flexed 90°	⊥ midcarpal	PA carpals, prox region metacarpals, dist radius, and ulna (Fig. 6–11A); *flexion of MCPs reduces OID*
lat	elbow flexed 90°, ulnar surface down, radius and ulna superimposed	⊥ midcarpal region	lat carpals, superimposed prox metacarpals and dist radius and ulna (Fig. 6–11B)
PA *semi-pronation* **obl**	elbow flexed 90°, wrist 45° w/IR, ulnar surface down	⊥ midcarpal region	useful for scaphoid and for other *latl carpals* (trapezium and trapezoid) *and their interspaces* (Fig. 6–11C) *(continued)*

A   B   C
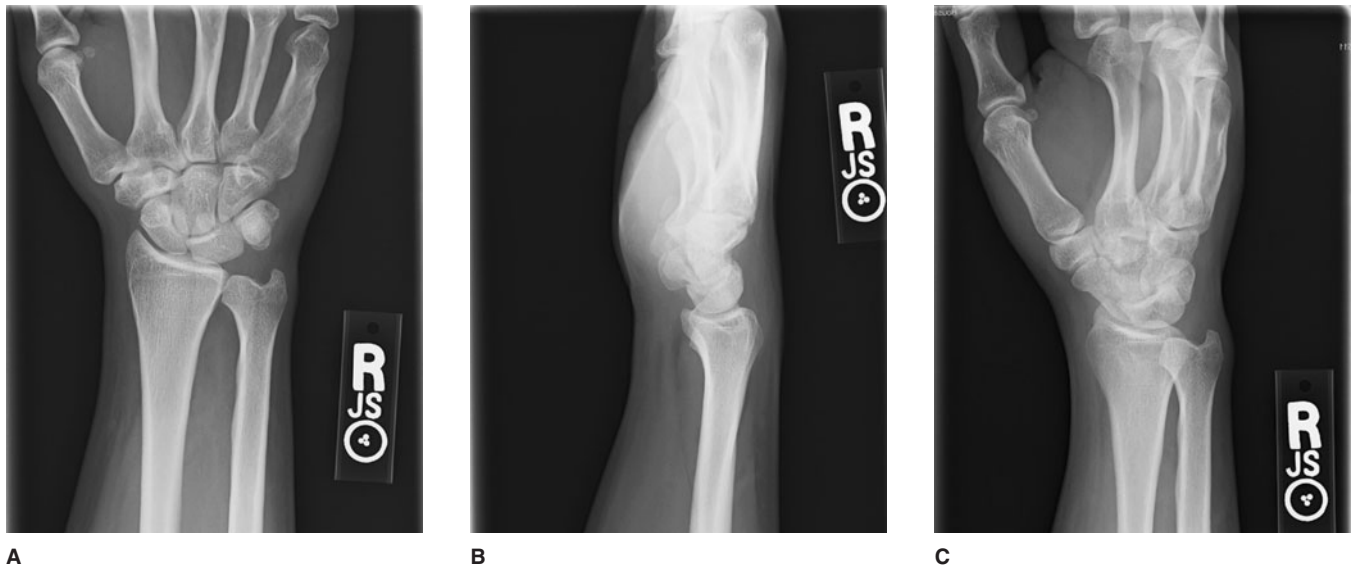
Figure 6–11. (**A**) PA projection of wrist. Flexion of the metacarpophalangeal joints reduces OID. (**B**) Lateral projection of the wrist. (**C**) Semipronation oblique projection of the wrist. (Courtesy of Conrad P. Ehrlich, M.D.)

WRIST (*con't*)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP *semi-supination* **obl**	arm extended, 45° w/IR, ulnar surface down	⊥ midcarpal	useful for pisiform, region triquetrum, and hamate *medial carpals and their interspaces*
ulnar flexion/ deviation	position as PA wrist, evert hand (laterally) without moving forearm	⊥ scaphoid	scaphoid and other *lat* carpal interspaces; *reduces foreshortening of navicular*
radial flexion/ deviation	position as PA wrist, move elbow toward body w/o moving hand/wrist	⊥ midcarpal region	*medial* carpal interspaces (Fig. 6–12)
scaphoid (*Stecher*)	forearm (a) pronated *or* (b) pronated and elevated 20°	(a) 20° toward elbow entering scaphoid *or* (b) ⊥ scaphoid	scaphoid w/o *foreshortening* and self-superimposition
carpal canal (*Gaynor– Hart*)	*hyperextend* wrist w/palm vertical	25°–30° into long axis of hand	carpal canal (*tunnel*); trapezium, scaphoid, capitate, triquetrum, and pisiform

Figure 6–12. Radial flexion/deviation maneuver of left wrist. Radial flexion/deviation is used to better demonstrate the medial carpals (pisiform, triangular, hamate, and medial aspect of capitate and lunate).

A

B
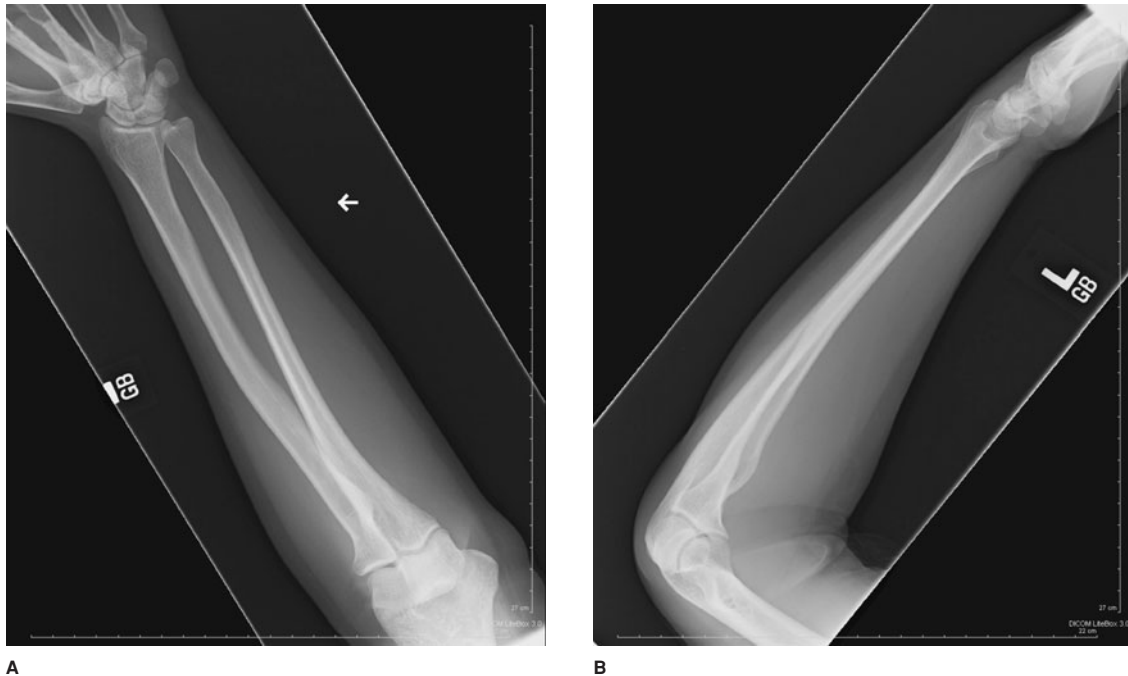
Figure 6–13. (**A**) AP projection of the forearm. The hand must be supinated to avoid overlap of the proximal radius and ulna. (**B**) Lateral projection of the forearm. Humerus should be on same plane as forearm to superimpose humeral epicondyles. (Courtesy of Conrad P. Ehrlich, M.D.)

FOREARM	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	supinated and extended, epicondyles ‖ IR; *shoulder and elbow on same plane*	⊥ midfore-arm	AP radius and ulna, including wrist and elbow jts (Fig. 6–13A); *arm must be supinated* to avoid overlap of radius and ulna
lat	elbow flexed 90°, epicondyles superimposed and ⊥ IR, hand lat; *shoulder and elbow on same plane*	⊥ midfore-arm	radius and ulna superimposed distally, lat proj of radius and ulna, elbow and wrist jts (Fig. 6–13B)

ELBOW	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	extended, supinated; epicondyles ‖ IR	⊥ elbow jt m/w b/w epicon-dyles	AP elbow jt, proximal radius and ulna, dist humerus; radial head and tuberosity partially superimposed on ulna

(continued)

ELBOW (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN

Note: An ***elbow in partial flexion***, unable to be extended, requires two projections to achieve an AP elbow: (1) *humerus* is placed ‖ the IR (with elbow still in partial flexion) and the CR is ⊥ elbow jt; (2) *forearm* is placed ‖ the IR (with elbow still in partial flexion) and the CR is ⊥ elbow jt. Thus, an AP of the dist humerus and proximal forearm are obtained separately. (An AP with the CR directed through the flexed elbow demonstrates a "closed" jt space.)

ELBOW (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat	flexed 90°, epicondyles ⊥ IR, forearm, and wrist lat	⊥ elbow jt at the epi- condyles	lat elbow jt, prox radius, and ulna and dist humerus; radial head partially super- imposed on ulna; olecranon process in profile (Fig. 6–14A)
internal (*medial*) **obl**	arm extended, palm down, epicondyles 45° to IR	⊥ elbow jt midway b/w epi- condyles	obl elbow jt; *coronoid process in profile* (Fig. 6–14B)
external (*lat*) **obl**	forearm extended and rotated laterally, radial surface down, epicondyles 45° to IR	⊥ elbow jt midway b/w epi- condyles	obl elbow jt; radial head, neck, and tuberosity free from superimposition of ulna (see Fig. 6–14C)

(continued)

A   **B**

Figure 6–14. (**A**) Lateral projection elbow; elbow flexed 90°, and humeral epicondyles superimposed. (**B**) Medial (internal) oblique view of elbow; the coronoid process is seen free of superimposition. (Courtesy of Stamford Hospital, Department of Radiology.)

C

Figure 6–14. *(Continued)* (**C**) Lateral (external) oblique view of elbow. Note that the radial tuberosity is free of ulnar superimposition. The proximal radioulnar articulation is nicely shown. (Courtesy of Stamford Hospital, Department of Radiology.)

ELBOW *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
axial lat *(Coyle)*	1) flexed 90°, hand pronated 2) flexed 80°, hand pronated	1) to elbow, at 45° toward shoulder 2) from shoulder to elbow, at 45°	replaces lat and med obliques when patient unable to extend arm 1) for radial head 2) for coronoid process

HUMERUS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	arm extended and supinated; epicondyles ‖ IR	⊥ mid-humerus	AP humerus, includes shoulder and elbow jts; *greater tubercle in profile*; epicondyles ‖ IR
lat	elbow flexed 90°; epicondyles ‖ IR	⊥ mid-humerus	lat humerus including shoulder and elbow jts; *lesser tubercle in profile*; epicondyles superimposed and ⊥ IR
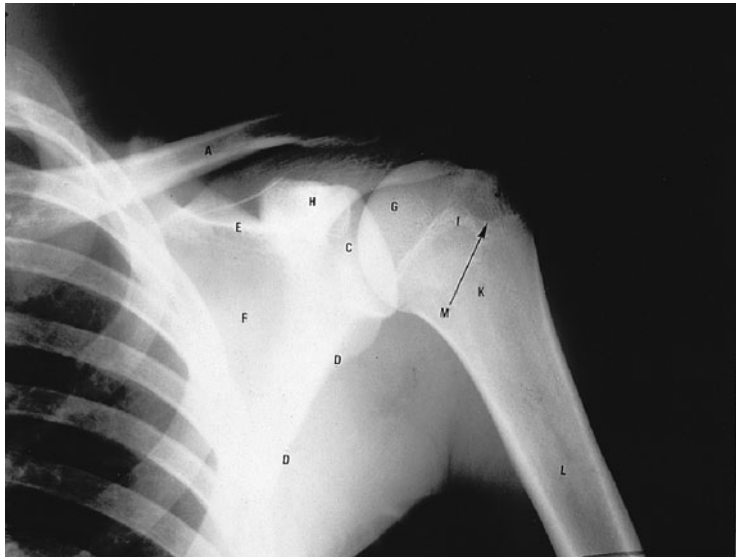
A

B

Figure 6–15. (**A**) Shoulder in external rotation places humerus in a true AP position and places the greater tubercle (J) in profile. *Review the skeletal anatomy* of the shoulder by correctly identifying each of the labeled structures. (Courtesy of Bob Wong, RT.) (**B**) Posterior oblique (Grashey method) for glenoid cavity (Courtesy of Stamford Hospital, Department of Radiology.)

SHOULDER	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP *rotational projections*	Arm extended and (1) supinated, w/epicondyles ∥ IR, (2) palm against thigh, epicondyles 45° to IR, and (3) elbow slightly flexed, back of hand against thigh	⊥ coracoid process	(1) External rotation: true AP humerus, shows greater tubercle in profile (Fig. 6–15A), (2) neutral position: good for calcific deposits, trauma, and (3) internal rotation: lat of humerus, shows lesser tubercle in profile

Note: In case of trauma, the shoulder must be examined in a *neutral* position to avoid unnecessary pain and additional injury.

Posterior oblique *Grashey Method*	Patient. RPO or LPO (erect or recumbent), MSP 35°–45° to affected side; scapula ∥ IR border; suspend respiration	⊥ 2″ medial and 2″ inferior to superior and lat shoulder	glenohumeral jt and glenoid cavity (Fig. 6–15B)
Trans-thoracic lat	Patient erect lat w/affected surgical neck centered to IR; unaffected arm over head	affected surgical neck	lat shoulder and proximal humerus through thorax

(continued)

Figure 6–16. PA oblique projection; scapular Y view of the shoulder. Useful for demonstration of dislocations. Humeral head displaced inferior to coracoid process indicates *anterior dislocation*, while humeral head displaced inferior to acromion process indicates *posterior dislocation*. (Courtesy of Stamford Hospital, Department of Radiology.)

SHOULDER (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA obl *scapular Y*	Affected shoulder centered with MCP 60° to IR	⊥ shoulder jt	Oblique shoulder; especially good for *demonstration of dislocations* (Fig. 6–16)
Infero-superior (***non-trauma***)	Patient supine w/ shoulder elevated from table ≈ 2″ , arm abducted 90°, in external rotation	Horizontally to axilla	Lat. of prox humerus, glenohumeral jt; coracoid process and lesser tubercle in profile

CLAVICLE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA or AP	Patient recumbent or erect; center affected clavicle to IR; less OID in PA position	⊥ midshaft	Entire length of clavicle and articulations, best done PA erect or AP recumbent for patient comfort (Fig. 6–17A)
PA or AP axial	Patient PA/AP, affected clavicle centered to IR	to supraclavicular fossa 15°–30° caudad for PA; cephalad for AP	Axial projection of clavicle; can demonstrate fxs not seen in direct PA or AP (Fig. 6–17B)

Note: *PA* best for optimum detail (less OID); *erect* PA or recumbent AP usually best for comfort (less discomfort to injured part).

A

B

Figure 6–17. (**A**) AP projection of fractured clavicle. (**B**) AP axial projection of fractured clavicle, better illustrating extent of fracture. (Courtesy of Conrad P. Ehrlich, M.D.)

ACROMIO-CLAVICULAR JOINTS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP or PA	Patient AP or PA erect, MSP to mid-IR, arms at sides (always bilateral for comparison)	⊥ midline at level of AC jts	AP/PA projection of AC jt and soft tissues; demonstrates *dislocation/separation* when performed erect (see Fig. 6–38)

Note: Often two exposures are made: one w/o and one w/*weights* (images must be properly identified).

SCAPULA	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	AP upright or recumbent; scapula centered w/arm abducted and elbow flexed	⊥ mid-scapula, ≈2″ inferior to coracoid process	AP scapula with lat portion away from ribs; exposure may be made during quiet breathing to blur lung markings (see Fig. 6–18A)

(continued)

A   B
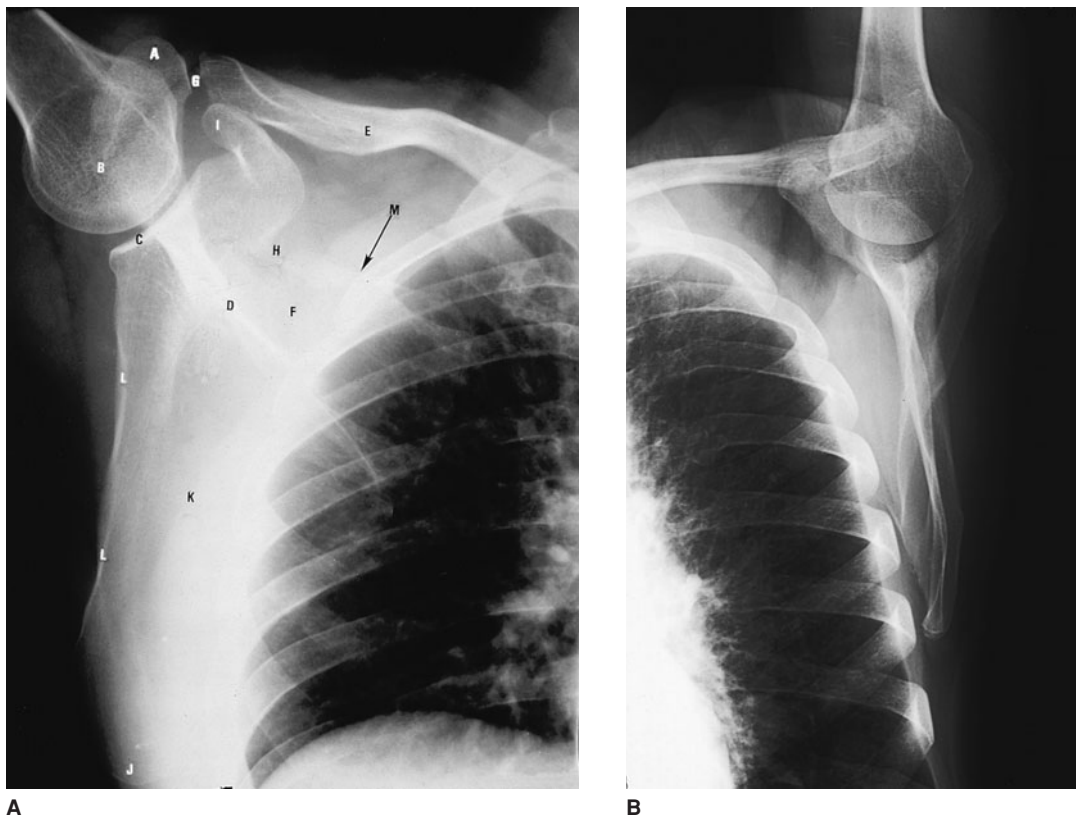
Figure 6–18. (**A**) AP projection of scapula. Note that arm abduction moves scapula away from rib cage, revealing a greater portion of the scapular body. *Review the skeletal anatomy* of the scapula by correctly identifying each of the labeled structures. (Courtesy of Bob Wong, RT.) (**B**) Lateral projection of scapula. Taken with arm elevated and forearm resting on head. Demonstrates scapular body with vertebral and axillary borders exactly superimposed. (Courtesy of Stamford Hospital, Department of Radiology.)

SCAPULA *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat *(anterior oblique)*	Erect PA 45°–60° (obl w/affected side toward IR and (1) arm across chest for acromion and coracoid or (2) palpate scapular borders and rotate body to superimposed	⊥ to midvertebral border	lat scapula, (1) acromion and coracoid processes, (2) superimposed vertebral and axillary borders (Fig. 6–18B) free of rib cage
lat (posterior oblique)	Recumbent AP obl w/affected side away from IR; palpate scapular borders and rotate patient till borders superimposed	⊥ to midaxillary border	lat scapula, borders superimposed, humerus away from scapula

B. LOWER EXTREMITY AND PELVIS

1. Foot and Toes. The bones of the foot (Fig. 6–19A and B) include the 7 *tarsal bones*, 5 *metatarsal bones*, and 14 *phalanges*. The *calcaneus* (os calsis), or heel bone, is the largest tarsal. It serves as attachment for the Achilles tendon posteriorly, articulates anteriorly with the *cuboid bone*, presents three articular surfaces superiorly for its articulation with the *talus*, and has a prominent shelf on its anteromedial edge called the *sustentaculum tali.*

The inferior surface of the talus (*astragalus*) articulates with the superior calcaneus to form the three-faceted *subtalar joint.* The talus also articulates anteriorly with the navicular. Articulating anteriorly with the navicular are the three *cuneiform bones:* medial/first, intermediate/ second, and lateral/third. The navicular articulates laterally with the cuboid.

Fractures of the calcaneus can occur, especially as a result of a fall from a height directly onto the heel; these fractures can be comminuted and impacted. The calcaneus can also be associated with painful *spur* formation.

Stress (fatigue, march) fractures can occur in the metatarsal shafts; x-ray examination will often "miss" these fractures until callus appears during repair process. Phalangeal fractures are common and usually occur as a result of a stubbing or crushing force. A common deformity of the first metatarsophalangeal joint is *hallux valgus.* The first ("great") toe slowly adducts (medially), resulting in an inflamed first metatarsophalangeal joint (*bunion*). The condition is relieved surgically.

The metatarsals and phalanges of the foot are similar to the metacarpals and phalanges of the hand. The bases of the fourth and fifth metatarsals articulate with the cuboid. The fifth (most lateral) metatarsal projects laterally and presents a large *tuberosity* at its base

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Tarsal Bones

Calcaneus/os calsis
Talus/astragalus
Navicular
Cuboid
First/medial cuneiform
Second/intermediate cuneiform
Third/lateral cuneiform
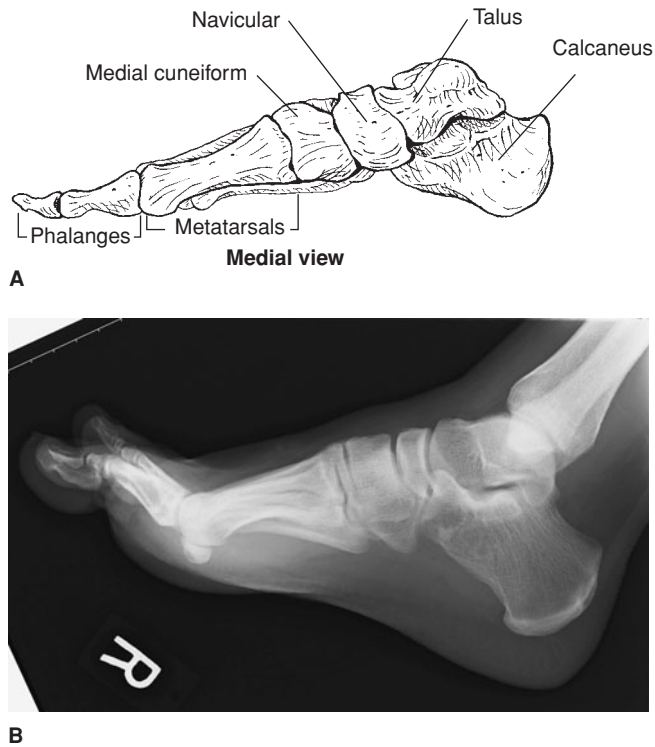
Figure 6–19. (**A**) Bones of the foot (medial view). (**B**) Mediolateral projection of the foot. (Courtesy of Conrad P. Ehrlich, M.D.)

thus making it very susceptible to fracture. *Stress fractures* are common to the metatarsals (Fig. 6–19).

The first, or great, toe (*hallux*) has two phalanges; the second through fifth toes have three phalanges each. The phalanges of the toes are shorter than those of the fingers. Stubbing and crushing-type injuries are common causes of fractured phalanges. The articulations of the foot are named similarly to those of the hand.

2. Ankle. The ankle joint (*mortise*) is formed by the articulation of the talus and distal portions of the tibia and fibula (Fig. 6–20). The medial and lateral malleoli are the most frequently *fractured* components of the ankle joint; severe fractures can disrupt the integrity of the joint and lead to permanent instability and/or arthritis.

3. Lower Leg. The *tibia* and *fibula* (Fig. 6–21) compose the bones of the lower leg. The tibia is larger and is situated medially. It articulates superiorly with the femur and inferiorly with the talus to form a portion of the ankle joint. The tibia consists of a shaft and two expanded extremities. Its distal extremity has a prominence, the *medial malleolus*, which also participates in the formation of the ankle *mortise*. The fibular notch provides articulation for the fibula to form the *distal tibiofibular joint*.

The proximal end of the tibia presents a *medial* and a *lateral condyle*, on whose superior surfaces there are facets for articulation with the femur. The articular facets form a smooth surface called the *tibial plateau*, which provides attachment for the cartilaginous *menisci*
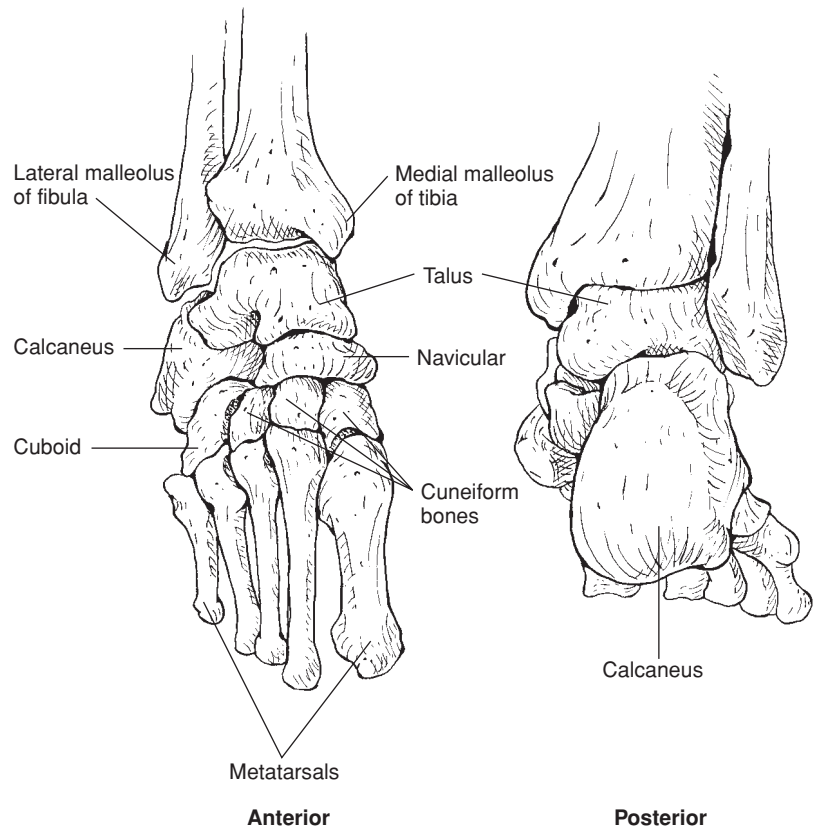
Figure 6–20. Ankle and foot: anterior and posterior views.

of the knee joint. Between the two articular surfaces is a raised prominence, the *intercondylar eminence* (*tibial spine*). The proximal anterior surface of the tibia presents the *tibial tuberosity*, which provides attachment for the patellar ligament. *Osgood–Schlatter disease* is a chronic *epiphysitis* of the tibial tuberosity that occurs in some active young adults. Its symptoms include pain and tenderness and it is manifested radiographically by bony separation at the epiphysis.

The fibula is the slender, lateral non–weight-bearing bone forming the lower leg; it also consists of a shaft and two expanded extremities. The bulbous distal end is the *lateral malleolus* (projects more distally than the medial), which helps form the ankle joint and has a facet for articulation with the tibia (*distal tibiofibular joint*). The expanded proximal portion of the fibula is the *head*, which articulates with the lateral tibial condyle, forming the *proximal tibiofibular joint*. A *styloid* process extends superiorly from the head of the fibula. The *neck* is the constricted portion just distal to the fibular head. The fibula is most commonly fractured at the malleolus, just above the ankle joint.

4. Knee. The knee is formed by the proximal tibia, the patella, and the distal femur, which articulate to form the *femorotibial* and *femoropatellar* joints. The distal posterior femur presents two large *medial* and *lateral condyles* separated by the deep *intercondyloid fossa*. Two small prominences, the *medial* and *lateral epicondyles*, are just superior to the condyles. The femoral and tibial condyles articulate to form the *femorotibial joint*.
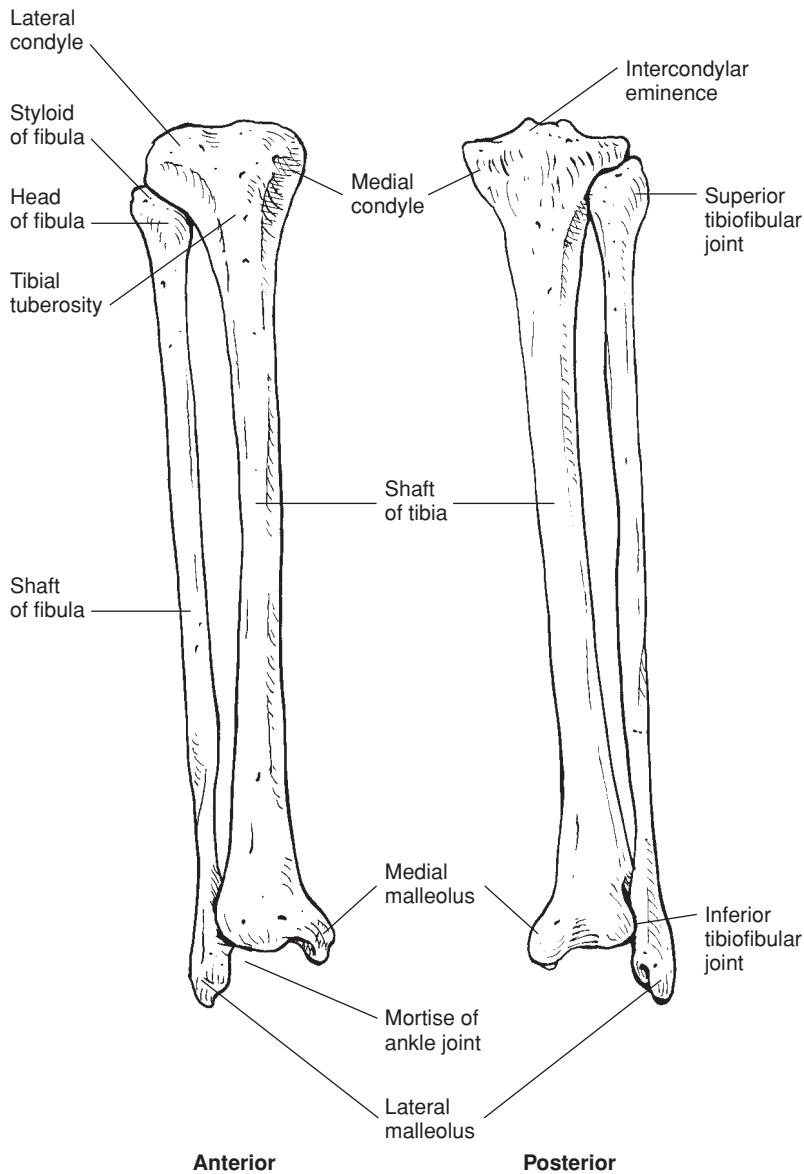
Figure 6–21. Right tibia and fibula.

Semilunar cartilages, the *menisci*, lie medially and laterally between the articulating bones and, together with the *cruciate* and *collateral ligaments*, help form the *articular capsule* of the knee (Fig. 6–22A).

The *patella* is a triangular bone with its *base* superior and *apex* inferior. The *patella* is the largest *sesamoid* bone and, attached to the tibial tuberosity by the patellar ligament, glides over the patellar surface of the distal femur (femoropatellar joint) during flexion and extension of the knee. Simple patellar fractures are usually *transverse* (Fig. 6–22B). Fractures of the patella can also be *stellate* or comminuted; the more complex fractures can require a patellectomy.

The congenital anomaly, *bipartite patella*, can be misinterpreted as a fracture. Just opposite the *patellar surface*, on the posterior distal femur, is the smooth *popliteal surface*, which accommodates the popliteal artery.
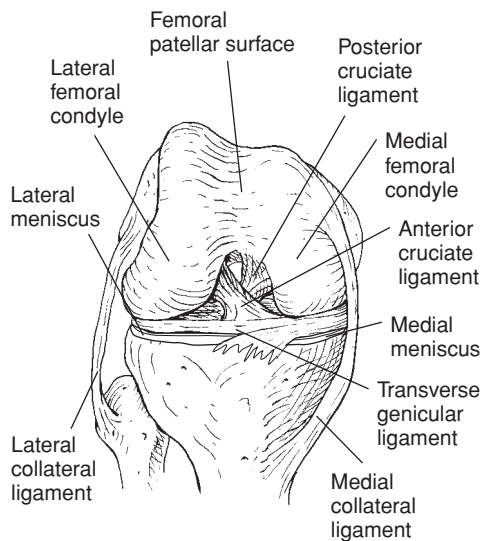
Figure 6–22. (**A**) Ligaments of the knee joint. (**B**) The knee should not be flexed more than 10° when transverse fracture of patella is known or suspected; flexion can cause pain, fragment separation, and fracture complication. The CR can be angled 5° cephalad to superimpose the magnified medial femoral condyle on the lateral condyle and permit better visualization of the joint space; angulation was not employed in this projection and the joint space is obscured by the magnified medial femoral condyle. (Courtesy of Stamford Hospital, Department of Radiology.)

5. Femur. The *femur* (Fig. 6–23) is the longest and strongest bone in the body. The femoral *shaft* is bowed slightly anteriorly. The proximal end of the femur consists of a *head*, which is received by the *acetabulum* of the pelvis. The femoral head has a small notch, the *fovea capitis femoris*, for ligament attachment. The *femoral neck*, which joins the head and shaft, angles upward approximately 120° and forward (in *anteversion*) approximately 15°. The *greater* (lateral) and *lesser* (medial) *trochanters* are large processes on the posterior proximal femur. The greater trochanter is a prominent positioning landmark that lies in the same transverse plane as the public symphysis and coccyx. The (posterior) *intertrochanteric crest* runs obliquely between the trochanters; the (anterior) *intertrochanteric line* runs anteriorly parallel to the crest. The femoral shaft presents a long narrow ridge posteriorly called the *linea aspera*.

Its distal anterior portion presents the *patellar surface*—a triangular depression over which the patella glides during flexion.

The distal posterior surface presents the *popliteal surface*—a depression that houses the popliteal artery. The medial and lateral

Fovea
capitis femoris

Head

Greater
trochanter

Head

Greater
trochanter

Neck

Neck

Lesser
trochanter

Lesser
trochanter

Linea
aspera

Shaft

Shaft

Lateral
supracondylar
line

Medial
supracondylar
line

Lateral
epicondyle

Medial
epicondyle

Intercondylar
fossa

Lateral
condyle

Medial
condyle

Lateral
condyle

Medial
condyle

Anterior   **Medial**   **Posterior**
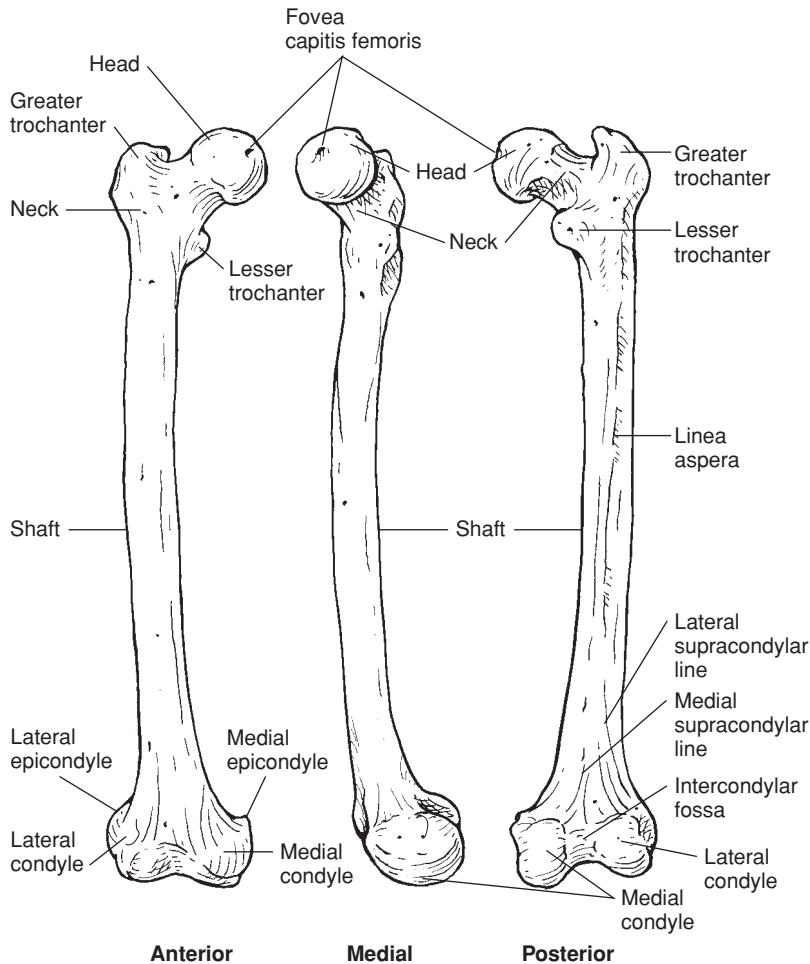
Figure 6–23. The right femur.

femoral condyles are very prominent posterior structures, and between them is the deep intercondyloid fossa. Just above the condyles are the medial and lateral femoral epicondyles.

The femoral neck is the most commonly *fractured* portion of the femur (Fig. 6–24). Fractures of the femoral shaft are usually the result of a direct blow; fracture *displacement* is dependent on muscular pull and traumatic impact. Dislocations of the hip joint are fairly uncommon because of the very strong pelvic and hip musculature. Disturbance of the fovea capitis femoris or disruption of the nutrient arteries supplying the femoral neck can result in *avascular necrosis* of the femoral head.

6. Pelvis. The pelvic girdle consists of two *innominate* (hip, or *coxal*) bones, one on each side of the sacrum. Each innominate bone consists of three fused bones: the *ilium, ischium*, and *pubis* (Fig. 6–25). Parts of these three bones contribute to the formation of the *acetabulum*—the socket articulation for the femoral head. The ilia are the large, superior bones whose medial *auricular* surfaces form the *sacroiliac joints* bilaterally. The broad, flat portion of each ilium is the *ala*, or wing; the upper part of the ala forms a ridge of bone called the *iliac crest*, which terminates in *anterior* and *posterior iliac spines*.

Articulation Summary: Lower Extremity and Pelvic Girdle

- Sacroiliac
- Hip (femoral head w/acetabulum)
- Knee (femorotibial)
- Proximal tibiofibular
- Distal tibiofibular
- Ankle (distal tibia and fibula w/superior talus)
- Intertarsal
- Tarsometatarsal
- Metatarsophalangeal
- Interphalangeal

Figure 6–24. AP projection of the left hip. Leg is internally rotated, placing femoral neck parallel to the IR. (Courtesy of Stamford Hospital, Department of Radiology.)

The ischium forms the posteroinferior portion of the pelvis. The posterior part of the ischium forms the major portion of the *greater* and *lesser sciatic notches* separated by the *ischial spine.* The most inferior portion is the *ischial tuberosity*—a large, rough prominence that provides attachment for posterior thigh muscles. The inferior *ramus* of the ischium extends medially from the tuberosities to unite with the inferior ramus of the pubis.

The pubic bones form the anterior portion of the pelvis. Their bodies unite to form the *pubic symphysis.* The superior ramus fuses with the ilium and inferior ramus with the ischium to form the large *obturator foramen.*

Pelvic fractures can cause disturbance of the urinary bladder or urethra; an *intravenous urogram/pyelogram* (IVU/IVP) may be required to diagnose any urinary leakage. The *female pelvis* differs from the *male pelvis* in that it is shallower and its bones are generally more delicate. The pelvic outlet is wider and more circular in the female; the ischial tuberosities and acetabula are further apart; and the angle formed by the pubic arch is also greater in the female. All these bony characteristics facilitate the birth process (Fig. 6–26).
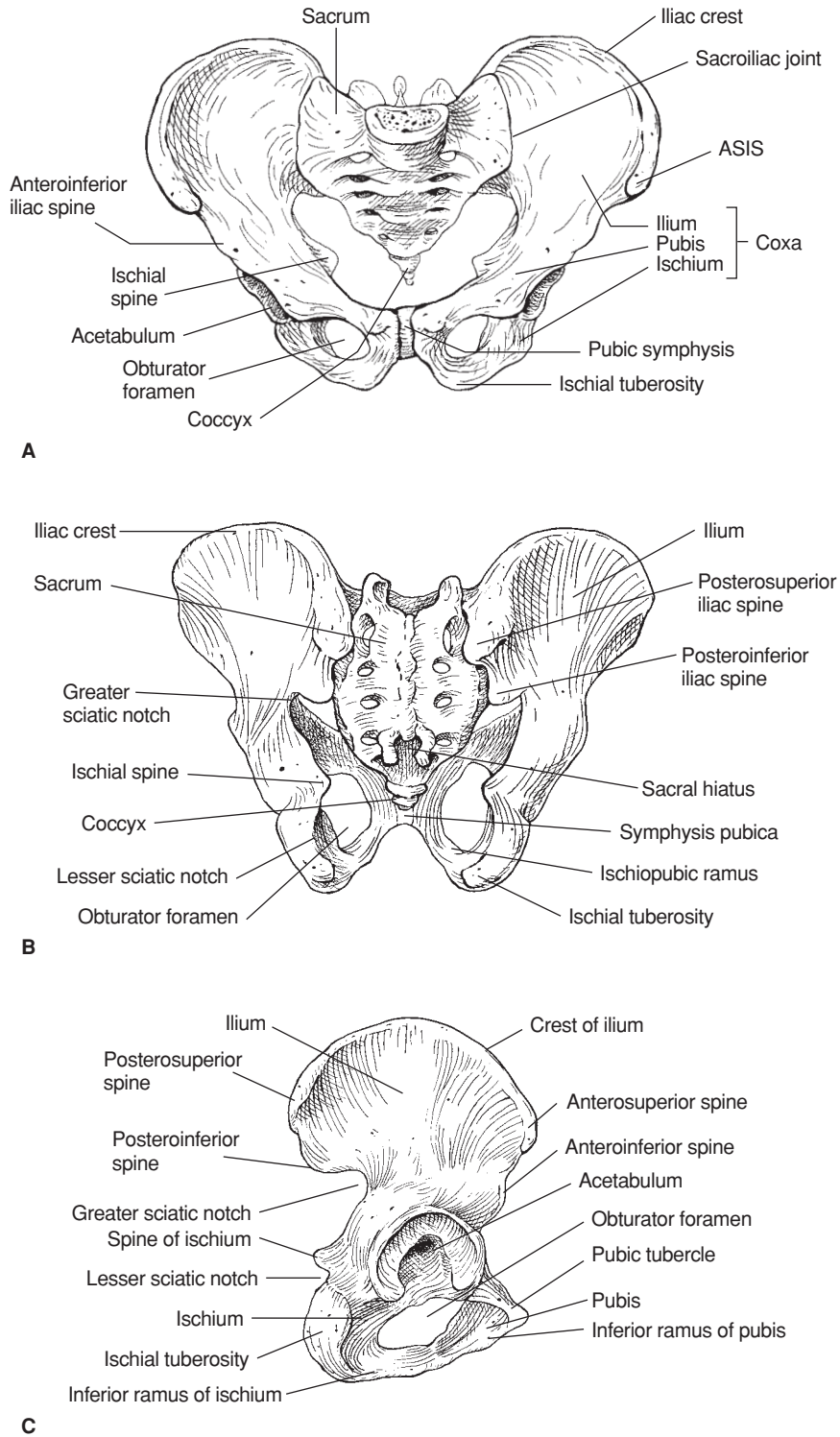
Figure 6–25. **(A)** The pelvis (anterior view). **(B)** The pelvic girdle (posterior view). **(C)** The right hip bone (lateral view), showing the acetabulum.
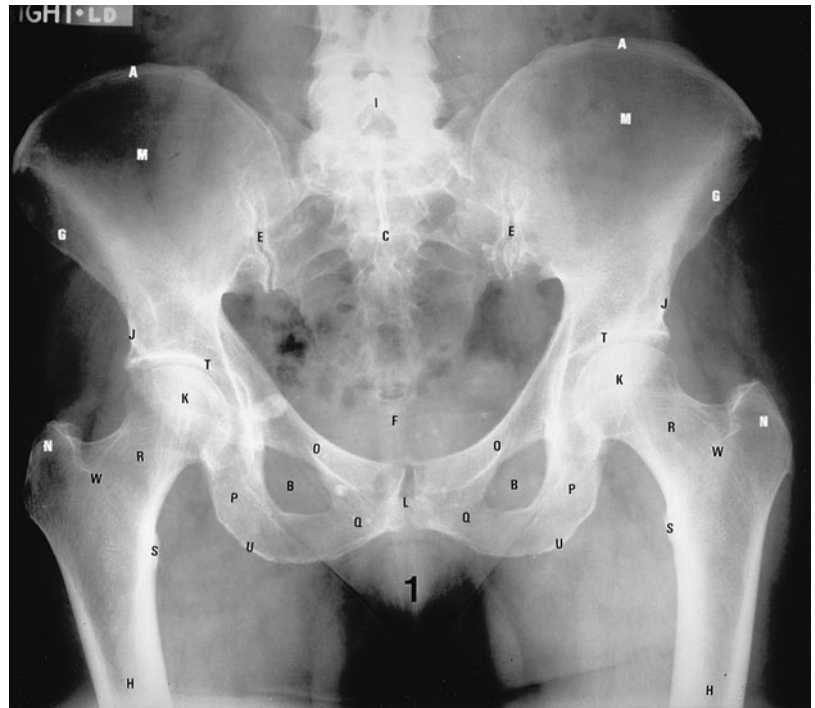
Figure 6–25. *(Continued)* **(D)** AP projection of the pelvis. The femoral necks are seen in their entirety: internal rotation of the feet/legs places them parallel to the IR. *Review the skeletal anatomy* of the pelvis by correctly identifying each of the lettered structures. (Courtesy of Bob Wong, RT.)

D

7. Positioning. Positioning of the lower extremity and pelvis requires a thorough knowledge of the skeletal anatomy—an awareness of possible pathologic conditions and their impact on positioning and technical factors.

Clothing with radiopaque objects such as buttons, snaps, or zippers should be removed whenever possible. Bulky or bunched clothing can produce undesirable radiographic artifacts and should therefore be removed whenever possible and replaced with a hospital dressing gown. Elastic-waisted garments can contribute to nonuniform density on abdominal radiographs.

The patient must be instructed about the importance of remaining still, and immobilization devices such as radioparent sponges, sandbags, or tape should be used as required. The shortest possible exposure time should be employed, especially when involuntary motion is a potential problem.

Many lower extremity examinations can be performed tabletop (i.e., non-Bucky); the knee frequently requires a grid; and femur, hip, and pelvis almost always do. *Suspended respiration* is suggested for radiography of the proximal portion of the lower extremity and the pelvis. Patients must be appropriately shielded.

Some of the lower leg examinations can be performed either AP or PA, depending on the condition and comfort of the patient. Lateral projections can be easily obtained using a horizontal (cross-table lateral) beam when extremity or patient movement is contraindicated.

The following tables provide a summary of routine and frequently performed special projections of the lower extremity and pelvis.

A

90°
or less

B

100°
or more

C

Figure 6–26. Architectural differences in the (**A**) male and (**B**) female pelves. **(C)** AP projection female pelvis. Femoral necks are parallel to the IR and greater trochanters are seen in profile. (Courtesy of Stamford Hospital, Department of Radiology.)

FOOT	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Dorso-plantar (AP)	Knee flexed ≈45°, plantar surface on IR	⊥ or 10° toward heel to base of third metatarsal	Tarsals (except calcaneus and part of talus), metatarsals and phalanges with their articulations, in frontal projection

Note: A 10° posterior angulation may be used to better demonstrate jt spaces.

Medial obl	Start as dorso-plantar, rotate medially 30°	⊥ base of third metatarsal	Most tarsals and metatarsals (except the most medial) and their articulations, sinus tarsi, tuberosity of fifth metatarsal (see Fig. 6–27)

Note: *lat obl* foot demonstrates interspaces b/w the first and second metatarsals and b/w the first and second cuneiforms.

(continued)

Figure 6–27. Medial oblique view of left foot demonstrates the articulations of the cuboid with the calcaneus, fourth and fifth metatarsals, and lateral cuneiform. The talonavicular articulation and sinus tarsi are also demonstrated. (Courtesy of Stamford Hospital, Department of Radiology.)

FOOT (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Lateral	Patient lateral, patella ⊥ tabletop, foot slightly dorsiflexed w/plantar surface ∥ IR	⊥ metatarsal bases	Lateral foot and ankle jt; dist tibia and fibula; superimposed tarsals, tibia, and fibula (see Fig. 6–28)

Note: The lateral projection is more *accurately* obtained in the *lateromedial* (rather than mediolateral) position.

Note: *Lateral weight-bearing feet* are occasionally requested to demonstrate the status of the *plantar arches*.

TOES	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Dorso-plantar (*AP*)	Knee flexed ≈45°, plantar surface on IR	⊥ or 10° toward heel, to second MTP	Phalanges, their articulations and dist metatarsals in frontal projection (usually entire foot examined in this position)
Medial obl	Start as dorsoplantar, rotate medially 30°–45°	⊥ 3rd MTP	Oblique projection of phalanges, and their articulations and dist metatarsals
lat	Turn to side that brings affected toe(s) closest to IR; unaffected toes may be taped back	⊥ proximal pip	Lateral projection of toe(s) and associated articulations
Sesamoids (*tangential*)	Patient prone, *foot* dorsiflexed 15°–20°, toes dorsiflexed 15°–20° and resting on cassette	⊥ or ≈10° caudad to IR to first MTP	Sesamoids in profile free of superimposition

Figure 6–28. Lateral projection of foot demonstrates superimposed tarsals, metatarsals, and phalanges; a little more of the distal tibia and fibula should be visualized. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 6–29. Plantodorsal projection of calcaneus; sustentaculum tali, trochlear process, and calcaneal tuberosity are well visualized. (Courtesy of Stamford Hospital, Department of Radiology.)

CALCANEUS/ (OS CALSIS)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Planto-dorsal	Patient seated on table with leg extended, plantar surface ⊥ tabletop (immobilize w/ strip of tape/gauze held by patient)	40° cephalad to base of third metatarsal	Axial projection of calcaneus; trochlear process, sustentaculum tali, talocalcaneal jt (see Fig. 6–29)
Dorso-plantar	Patient prone, plantar surface ⊥ tabletop; IR placed against plantar surface	40° caudally to level of base of second	Axial proj of calcaneus; trochlear process, sustentaculum tali, talocalcaneal jt
lat	Patient on affected side, patella ⊥ tabletop, foot, and ankle lateral	⊥ midcalcaneus	Lateral calcaneus, talus, navicular, ankle jt, and sinus tarsi (see Fig. 6–30)

Figure 6–30. Lateral calcaneus; sinus tarsi is well visualized. (Courtesy of Stamford Hospital, Department of Radiology.)

A

B

Figure 6–31. (**A**) AP projection of the ankle joint. (Courtesy of Stamford Hospital, Department of Radiology.) (**B**) The 15° to 20° medial oblique projection of the ankle is used to demonstrate the ankle mortise. An oblique projection of the distal tibia/fibula, proximal talus, and their articular surfaces is also demonstrated. (Courtesy of Stamford Hospital, Department of Radiology.)

ANKLE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Leg extended AP, plantar surface ⊥ IR	⊥ midway b/w malleoli thru tibiotalar jt	AP ankle jt, dist tibia/fibula, talus (see Fig. 6–31A)
AP mortise; medial obl	Leg extended AP, rotated 15°–20° medially until intermalleolar plane ⊥ IR	⊥ midway b/w malleoli, ⊥ intermalleolar plane	AP ankle mortise, talotibial and talofibular jts well seen; all three aspects of mortise jt seen in profile (see Fig. 6–31B)

Note: A 45° *medial oblique* is often used in ankle surveys. It demonstrates the distal tibia and fibula with perhaps some superimposition on the talus.

ANKLE *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat	Patient turned on to affected side, patella ⊥ tabletop, foot dorsiflexed (≈90°)	⊥ ankle jt	Lateral dist tibia/fibula, ankle jt, talus, calcaneus, navicular

Note: The lateral projection is more *accurately* obtained in the *lateromedial* (rather than mediolateral) position.

AP stress views	Leg extended, ankle true AP, foot dorsiflexed, plantar surface ⊥ • One exposure w/jt in stressed inversion • One exposure w/jt in stressed eversion	⊥ midway b/w malleoli	AP ankle jt in inversion and eversion – to evaluate jt separation or ligament tear

Note: If someone (e.g., the MD) must hold the ankle in position, be certain that appropriate radiation precautions are taken.

LOWER LEG	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Leg extended AP, no pelvic rotation, foot dorsiflexed	⊥ midshaft tibia	AP lower leg, both jts should be included (Fig. 6–32A)
lat	Patient on affected side, patella ⊥ tabletop, ankle, and foot lat	⊥ midshaft	lat tibia/fibula, both jts should be included (Fig. 6–32B)
AP obl *(medial and lat rotation)*	Leg extended w/foot dorsiflexed; leg rotated 45° medially or laterally	⊥ midshaft tibia	Medial rotation shows proximal and dist tibiofibular articulations

KNEE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Leg extended AP, no pelvic rotation (leg may be rotated 3°–5° internally)	to 1/2″ below patellar apex (knee jt); direction of CR depends on distance b/w ASIS and tabletop: up to 19 cm (thin pelvis) 3°–5° caudad; 19–24 cm ○ CR; >24 cm (thick pelvis) 3°–5° cephalad	AP knee jt, dist femur, and proximal tibia/fibula, patella seen thru femur

(continued)
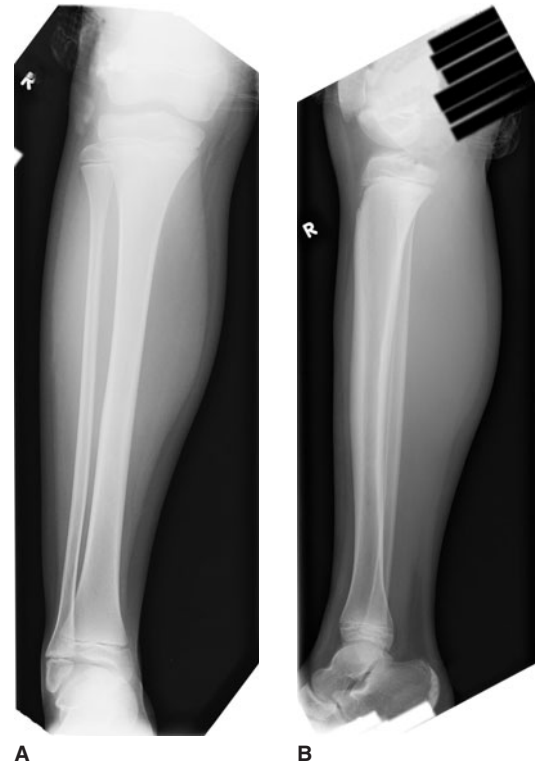
Figure 6–32. (**A**) AP projection tibia and fibula; both joints should be included whenever possible. (**B**) Lateral projection tibia and fibula; both joints should be included whenever possible. (Courtesy of Stamford Hospital, Department of Radiology.)

KNEE (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat	Patient on affected side, patella ⊥ tabletop, knee flexed 20°–30°	5° cephalad to knee jt	lat proj of knee and femoropatellar jts; superimposed femoral condyles; *knee should not be flexed > 10° with known or suspected patellar fx* (see Fig. 6–22B)
AP *weight bearing (bilateral)*	Patient AP erect against upright Bucky, weight evenly shared on legs	⊥ CR midway b/w knees at level of patellar apices	AP weight-bearing knee jts particularly useful for evaluation of *arthritic conditions* (see Fig. 6–41)

Note: If the oblique projections of the knee are requested, they are performed using a 45° oblique. The *proximal tibiofibular articulation* is best demonstrated in a 45° internal/medial oblique knee position.

Inter-condyloid fossa (*Camp– Coventry*)	Patient PA recumbent, knee flexed so tibia forms 40° w/tabletop and foot rested on support	CR 40° caudad (⊥ long axis of tibia) to knee jt	*PA axial* (superoinferior) proj of intercondyloid fossa, tibial plateau, and eminences; "tunnel view" (see Fig. 6–33A and B)

A
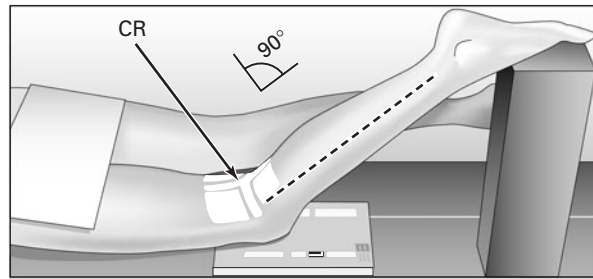
B

Figure 6–33. **(A)** Intercondyloid fossa, using the Camp–Coventry method. The tibial plateau and eminences are well visualized. (Courtesy of Stamford Hospital, Department of Radiology.) **(B)** Patient and CR positioning for Camp–Coventry method.

KNEE *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Inter-condyloid fossa (Bècleré)	Patient AP w/knee flexed ≈20°–30° resting on supported IR	∠ed cephalad (⊥ long axis of tibia) to knee jt	AP *axial* (inferosuperior) proj of intercondyloid fossa, tibial plateau, and eminences; "tunnel view"

Note: The *Holmblad* method of intercondyloid fossa is performed w/the patient in the kneeling position on the x-ray table. The affected knee is centered, and CR forms a 20° angle w/femur (femur is 70° with table).

PATELLA	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	Patient prone, leg rotated ≈5°–10° laterally to place patella ∥ tabletop	⊥ patella (enters popliteal region)	PA patella, including knee jt; better detail than the AP position (less OID)
Tangential (*Hughston*)	Patient prone, knee flexed 50°–60° with foot supported	45° cephalad through femoro-patellar jt	Tangential proj of patella, femoropatellar articulation; useful for r/o patellar *subluxation*
Tangential (*Settegast*)	Patient prone or seated on x-ray table; knee flexed to place patella nearly ⊥ IR	Directed to patellar apex, exiting at its base	*Tangential* projection of the patella (Fig. 6–34), femoropatellar articulation; useful for demonstrating *vertical* fx; *must not be attempted in known or suspected transverse fx of patella*

Note: The *tangential projection/Merchant method* of demonstrating the patella and femoropatellar jts can require the use of special equipment. However, the essential components of the method include relaxed quadriceps muscles, ≈45° knee flexion, ≈30°caudal CR angle, at a 6-foot SID to reduce magnification.
Note: The *lateral* projection of the patella requires that the patient be lateral with knee flexed *no more than 10°*, patellar surface ⊥ IR, and CR to midportion of femoropatellar jt.
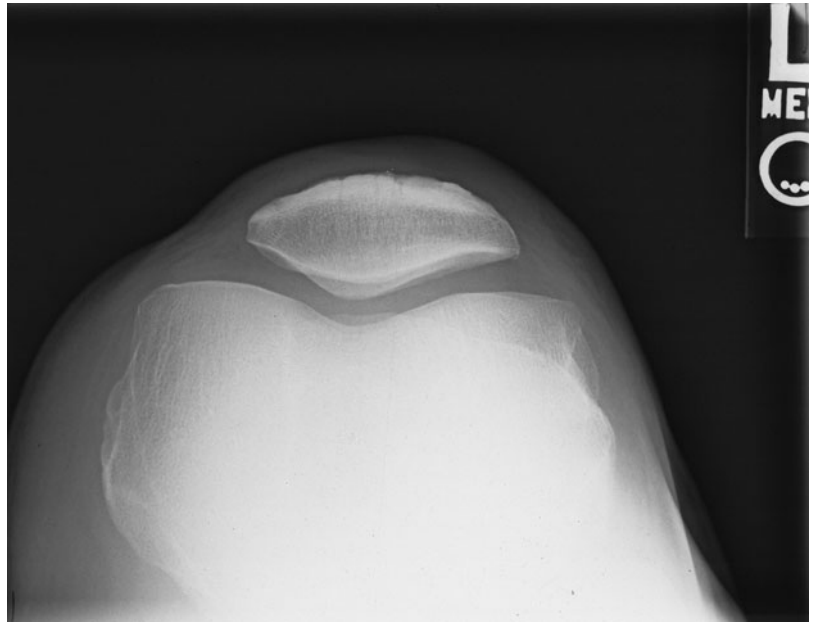
Figure 6–34. Tangential "sunrise" (Settegast) projection of the patella. The femoropatellar joint is well demonstrated. (Courtesy of Stamford Hospital, Department of Radiology.)

FEMUR	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine, affected femur centered to midline of grid w/leg internally rotated 15°	⊥ midfemoral shaft (to include hip and possibly knee jt)	AP proj femur, including hip jt; leg rotation *overcomes anteversion* of femoral neck and places neck ‖ IR
lat (*mediolateral*)	Patient recumbent lateral w/affected leg centered to grid; patella ⊥ tabletop	⊥ midshaft	Lateral proj femur, from knee jt up; may be performed w/horizontal beam if suspected fx or pathologic disease

Note: If an orthopedic appliance is present, the radiograph should include the entire appliance and the articulation closest to it.

HIP	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine, sagittal plane 2″ medial to ASIS centered to midline of grid, no pelvic rotation, leg rotated 15° internally	sagittal plane 2″ medial to ASIS at level of greater trochanter	AP hip jt, femoral neck and proximal femur; a portion of the pelvic bones is included; *the greater trochanter should be seen in profile*

Note: Another method of hip localization is to bisect the ASIS and pubic symphysis: this is the peak of the femoral head. A point ≈2.5″ dist and ⊥ is the midpoint of the femoral neck (see Fig. 6–24).

Note: *Leg inversion must never be forced and is contraindicated in cases of known or suspected fx or destructive disease.*

(continued)

Figure 6–35. AP oblique (modified Cleaves) view of hip. The femoral neck and greater and lesser trochanters are well defined; the lesser trochanter is seen medially.

HIP *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP Oblique (*modified Cleaves*)	Patient supine, ASIS of affected side centered to grid, knee and hip acutely flexed, thigh(s) abducted 40°	⊥ the affected hip at a level 1″ above the pubic symphysis	AP oblique proj hip jt; lesser trochanter should be seen on the medial aspect of the femur (see Fig. 6–35).

Note: Bilateral examination can be performed by positioning both hips and directing the CR to the MSP at a point 1″ above the pubic symphysis.

Note: The above position must not be attempted when fx is suspected.

Axio-lateral infero-superior (*Danelius-Miller*)	Patient supine, unaffected leg elevated; leg rotated internally 15°, grid placed against thigh to femoral neck	⊥ femoral neck and grid	Lateral proj of proximal femur and its articulation with the acetabulum; *the lesser trochanter will be prominently seen on the posterior aspect of the femur*

Note: Leg inversion must never be forced and is contraindicated in cases of known or suspected fx or destructive disease. This position requires localization of the long axis of the femoral neck. First *mark* the midpoint b/w the ASIS and pubic symphysis of affected side; next *mark* a point 19 dist to the prominence of the greater trochanter. A line b/w these 2 points parallels the long axis of the femoral neck.

(continued)

HIP (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Trauma axio-lateral infero-superior	Patient supine, legs extended; affected side to *edge* of table (Bucky side). Cassette placed on extended Bucky tray, and tilted back ≈ 15°–20°, ⊥ CR	CR angled 15°–20° posteriorly, entering proximal medial thigh, ⊥ mid femoral neck	Lateral oblique of proximal femur, hip jt
Aceta-bulum posterior obl. (*Judet*)	Patient recumbent, 45° post obl	If affected side *down*, CR ⊥ 2″ medial and dist to (down side) ASIS If affected side *up*, CR ⊥ 2″ dist to (upside) ASIS	*Downside* shows anterior rim of acetabulum *Upside* shows posterior rim and obturator foramen

PELVIS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine, MSP ⊥ tabletop, no pelvic rotation, legs rotated internally 15°	⊥ midline at a level 2″ above greater trochanter; top of IR 1–2″ above iliac crest	AP proj pelvis and upper femora w/femoral necks ‖ IR and greater trochanters free of superimposition (Fig. 6–36)
Pelvic bones *outlet/inlet projec-tions*	Patient supine, no pelvic rotation	*Outlet*: CR to pubic symphysis/greater trochanter at 20°–35° cephalad (*males*), 30°–45° cephalad (*females*) *Intlet*: CR 40° caudad, entering m/w b/w ASISs	*Outlet*: shows ischial body and ramus, pubic superior and inferior rami *Inlet*: shows entire (upper) pelvic unlet

Figure 6–36. AP projection of the pelvis. The femoral necks are seen in their entirety: internal rotation of the feet/legs places them parallel to the IR. *Review the skeletal anatomy* of the pelvis by correctly identifying each of the lettered structures. (Courtesy of Bob Wong, RT.)

ILIUM	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine, sagittal plane passing through hip jt of affected side centered to grid, patient obliqued 40 toward affected side	⊥, enters the sagittal plane 2″ medial to ASIS at level m/w b/w crest and greater trochanter	AP proj of ilium, patient obliquity "opens" the ilium by placing it ‖ to the IR

SACRO- ILIAC JTS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP obl *(LPO and RPO)*	Patient supine and obliqued 25°–30° affected side up with sagittal plane passing 1″ medial to ASIS centered to grid	⊥ a point 1″ medial to ASIS	Sacroiliac (SI) jt of the elevated side; the opposite obl is similarly obtained; SI jt is placed ⊥ IR (Fig. 6–37A and B)
PA obl **(LAO and RAO)**	Patient prone and obliqued 25°–30° affected side *down* with sagittal plane passing 1″ medial to ASIS centered to grid	⊥ a point 1″ medial to ASIS	Sacroiliac (SI) jt of the "down" side; the opposite obl is similarly obtained; SI jt is placed ⊥ IR

Note: The AP axial projection requires the CR directed 30°–35° cephalad.

A   **B**

Figure 6–37. (**A**) AP right SI joint with perpendicular CR. (Courtesy of Conrad P. Ehrlich, M.D.) (**B**) LPO right SI joint with perpendicular CR; 25° obliquity opens SI joint nicely. (Courtesy of Conrad P. Ehrlich, M.D.)

8. Long Bone Measurement. Accurate measurement of long bones, usually lower extremities, is occasionally required to evaluate abnormal growth patterns in children or lower back disorders in adults.

LONG BONE MEASUREMENT	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP (leg)	Patient supine, leg extended and centered to grid w/metal ruler taped alongside; one exposure each at hip, knee, and ankle jts (on one IR)	⊥ hip, knee, ankle jts	Tightly collimated AP projections of hip, knee, and ankle jts with metallic ruler alongside

Note: For bilateral examination, ruler is placed b/w legs, there must be no rotation, and if one knee is somewhat flexed, the other must be identically flexed for the exposure.

To Locate Joints

Hip: Bisect the ASIS and pubic symphysis; center 1″ distal and lateral to that point
Knee: Center immediately below the patellar apex
Ankle: Center midway between the malleoli

9. Arthrography. *Arthrography* is a contrast examination performed to evaluate soft-tissue joint structures, such as articular cartilages, menisci, ligaments, and bursae. The examination is most often performed as *double* contrast, with a *positive contrast agent* (water-soluble iodinated) coating the structures and a *negative* contrast agent (air) filling the joint cavity. Fluoroscopic images are made during the examination while applying various *stress maneuvers*. Overhead radiographs could be requested as supplemental images. The knee is the most common joint to be examined in this way, although the hip, wrist, shoulder (Fig. 6–38A), and temporomandibular joint (TMJ) can also be evaluated with contrast arthrography.

A

B
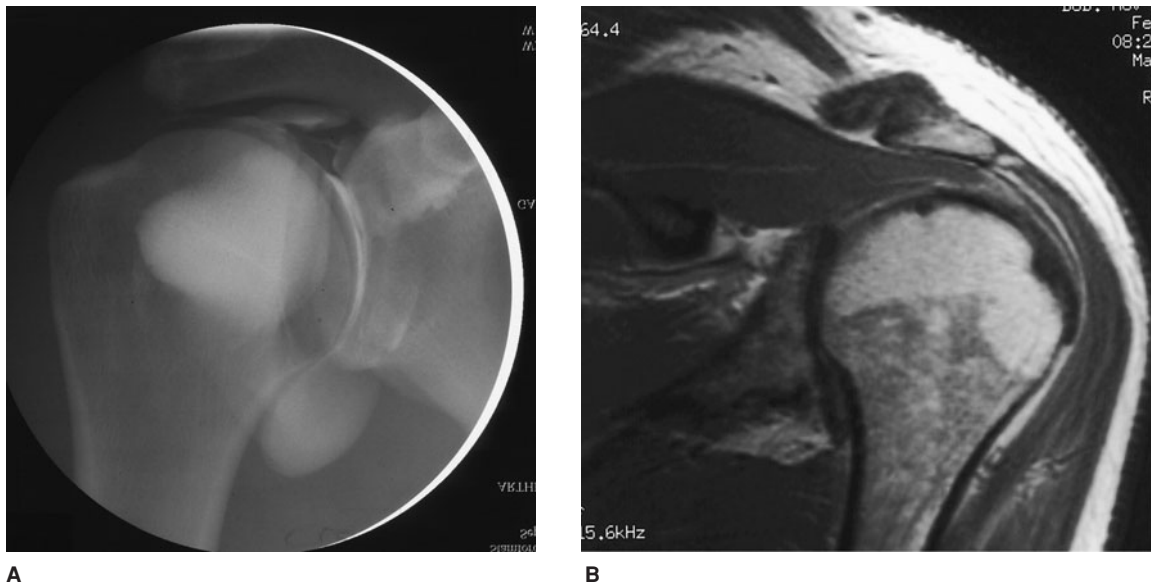
Figure 6–38. **(A)** A shoulder arthrogram. **(B)** MR imaging of the shoulder is accomplished noninvasively and provides visualization of structures having subtle differences in tissue density. (Courtesy of Stamford Hospital, Department of Radiology.)

Many arthrographic procedures have been supplemented or replaced by magnetic resonance (MR) imaging studies, which have the advantage of being *noninvasive* and provide excellent soft-tissue diagnostic value (Fig. 6–38B). Another option is to perform traditional arthrography using gadodiamide (gadolinium) as the contrast agent. The arthrogram is followed up immediately with an MR examination of the affected joint.

10. Terminology and Pathology. Some of the radiologically significant skeletal disorders or conditions of upper and lower extremities with which the student radiographer should be familiar are listed as follows:

Acromegaly	Osteochondroma
Battered child syndrome	Osteomalacia
Bone metastases	Osteomyelitis
Bursitis	Osteoporosis
Carpal tunnel syndrome	Paget's disease (Fig. 6–40)
Epicondylitis	Rickets
Fracture (Figs. 6–4, 6–39, and 6–42)	Slipped femoral capital epiphysis (Fig. 6–41)
Gout	Subluxation
Osgood–Schlatter disease	Talipes
Osteoarthritis	Tendonitis

11. Types of Fractures

- Simple: an undisplaced fracture (fx)
- Compound: fractured end of bone has penetrated skin (open fx)
- Incomplete: fx does not traverse entire bone; little or no displacement
- Greenstick: break of cortex on one side of bone only; found in infants and children
- Torus/buckle (see Fig. 6–42): greenstick fx with one cortex buckled/compacted and the other intact

Some Conditions Requiring Adjustment in Exposure	
Decrease in Exposure Factors	**Increase in Exposure Factors**
Arthritis	Acromegaly
Ewing's sarcoma	Chronic gout
Osteomalacia	Multiple myeloma
Osteoporosis	Osteochondroma
Rickets	Osteopetrosis
Thalassemia	Paget's disease (osteitis deformans)
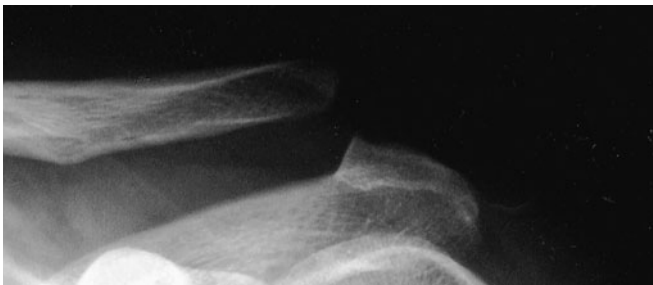
Figure 6–39. Acromioclavicular separation. The examination must be performed erect (in the recumbent position, small separations may not be seen). (Reproduced with permission, from Haig SV, Flores CR. *Orthopedic Emergencies: A Radiographic Atlas.* New York: McGraw-Hill, 2005.)
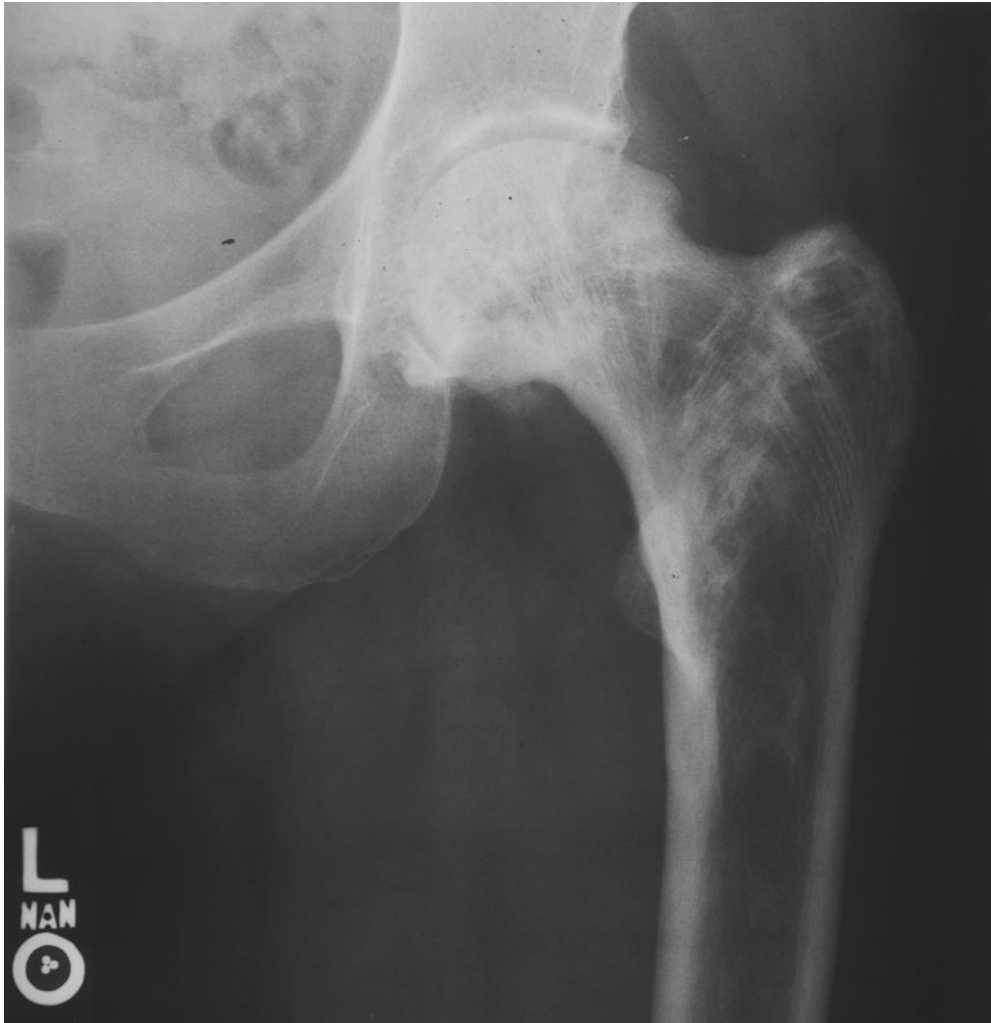
Figure 6–40. AP projection of the hip and proximal femur demonstrates Paget's disease. Early lytic changes are seen throughout the bone; observe the beginning of typical "cotton wool" appearance in the region of the head and trochanters. The hip is well positioned, the femoral neck is parallel to the image receptor (not foreshortened), and the greater trochanter is seen in profile. (Courtesy of Stamford Hospital, Department of Radiology.)

- Stress/fatigue: response to repeated strong, powerful force (e.g., jogging, marching)
- Avulsion: small bony fragment pulled from bony prominence as a result of forceful pull of the attached ligament or tendon (chip fracture)
- Hairline: faint undisplaced fx
- Comminuted: one fracture composed of several fragments
- Butterfly: comminuted fx with one or more wedge or butterflywing-shaped pieces
- Spiral: long fx encircling a shaft; result of torsion (twisting force); especially lower leg (distal tibia and proximal fibula)

Figure 6–41. **(A)** AP knee joint, recumbent. **(B)** The same knee joint taken weight bearing. Note demonstration of significant joint narrowing. (Reproduced with permission, from Miller TT, Schweitzer ME. *Diagnostic Musculoskeletal Imaging.* New York: McGraw-Hill, 2005.)

- Oblique: longitudinal fx forming an angle (approximately 45°) with the long axis of the shaft
- Transverse: fx occurring at right angles to long axis of bone
- Boxer's: fx just proximal to head of fifth metacarpal
- Monteggia: fx proximal third of ulnar shaft with anterior dislocation of radial head
- Colles' transverse fracture of distal third of radius with posterior angulation and associated avulsion fx of ulnar styloid process
- Trimalleolar: fx lateral malleolus, fx medial malleolus on medial and posterior surfaces
- Jones': fx base of fifth metatarsal
- Potts: fx distal tibia and fibula with dislocation of ankle joint
- Pathologic: fx of bone weakened by pathologic condition, for example, metastatic bone disease

Figure 6–42. Torus/buckle-type greenstick fracture. (Reproduced with permission, from Simon RS, Koenigsknecht SJ. *Emergency Orthopedics: The Extremities.* 3rd ed. East Norwalk, CT: Appleton & Lange, 1995, Figure X-ray 32–X5, p. 511.)

Chapter Review Questions

⭐ ***Congratulations!*** *You have completed a large portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure to also complete the short-answer questions found at the end of this chapter.*

1. In the lateral projection of the knee the:
    1. femoral condyles are superimposed
    2. femoropatelloar joint is visualized
    3. knee is flexed 20°–30°
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

2. Which of the following is (are) proximal to the tibial plateau?
    1. femoral condyles
    2. tibial condyles
    3. tibial tuberosity

(A) 1 only
(B) 1 and 2 only
(C) 1 and 3 only
(D) 1, 2, and 3

3. Which of the following projections require that the humeral epicondyles be superimposed?

    1. lateral hand
    2. lateral thumb
    3. lateral humerus

(A) 1 only
(B) 1 and 2 only
(C) 1 and 3 only
(D) 1, 2, and 3

4. An axial projection of the clavicle is often helpful in demonstrating a fracture not visualized using a perpendicular central ray. When examining the clavicle in the PA position, how is the central ray directed for the axial projection?

(A) cephalad
(B) caudad
(C) medially
(D) laterally

5. Which of the following should not be performed until a transverse fracture of the patella has been ruled out?

    1. AP knee
    2. lateral knee
    3. axial/tangential patella

(A) 1 only
(B) 1 and 2 only
(C) 2 and 3 only
(D) 1, 2, and 3

6. Which of the following best demonstrates the navicular, the first and second cuneiforms, and their articulations with the first and second metatarsals?

(A) lateral foot
(B) lateral oblique foot
(C) medial oblique foot
(D) weight-bearing foot

7. In which of the following positions or projections will the subtalar joint be visualized?

(A) dorsoplantar projection of the foot
(B) plantodorsal projection of the os calsis
(C) medial oblique position of the foot
(D) lateral projection of the foot

8. The proximal tibiofibular articulation is best demonstrated in which of the following positions?

(A) medial oblique
(B) lateral oblique
(C) AP
(D) lateral

9. In the 15° to 20° mortise oblique projection of the ankle, the:
    1. talofibular joint is visualized
    2. talotibial joint is visualized
    3. plantar surface should be vertical

    (A) 1 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

10. The scapular Y projection of the shoulder demonstrates:
    1. an oblique projection of the shoulder
    2. anterior or posterior dislocation
    3. a lateral projection of the shoulder

    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

Answers and Explanations

1. (D) To better visualize the joint space in the lateral projection of the knee, 20° to 30° flexion is recommended. The femoral condyles are superimposed so as to demonstrate the femoropatellar joint and the articulation between the femur and the tibia. The correct degree of forward or backward body rotation is responsible for the visualization of the femoropatellar joint. Cephalad tube angulation of 5° to 7° is responsible for demonstrating the articulation between the femur and the tibia (by removing the magnified medial femoral condyle from superimposition on the joint space).

2. (A) The knee joint is formed by the femur, tibia, and patella. The most superior aspect of the tibia is the *tibial plateau*—formed by the *tibial condyles just distal* to it. The proximal tibia also presents the *tibial tuberosity* on its anterior surface, just distal to the condyles. *Proximal* to the tibial plateau, and articulating with it, are the *femoral condyles*. The term *proximal* refers to a part located closer to the point of attachment; the term *distal* refers to a part located farther away from the point of attachment.

3. (C) For the lateral projections of the hand, wrist, forearm, and elbow, the elbow must be flexed 90° to superimpose the distal radius and ulna and humeral epicondyles. Although a lateral humerus can be performed with the elbow flexed, if the patient is unable to flex the arm, it may be left anteroposterior (AP) and a transthoracic lateral projection of the upper one half to two thirds of the humerus may be obtained. Because a coronal plane passing through the epicondyles is perpendicular to the IR in this position, the epicondyles will be superimposed. To obtain a lateral projection of the thumb (first digit), the patient's wrist must be somewhat internally rotated. Remember that an oblique projection of the thumb is obtained in a PA projection of the hand.

4. (B) With the patient in the AP position, the central ray is directed cephalad. The reverse is true when examining the clavicle in the *PA* position. This serves to project the pulmonary apices away from the clavicle. Patients having clavicular pain are more comfortably examined in the PA erect or AP recumbent position.

5. (C) If a transverse fracture of the patella is present and the knee is *flexed*, there is a danger of *separation* of the fractured segments. Because both a lateral knee and axial patella require knee flexion, they should be avoided until a transverse fracture is ruled out. When present, a transverse fracture may be seen through the femur on the AP projection. The axial ("sunrise") projection of the patella is generally used for demonstrating vertical patellar fractures.

6. (B) The lateral oblique projection of the foot demonstrates the navicular and first and second cuneiforms. To demonstrate the rest of the tarsals and intertarsal spaces, including the cuboid, sinus tarsi, and tuberosity of the fifth metatarsal, a medial oblique is required (plantar surface and IR form a 30° angle). Weight-bearing lateral feet are used to demonstrate the longitudinal arches.

7. (B) The subtalar, or talocalcaneal, joint is a three-faceted articulation formed by the talus and os calcis (calcaneus). The plantodorsal and dorsoplantar projections of the os calcis should exhibit radiographic density sufficient to visualize the subtalar joint. If the evaluation of the subtalar joint is desired, special views (such as Broden and Isherwood methods) would be required.

8. (A) With the femoral condyles of the affected side rotated *medially/internally* to form a 45° angle with the IR, the *proximal* tibiofibular articulation is placed parallel with the IR and the fibula is free of superimposition with the tibia. The lateral oblique completely superimposes the tibia and fibula. The AP and lateral projections superimpose enough of the tibia and fibula so that the tibiofibular articulation is "closed."

9. (D) The medial oblique projection (15°–20° mortise view) of the ankle is valuable because it demonstrates the tibiofibular joint as well as the talotibial joint, thereby visualizing all the major articulating surfaces of the ankle joint. To demonstrate maximum joint volume, it is recommended that the plantar surface be vertical.

10. (B) The scapular Y projection requires that the coronal plane be about 60° to the IR, thus resulting in an oblique projection of the shoulder. The vertebral and axillary borders of the scapula are superimposed on the humeral shaft and the resulting relationship between the glenoid fossa and humeral head will demonstrate anterior or posterior dislocation. Lateral or medial dislocation is evaluated on the AP projection.

III. THE AXIAL SKELETON

The axial skeleton (Fig. 6–43A) consists of the facial and cranial bones of the *skull*, the five sections of the *vertebral column*, and the sternum and ribs of the *thorax*.

A. VERTEBRAL COLUMN

The vertebral column (Fig. 6–43B) is composed of 33 bones divided into 7 cervical, 12 thoracic, 5 lumbar, 5 (fused) sacral, and 4 (fused) coccygeal regions, with each region having its own characteristic shape. The vertebral bodies gradually increase in size through the lumbar region. The vertebrae are joined by ligaments and cartilage; the first 24

Neural Arch

Composed of
Two pedicles
Two laminae

Encloses
Vertebral foramen

Supports Seven Processes
Two superior articular processes
Two inferior articular processes
Two transverse processes
One spinous process
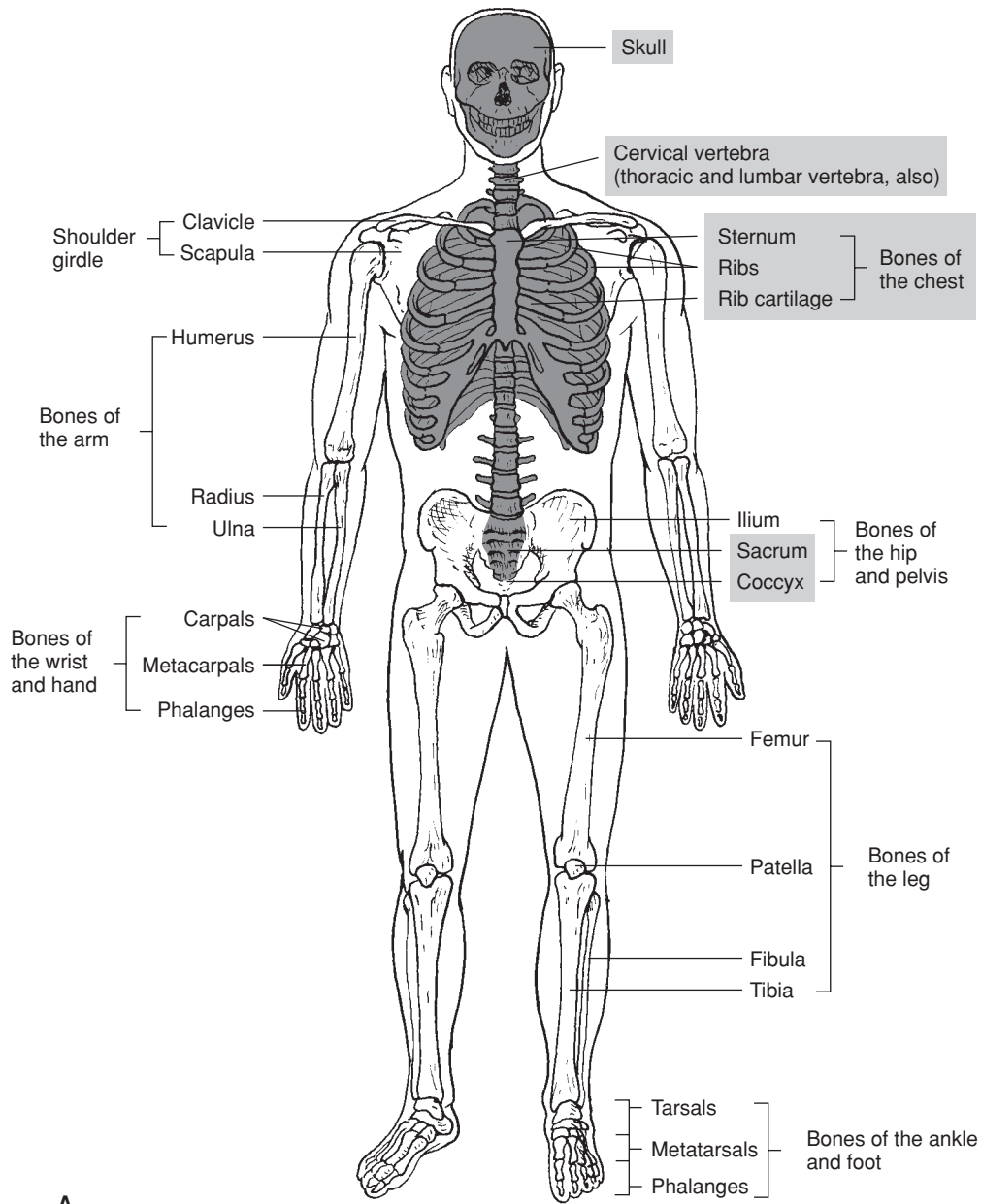
Figure 6–43. (**A**) The axial skeleton. (Modified with permission, from Rice J. *Terminology with Human Anatomy.* 3rd ed. East Norwalk, CT: Appleton & Lange, 1995.)

are separate and movable while the last 9 are fixed. *Intervertebral disks* between the vertebral bodies form *amphiarthrotic* joints.

The cervical and lumbar regions form *lordotic* curves; the thoracic and sacral regions form *kyphotic* curves (Fig. 6–43B, lateral). An exaggerated thoracic curve is called *kyphosis* ("hunchback"); an exaggerated lumbar curve is *lordosis* ("swayback"). Lateral curvature of the vertebral column is called *scoliosis*.

The typical vertebra has a *body* and a *neural/vertebral arch* surrounding the *vertebral foramen*. The neural arch is composed of two *pedicles*, two laminae that support four articular processes, two

C1
C2
C3
C4
C5
C6
C7
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T12
L1
L2
L3
L4
L5
Sacrum
Coccyx

B   Anterior view   Left lateral view
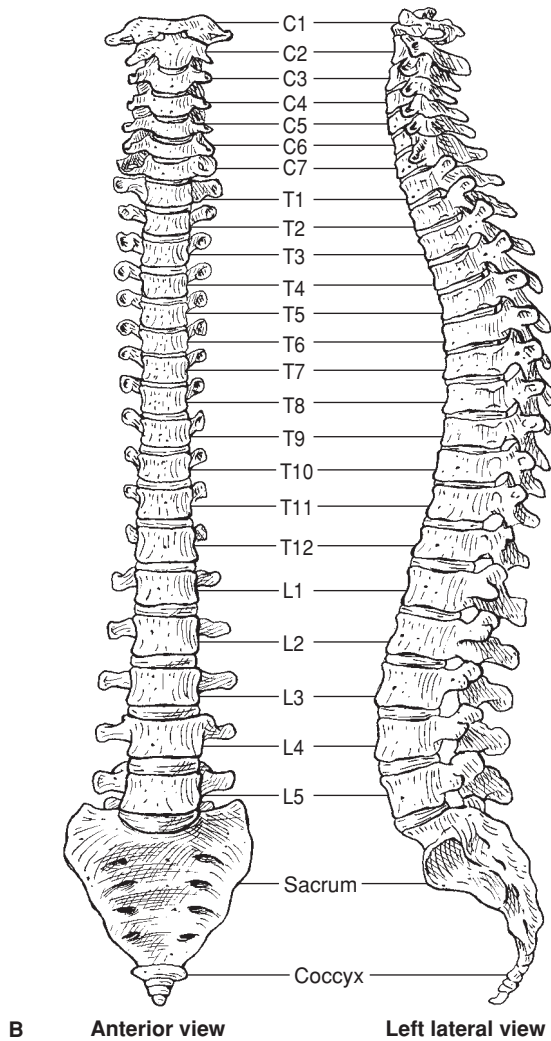
Figure 6–43. *(Continued)* (**B**) AP and lateral views of the vertebral column.

transverse processes, and one spinous process. The pedicles are short thick processes extending back from the posterior aspect of the verte-bral body, each one sustaining a *lamina*. The laminae extend posteri-orly to the midline and join to form the *spinous process* (lack of union, or malunion, results in *spina bifida*). Each pedicle has notches super-iorly and inferiorly (*superior* and *inferior vertebral notches*) that—with adjacent vertebrae—form the *intervertebral foramina*, through which the spinal nerves pass. The neural arch also has lateral *transverse pro-cesses* for muscle attachment and *superior* and *inferior articular pro-cesses* for the formation of *apophyseal joints* (classified as *diarthrotic*). The vertebral column permits flexion, extension, lateral, and rotary motions through its various articulations.

1. Cervical Spine. There are seven cervical vertebrae (Fig. 6–44). The *atlas* (C1) is a ring-shaped bone having no body and no spinous process; it is composed of an anterior and posterior arch, two lateral masses, and two transverse processes.
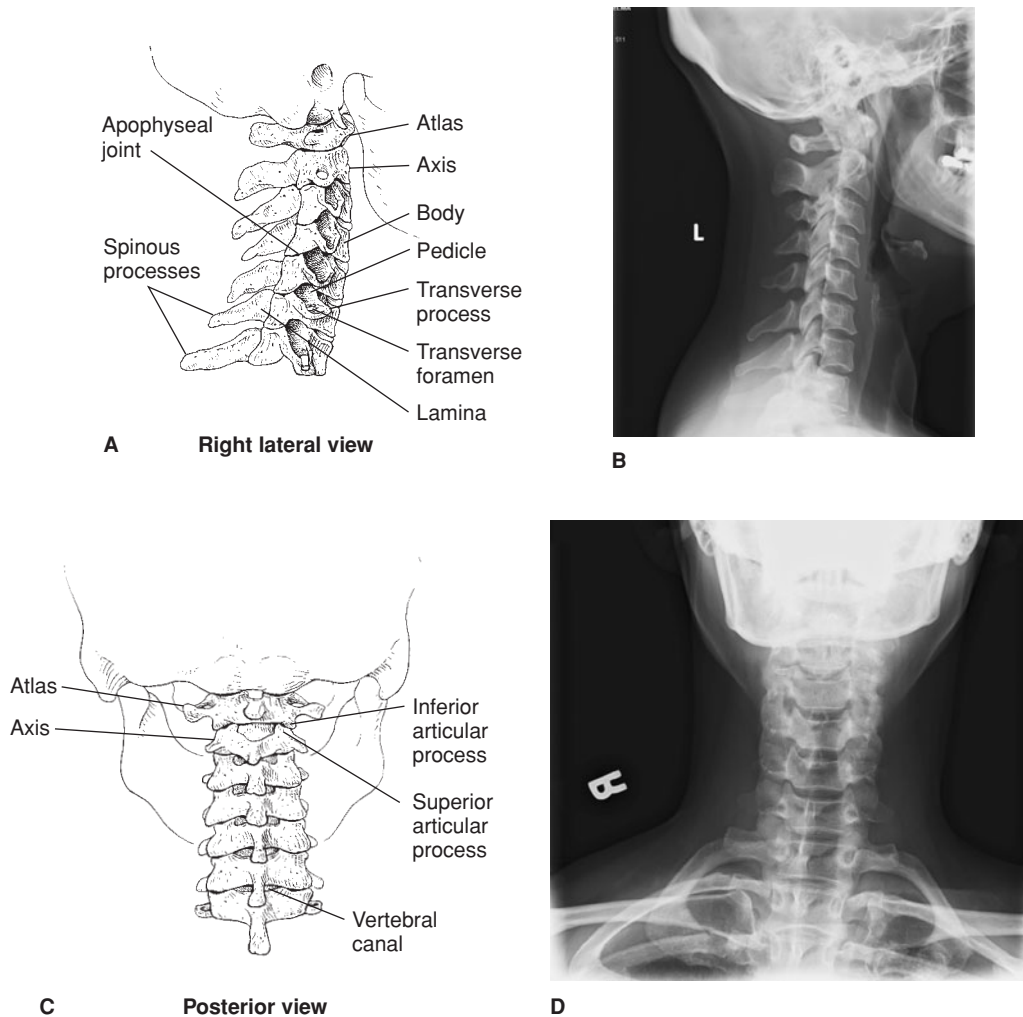
Figure 6–44. (**A**) Right lateral view of the cervical spine. (**B**) Lateral projection, cervical spine. (**C**) Posterior view of the cervical spine. (**D**) AP projection, cervical spine. (B and D: Courtesy of Conrad P. Ehrlich, MD.)

The anterior arch has a tubercle at its midpoint and has a facet on its posterior surface for articulation with the anterior portion of the odontoid process/dens. The posterior arch has a tubercle as well. The lateral masses have superior articular processes that articulate with the skull at the *atlanto-occipital joint*, where flexion and extension occurs. Its lateral masses articulate inferiorly with the *axis* (C2).

The axis (C2) has a superior projection, the *dens*, or *odontoid process*. The axis articulates superiorly with the atlas at the *atlantoaxial joint*, a *pivot* joint where rotation takes place, and inferiorly with C3 at the apophyseal articulation. The dens has a facet on its anterior surface for articulation with the posterior aspect of the anterior arch of C1. The spinous process of C2 is particularly large and strong.

The typical cervical vertebra is small and has a *transverse foramen* in each transverse process for passage of the vertebral artery and vein. The cervical laminae are thin and narrow; they meet at midline to form a short spinous process. Cervical spinous processes are almost horizontal and usually *bifid*. The spinous process of C7 (*vertebra prominens*) is not bifid, is larger and more horizontal, and is a useful positioning landmark.

Fractures and/or dislocations of the cervical spine are usually due to acute *hyperflexion* or *hyperextension* as a result of indirect trauma. *Whiplash* injury is caused by a sudden, forced movement in one direction and then the opposite direction (as in rear-end automobile impacts). Whiplash symptoms frequently include neck pain and stiffness, headache, and pain and numbness of the upper extremities. Whiplash is often evidenced radiographically by straightening or reversal of the normal lordotic curve.

Osteoarthritis is characterized in the cervical and lumbar spine by chronic, progressive degeneration of cartilage and *hypertrophy* of bone along the articular margins, characterized radiographically by narrowed joint spaces, and *osteophytes*. It can also be seen in the articulations of the fingers, toes, hips, and knees.

Articulation Summary: Vertebral

- Occipitoatlantal
- Atlantoaxial
- Costovertebral
- Costotransverse
- Lumbosacral
- Sacroiliac
- Sacrococcygeal
- Intervertebral
- Apophyseal/interarticular

CERVICAL SPINE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine, MSP ⊥ table; adjust flexion so mastoid tip and occlusal plane are aligned	15°–20° cephalad to thyroid cartilage	AP of *lower 5* cervical vertebrae and intervertebral disk spaces
AP *Atlas and Axis*	Patient supine, MSP ⊥ table, w/patient's mouth open, adjust flexion so mastoid tips and upper occlusal plane are aligned ⊥ IR (‖ CR)	⊥ center of opened mouth	AP proj of C1 and C2 (atlas and axis) (Fig. 6–45A) and their articulations; *too much flexion* superimposes teeth on odontoid; *too much extension* superimposes base of skull on odontoid

Note: If the upper portion of the odontoid process is not seen, the AP (Fuchs) or PA (Judd) projection may be attempted *if upper cervical fx or degenerative disease is not suspected*. The PA is similar to a Waters position; the AP similar to the reverse Waters. The odontoid is seen projected within the foramen magnum. *Since extension of the neck is required, this position must not be attempted if upper cervical fx or degenerative disease is suspected.*

lat	Patient erect w/L side adjacent to IR, chin slightly elevated, shoulders depressed, MSP ‖ IR centered, at level of C4	⊥ C4	Lateral proj of all 7 vertebrae (Fig. 6–45B). Shows intervertebral jt spaces, apophyseal jts, spinous processes, bodies; due to the unavoidable OID, a 72° SID should be used

Note: *Flexion* and *extension* views (Fig. 6–46) may be obtained in this position in cases of *whiplash* injury. A recumbent lateral w/horizontal beam is often performed as the first radiograph in cases of suspected *subluxation*.

A

B

C
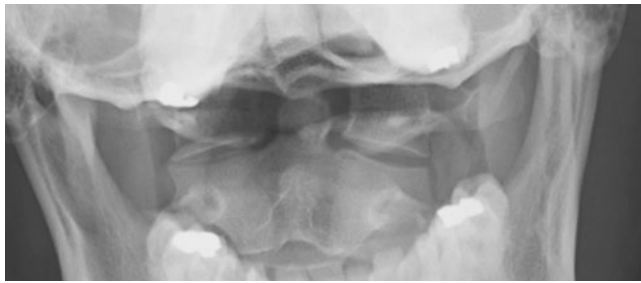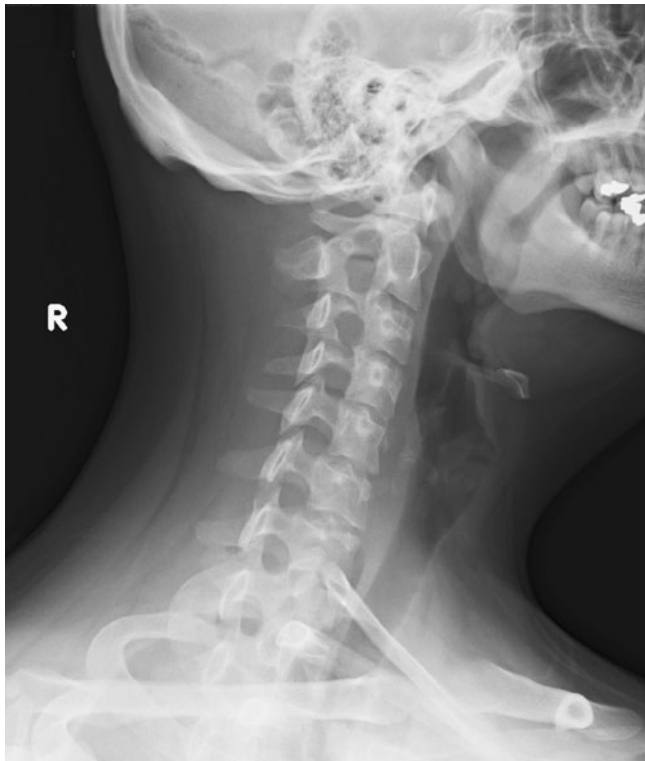
Figure 6–45. (**A**) Open-mouth projection of C1–C2. Locate and identify the bony structures shown particularly well in the this projection. (Courtesy of Conrad P. Ehrlich, M.D.) (**B**) Lateral projection of the cervical spine. Locate and identify the bony structures shown particularly well in the lateral. (Courtesy of Conrad P. Ehrlich, M.D.) (**C**) An RPO cervical spine. Locate and identify the bony structures shown particularly well in the oblique. (Courtesy of Conrad P. Ehrlich, M.D.)
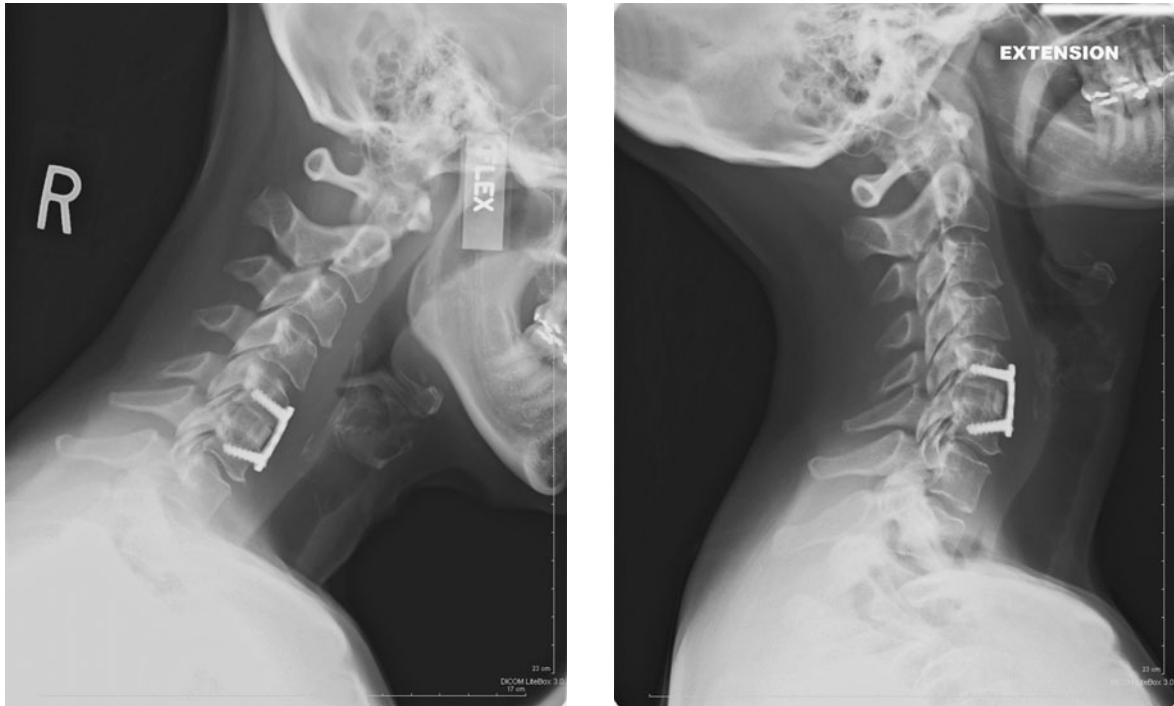
Figure 6–46. Lateral projections of the cervical spine in flexion and extension—used to demonstrate degree of AP motion. (Courtesy of Conrad P. Ehrlich, M.D.)

CERVICAL SPINE (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Note: A *cross-table/horizontal beam lateral* must be performed for trauma patients. The patient's neck must not be moved and any cervical collar in place must stay in place until images have been reviewed for fx, subluxation, etc.			
obl *(LAO and RAO)*	Patient PA erect, MSP 45° to IR centered to C5 (1″ inferior to thyroid cartilage), chin slightly raised	15°–20° caudad to center of IR	Oblique cervical spine; best view of intervertebral foramina *closest* to IR; a similar view can be obtained w/the patient *LPO* and *RPO*, CR ed cephalad, and showing the foramina *farthest* from the IR (see Fig. 6–45C)
Note: Oblique cervical spine may be performed in the *recumbent position* on patients whose trauma prohibits moving them. The CR is directed 45° medially for one oblique and 45° laterally for the other.			
lat *cervico-thoracic (swim-mer's lateral)*	Patient erect (or recumbent) lat *w/midaxillary line* centered to grid, MSP ∥, arm adjacent to IR over head, depress opposite shoulder farthest from grid	⊥ T2	lat proj of lower cervical and upper thoracic vertebrae; particularly useful for broad-shouldered individuals
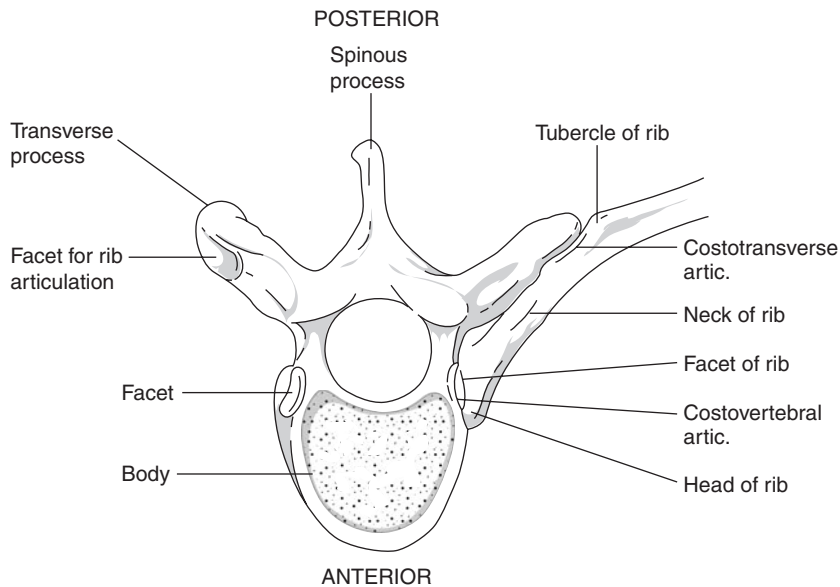
Figure 6–47. Thoracic vertebra and its articulation with rib (superior view).

2. Thoracic Spine. There are 12 thoracic vertebrae, which are larger in size than cervical vertebrae and which increase in size as they progress inferiorly toward the lumbar region. Thoracic spinous processes are fairly long and sharply angled caudally (T8 usually has the longest vertical spinous process). The bodies and transverse processes have *articular facets* for the *diarthrotic* rib articulations (see Fig. 6–47).

A common metabolic bone disorder frequently noted in radiographic examinations of the thoracic spine is osteoporosis. *Osteoporosis* is characterized by bone demineralization and can result in compression fractures of the vertebrae. The condition is most common in sedentary and postmenopausal women.

THORACIC SPINE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine, MSP ⊥ tabletop, top of IR 1″ above shoulders	⊥ T7	AP proj of thoracic vertebrae and intervertebral spaces; it is helpful to use the anode heel effect and/or compensating filtration to provide more uniform density (see Fig. 6–48A)

Note: To demonstrate *apophyseal jts, 70° obliques* are performed.

lat	Patient L lat recumbent, midaxillary line centered to table, arms⊥ long axis of body, top of IR 1″ above shoulders	5°–15° cephalad (⊥ long axis of spine)	lat proj of thoracic vertebrae, especially bodies, intervertebral spaces and foramina; a vertical CR may be used if MSP is ‖ the tabletop (see Fig. 6–48B)

Note: This exposure can be made at the end of *expiration*. Or, a long exposure time (with low mA) can be used while the patient *breathes* quietly. This has the effect of blurring vascular markings and superimposed ribs.

Figure 6–48. (**A**) AP projection of the thoracic spine. Note density difference between upper and lower spine; this can be improved by using the anode heel effect to advantage (placing cathode over lower spine). (**B**) Lateral projection of thoracic spine. "Breathing technique" has helped blur pulmonary vascular markings and provided good visualization of nearly all the thoracic vertebrae. (Courtesy of Stamford Hospital, Department of Radiology.)

3. Lumbar Spine. The five lumbar vertebrae are the largest of the vertebral column and increase in size toward the sacral region. The spinous processes are short and horizontal and serve as attachment for strong muscles (see Fig. 6–49). The causes of lumbar pain are numerous. Trauma, fracture, spasm of the paralumbar muscles, herniated intervertebral disk, and osteoarthritis are a few causes of low back pain. Some of the disorders that can be detected radiographically include *osteoarthritis*, *spondylolysis*, *spondylolisthesis*, and *ankylosing spondylitis*. Myelography and especially MRI are used to evaluate *herniated intervertebral disks*.

LUMBAR SPINE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine, MSP ⊥ tabletop, knees flexed, feet flat on table	⊥ to L3	AP proj of lumbar vertebrae L1–L4, intervertebral spaces, transverse processes; *flexion of the knees reduces lumbar curve and OID* (see Fig. 6–50)

Note: The *AP projection* of the lumbar spine is most comfortable for very thin patients and those with low back pain. The *PA projection* has the advantages of delivering lower gonadal dose and of placing the intervertebral jts more closely parallel with the divergent x-ray beam.

(continued)

Intervertebral foramen

Superior
articular
process   Lamina   Spinous
process

Inferior
articular
process

Transverse
process

Pedicle

Vertebral
canal
foramen

Body

L5

Lower 4 lumbar vertebrae

**Second lumbar vertebra
(superior view)**

Superior
articular
process   Body

Spinous
process

Superior
articular
process

Pedicle

Inferior
articular
process   Lamina

Inferior
articular
process   Spinous
process

**Second lumbar vertebra
(right lateral view)**

**Second lumbar vertebra
(posterior view)**

Figure 6–49. Lateral view of the lower lumbar vertebrae. Superior, right lateral, and posterior views of L2.

Figure 6–50. AP projection of the lumbar spine. Flexion of the knees reduces lumbar curve and OID and relieves strain on lower back muscles; patients are most comfortable with sponge or pillow support placed under knees. (Courtesy of Stamford Hospital, Department of Radiology.)

LUMBAR SPINE *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP (L5–S1)	Patient supine, MSP ⊥ tabletop, legs extended	To MSP at 30°–35° cephalad to MSP, ≈$1\frac{1}{2}''$ above pubic symph	AP of lumbosacral articulation not seen on AP lumbar
obl *(RPO and LPO)*	Patient AP recumbent, obliqued 45° w/spine centered to grid	⊥ L3	obl proj of lumbar vertebrae, especially for apophyseal articulations (L1–L4) of side *adjacent* to table; opposite obl is done to show opposite articulations (see Fig. 6–51).

Note: *This proj demonstrates the characteristic* "scotty dogs" (see Fig. 6–51); obl lumbar spine may also be performed in the PA position and demonstrates the apophyseal articulations *away* from the IR.

Note: L5–S1 apophyseal articulations shown in 35° obl.

(continued)
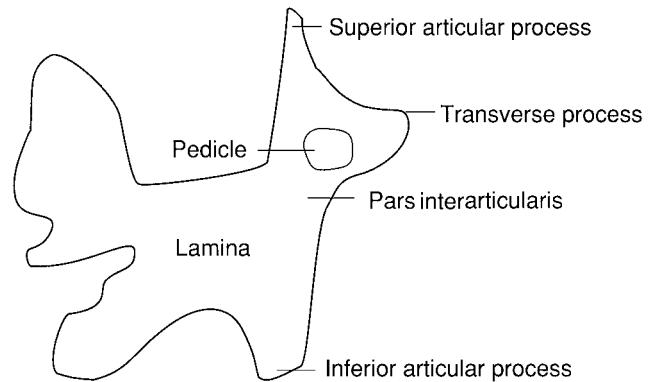
Figure 6–51. Oblique lumbar spine, illustrating the lumbar apophyseal joints. Note "scotty dog" images. The scotty's "ear" corresponds to the *superior articular process*, his "nose" to the *transverse process*, his "eye" is the *pedicle*, his "neck" the *pars interarticularis*, his "body" is the *lamina*, and his "front foot" is the *inferior articular process.* (Courtesy of Stamford Hospital, Department of Radiology.)

LUMBAR SPINE *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat	Patient L lat recumbent, midaxillary line centered to grid	5°–8° caudad L3	lat proj, especially for vertebral bodies, interspaces, intervertebral foramina, spinous processes; if MSP adjusted ∥ tabletop, CR is vertical (Fig. 6–52A)

Note: Lateral lumbar spine in *flexion and extension* is often used to demonstrate presence or absence of motion in area(s) of *spinal fusion*.

lat (L5–S1)	Patient L lat recumbent, center plane 1.5″ posterior to midaxillary line to grid, adjust MSP ∥ tabletop	⊥ coronal plane at level m/w b/w crest and ASIS	lat proj L5–S1; if MSP not adjusted tabletop CR is ∠ed 5°–8° caudad (Fig. 6–52B)

4. Sacrum. There are five fused sacral vertebrae (Fig. 6–53A); the fused *transverse processes* form the *alae*. The anterior and posterior *sacral foramina* transmit spinal nerves. The *sacrum* articulates

A   **B**
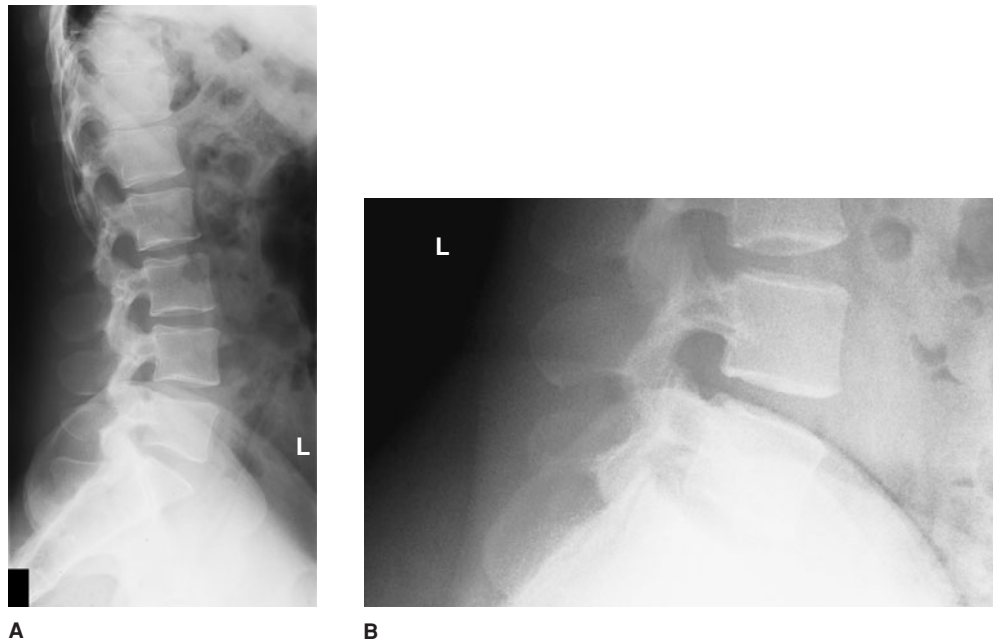
Figure 6–52. (**A**) Lateral projection of the lumbar spine. If MSP is adjusted parallel to table-top, CR angulation is unnecessary. (**B**) Lateral projection L5–S1. (Courtesy of Stamford Hospital, Department of Radiology.)

superiorly with the fifth lumbar vertebra, forming the L5–S1 articulation and inferiorly with the *coccyx* to form the *sacrococcygeal joint.*

SACRUM	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient AP supine, MSP ⊥ tabletop	15°–25° cephalad to midline, to point m/w b/w pubic symphysis and ASIS	AP proj of sacrum; CR < parallels sacral curve and provides less distorted visualization (see Fig. 6–53B)

Note: See *sacroiliac jts* on page 115.

lat	Patient L lat recumbent, 3″ posterior to MCP centered to grid	⊥ a point 3″ post to ASIS	Lateral proj of sacrum

5. Coccyx. There are four or five fused coccygeal vertebrae (see Fig. 6–53). Fracture of the coccyx usually results from a fall onto it, landing in a seated position. Fracture displacement is fairly common and occasionally requires removal of the fractured fragment to relieve the painful symptoms.

Right lateral view   **Posterior view**

A

B

C
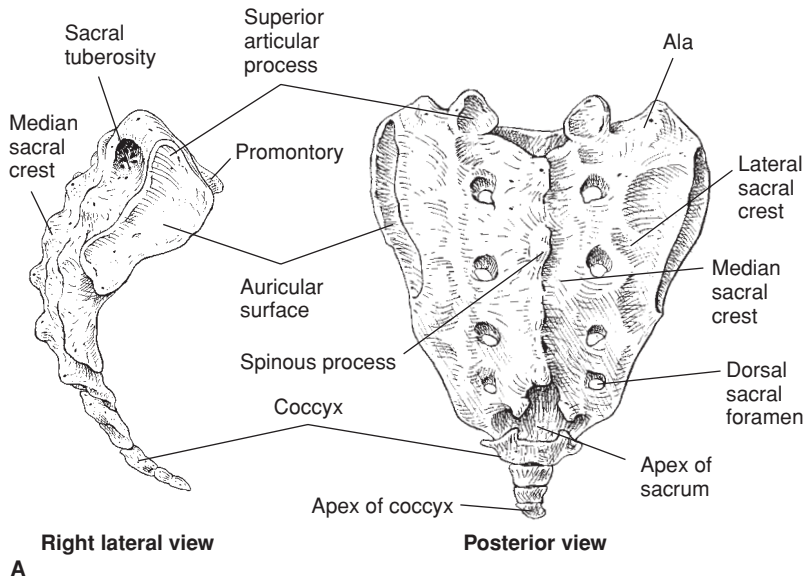
Figure 6–53. (**A**) Sacrum and coccyx. (**B**) AP projection of the sacrum. Cephalad angulation "opens" the sacral foramina. (**C**) AP projection of the coccyx. Caudal angulation "opens" the coccygeal curve. (A: Reproduced with permission from Chusid JG. *Correlative Neuroanatomy & Functional Neurology*, 19th ed. East Norwalk, CT: Appleton & Lange, 1985. B and C: Courtesy of Stamford Hospital, Department of Radiology.)

COCCYX	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient AP supine, MSP ⊥ tabletop	10°–20° caudad to midline to point 2″ above pubic symphysis	AP proj of coccyx; CR < parallels coccygeal curve and provides less distorted visualization (see Fig. 6–53C)
lat	Patient L lateral recumbent, 5″ post. to MCP centered to grid	⊥ a point 5″ post to MCP at level of mid coccyx	lat proj of coccyx and its articulation with the sacrum

6. Scoliosis Series

SCOLIOSIS SERIES	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA bending	14″ × 17″ or 14″ × 36″ IR of vertebrae to include 1″ of iliac crest/L5–S1. Four exposures made: PA recumbent, PA erect, PA/bending L and R	⊥ center of IR	*Radiation dose is reduced when gonadal, breast, and thyroid shields are used and when examination is performed PA rather than AP* (Fig. 6–54)
PA Ferguson method	14″ × 17″ or 14″ × 36″ IR of vertebrae to include 1″ of iliac crest/L5–S1; three exposures made with *no rotation*: PA (or AP), PA w/ (3″–4″) block under one foot, PA w/ (3″–4″) block under *opposite* foot	⊥ center of IR	Images used to distinguish primary curve from compensatory curve; protective shielding must be utilized

Figure 6–54. AP scoliosis series with protective shielding in place. (Courtesy of Nuclear Associates.)

Articulation Summary: Thorax

- Sternoclavicular
- Sternochondral
- Costochondral
- Costovertebral
- Costotransverse

B. THORAX

1. Sternum and Sternoclavicular Joints. The bones of the *thorax* (sternum, ribs, thoracic vertebrae; Fig. 6–55) function to protect the vital organs within heart, lungs, and major blood vessels. The *sternum* forms the anterior central portion of the thorax and is composed of three major divisions: the *manubrium*, *body*, and *xiphoid process*. Sternal fractures are uncommon; when they do occur, fracture displacement is rare, but the possibility of traumatic injury to the heart must still be considered.

2. Ribs. The *rib* cage (see Fig. 6–55) consists of 12 pair of ribs. Ribs 1 to 7 articulate with thoracic vertebrae and the sternum and are called *vertebrosternal* or "true" ribs. The first pair of ribs lies under the clavicles and is not palpable; the remaining 11 pairs of ribs are usually palpable. Ribs 8 to 10 articulate with thoracic vertebrae and the superjacent costal cartilage to form the anterior costal margin and are called

Anterior view

Figure 6–55. The thoracic cage, anterior aspect.

vertebrochondral or *false ribs.* The last two pairs of false ribs articulate only with thoracic vertebrae and are referred to as *floating ribs.* The spaces between the ribs are called *intercostal spaces* and are occupied by two sets of intercostal muscles.

 Rib fractures are a common injury in thoracic trauma because of their relative thinness and exposed position. Their fracture may be complicated by *pneumothorax*, *hemothorax*, liver laceration (right lower ribs), or spleen laceration (left lower ribs).

STERNUM	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA obl (RAO)	Patient 15°–20° RAO; greater obliquity for thin patients, sternum centered to midline of table	⊥ midster-num	obl–frontal proj RAO projects sternum into heart shadow for *uniform density.*

Note: *A long exposure* can be used during *quiet breathng* to *blur* pulmonary vascular markings, or exposure can be made on *expiration* (Fig. 6–56).

lat	Patient erect L lateral, shoulders rolled back, MSP vertical, IR top 1.5″ above manubrial notch	⊥ midster-num	lat proj of sternum free of superimposition of ribs; exposure made on deep inspiration to move sternum away from ribs

Radiographically Significant Skeletal Disorders and Conditions of the Axial Skeleton

Achondroplasia
Ankylosing spondylitis
Cervical rib
Degenerative disk disease
Flail chest
Herniated disk
Hydrocephalus
Kyphosis
Lordosis
Osteophyte
Osteoporosis
Pectus excavatum
Scoliosis
Spina bifida
Spondylolisthesis
Spondylolysis
Transitional vertebra
Whiplash

Figure 6–56. RAO sternum. (Courtesy of Stamford Hospital, Department of Radiology.)

STERNO CLAVICULAR JOINTS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	Patient prone, MSP centered to grid, IR centered at T3 (suprasternal notch)	⊥ T3	Bilateral PA proj of sternoclavicular jts visualized through superimposed vertebrae and ribs
PA obl *(LAO and RAO)*	Patient prone, MSP centered to grid, rotate body ≈15° *affected side down*	⊥ affected jt	obl proj of sternoclavicular jt *closest to IR;* similar results can be obtained w/a ⊥ MSP and w/CR 15° toward midline from the affected side

RIBS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine or AP erect, MSP ⊥ midline of table, top of IR 1″ above shoulder	⊥ center of IR, about level of T7	AP proj, upper posterior ribs best delineated; do PA for better detail of anterior ribs
PA obl *(LAO, RAO)*	Patient prone or erect PA, rotate 45°, *unaffected side down*	⊥ center of IR, about level of T7 (at T10 to T12 for below diaphragm)	obl shows *axillary* portions of ribs, RAO shows left ribs, LAO shows right ribs
AP obl *(LAO, RAO)*	Patient supine or erect AP, rotate to 45° affected side toward the IR	⊥ center of IR, about level of T7 (at T10 to T12 for below diaphragm)	LPO shows *left* posterior ribs and their axillary portions, RPO shows *right* ribs and their axillary portions

Note: *Above-diaphragm* ribs are exposed on deep *inspiration* or during quiet breathing (long exposure). *Below-diaphragm* ribs are exposed on forced *expiration*.

C. HEAD AND NECK

1. Skull. The *skull* has two major parts: the *cranium*, which is composed of eight bones and houses the brain; and the 14 irregularly shaped *facial bones* (Figs. 6–57 and 6–58). The eight cranial bones are the paired *parietal* and *temporal* bones and the unpaired *frontal*, *occipital*, *ethmoid*, and *sphenoid* bones. The 14 facial bones include the paired *nasal*, *lacrimal*, *palatine*, *inferior nasal conchae*, *maxillae*, and *zygomatic* bones and the unpaired *vomer* and *mandible*.

The average shaped skull is termed *mesocephalic* (petrous pyramids and MSP form $\approx$47°), the broad skull is termed *brachycephalic* (petrous pyramids and MSP form $\approx$54°), and the elongated skull is termed *dolichocephalic* (petrous pyramids and MSP form $\approx$40°). These deviations are readily observable in axial CT and MR images. The inner and outer compact tables of the skull are separated by cancellous tissue called *diploë*. The internal table has a number of branching *meningeal grooves* and larger *sulci* that house blood vessels.

The bones of the skull are separated by immovable (*synarthrotic*) joints called *sutures*. The major sutures of the cranium are the *sagittal*, which separates the parietal bones, the *coronal*, which separates the frontal and parietal bones, the *lambdoidal*, which separates the parietal and occipital bones, and the *squammosal*, which separates the temporal and parietal bones (see Figs. 6–57 and 6–58). The articular surfaces of these bones have serrated-like edges with small projecting bones called *wormian* bones that fit together to form the articular sutures. The sagittal and coronal sutures meet at the *bregma*, which corresponds to the fetal anterior fontanel. The sagittal and lambdoidal sutures meet posteriorly at the *lambda*, which corresponds to the fetal

Cranial Bones (8)

(1) Frontal
(2) Parietal
(2) Temporal
(1) Occipital
(1) Ethmoid
(1) Sphenoid

Glabella

Frontal bone

Nasion

Nasal bone

Supraorbital foramen

Lacrimal bone

Parietal bone

Ethmoid bone

Sphenoid bone

Optic foramen

Orbital cavity

Zygomatic process

Inferior orbital fissure

Superior orbital fissure

Temporal bone

Infraorbital foramen

Zygomatic arch

Zygomatic bone

Ethmoid bone

Mastoid process

Nasal conchae/turbinates

Nasal cavity

Ramus
of mandible

Vomer

Maxilla

Mental
foramen

Angle
of mandible

Mandible

Symphysis
menti

A

Parietal
bone

Bregma

Squamosal
suture

Temporal
bone

Coronal suture

Frontal bone

Pterion

Asterion

Greater wing
of sphenoid

Lambda

Glabella

Lambdoidal
suture

Nasion

Occipital
bone

Nasal bone

Lacrimal bone

External
occipital
protuberance

Ethmoid bone

External
acoustic meatus

Zygomatic
bone

Anterior nasal spine

Maxilla

Mastoid process

Styloid process

Zygomatic arch

Angle
of mandible

Mandible

B

Figure 6–57. (**A**) Anterior view of the skull, labeled. (**B**) Lateral view of the skull, labeled.
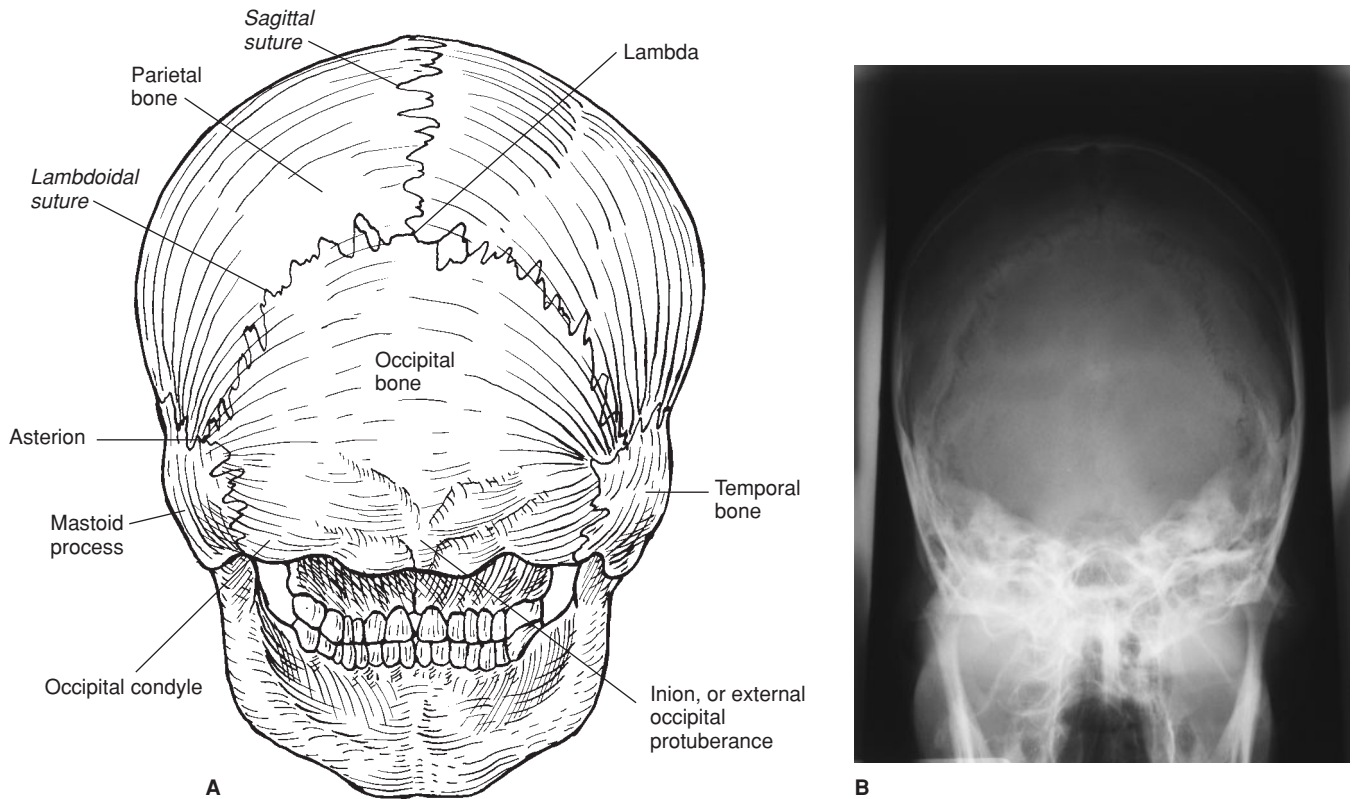
Figure 6–58. (**A**) Posterior view of the skull, labeled. (**B**) AP axial skull (Towne) demonstrates the occipital bone. (Courtesy of Stamford Hospital, Department of Radiology.)

posterior fontanel. The parietal, frontal, and sphenoid bones meet at the *pterion* (see Fig. 6–57), the location of the anterolateral fontanel. The highest point of the skull is called the *vertex.*

a. Cranial Bones

Frontal Bone

- The frontal bone corresponds to the forehead region (Fig. 6–57).
- *Orbital plates* (2): horizontal part of frontal bone; forms much of superior aspect of bony orbit.
- *Frontal eminences* (2): on anterior surface of frontal bone, lateral to MSP.
- *Glabella:* smooth prominence between eyebrows.
- *Frontal sinuses* (2): directly behind glabella, between the tables of the skull.
- *Superciliary arches/ridges* (2): ridge of bone under eyebrow region.
- *Supraorbital margins* (2): upper border/rim of bony orbit.
- *Supraorbital notches/foramina* (2): midportion of supraorbital margin; passage for artery and nerve to forehead.
- *Frontonasal suture:* where frontal bone articulates with nasal bones (corresponds exteriorly with *nasion*).

Parietal bones
- Paired; form the vertex and part of lateral portions of cranium.
- Meet at midline to form sagittal suture; other borders help form coronal, squammosal, and lambdoidal sutures (Fig. 6–58).
- *Parietal eminences:* rounded prominence on lateral surface of each parietal bone.

Ethmoid bone
- Located between orbits; helps form parts of nasal and orbital walls (Figs. 6–57 and 6–60).
- *Cribriform plate:* porous, passage for olfactory nerves; horizontal portion between orbital plates of frontal bone.
- *Crista galli:* extends superiorly from midportion of cribriform plate.
- *Perpendicular plate:* extends downward from crista galli to form major portion of nasal septum.
- *Superior and middle nasal turbinates/conchae:* cartilaginous; within nasal cavity, attached to perpendicular plate.
- *Ethmoidal labyrinths/lateral masses:* help form medial wall of orbit; ethmoidal sinuses within.

Sphenoid bone
- Wedge- or bat-shaped bone located between frontal and occipital bones (Figs. 6–59 and 6–60).
- Anchor for eight cranial bones.
- Forms small part of lateral cranial wall and part of skull base.
- Consists of body, two lesser wings, two greater wings, two pterygoid processes, and hamuli.
- *Body:* central portion; midline of skull base; anterior part joins ethmoid bone; contains the two sphenoid sinuses.
- *Lesser (minor) wings:* anterior portion, articulates with orbital plates; contain optic canals for passage of optic nerves and ophthalmic arteries.
- *Anterior clinoid processes:* formed by medial aspect of lesser wings.
- *Tuberculum sellae:* ridge of bone between anterior clinoid processes; anterior boundary of sella turcica.
- *Optic (chiasmic) groove:* horizontal depression crossing body of bone in front of sella turcica, where optic nerves cross.
- *Optic foramen and canal:* passage for optic nerve and ophthalmic artery at the orbit's apex.
- *Sella turcica:* deep depression in sphenoid bone; houses pituitary gland.
- *Dorsum sellae:* posterior boundary/wall of sella turcica.
- *Posterior clinoid processes:* extend laterally from dorsum sellae.
- *Clivus:* basilar portion; slopes down and posteriorly from dorsum sellae; articulates with basilar portion of occipital bone.
- *Superior orbital fissures:* large spaces between greater and lesser wings; for passage of four cranial nerves.
- *Greater (major) wings:* larger, posterior portion of sphenoid bone; contains the foramina rotundum, ovale, and spinosum for transmission of cranial nerves.
- *Pterygoid processes:* extend inferiorly from junction of body with great wing; each has a medial and lateral plate that articulates with posterior part of adjacent maxillae.

Types of Fractures

Linear fx
A skull fx, straight and sharply defined

Depressed fx
A comminuted skull fx, with one or more portions pushed inward

Hangman's fx
Fx of C2 with anterior subluxation of C2 on C3; result of forceful hyperextension

Compression fx
Especially of spongy (cancellous) bone; diminished thickness or width as a result of compression-type force (e.g., vertebral body)

Blowout fx
Fx of orbital floor as a result of a direct blow
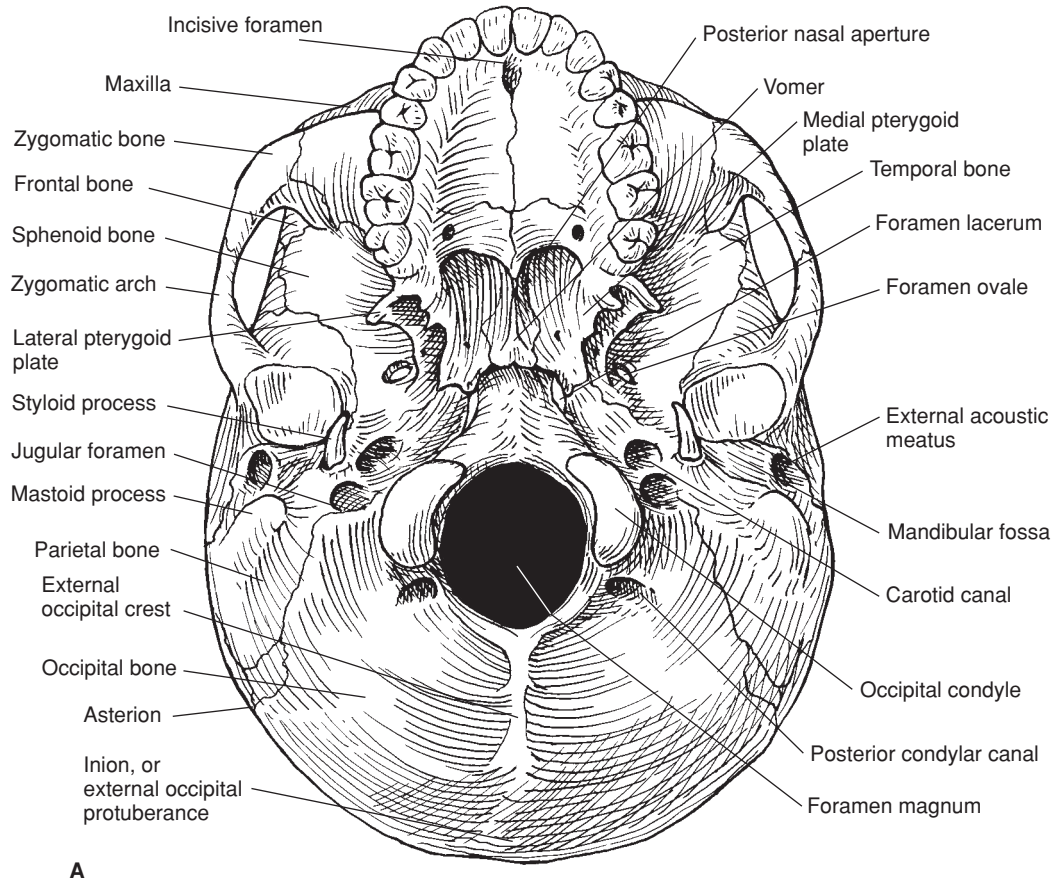
Figure 6–59. (**A**) Basal view of the skull (external aspect, inferior view). (**B**) SMV skull demonstrates the base of the skull. (Courtesy of Stamford Hospital, Department of Radiology.)

Foramina	Structures
Cribriform plate of ethmoid	Olfactory nerves
Optic foramen	Optic nerve Ophthalmic artery Meninges
Superior orbital fissure	Oculomotor, trochlear, and abducens nerves and ophthalmic division of trigeminal nerve; superior ophthalmic vein
Foramen rotundum	Maxillary division of trigeminal nerve
Foramen ovale	Mandibular division of trigeminal nerve
Foramen lacerum	Internal carotid artery Sympathetic plexus
Foramen spinosum	Middle meningeal artery and vein
Internal acoustic meatus	Facial and auditory nerves Internal auditory artery
Jugular foramen	Glossopharyngeal, vagus, and spinal accessory nerves Transverse sinus
Hypoglossal canal	Hypoglossal nerve
Foramen magnum	Medulla and meninges Spinal accessory nerve Vertebral arteries Anterior and posterior spinal arteries

Other labels on figure: Anterior cranial fossa, Sphenoid ridge, Middle cranial fossa, Petrous pyramid, Posterior cranial fossa.

Figure 6–60. Base of the skull showing the fossae and principal foramina (superior view).

- *Inferior orbital fissures:* large openings, lie between the greater wings and the maxilla.

Occipital bone
- Forms part of posterior wall and inferior part of cranium (Figs. 6–58A and B and 6–60).
- Upper portion of each side articulates with parietal bones to form lambdoidal suture.
- *Basilar portion:* articulates anteriorly with basilar portion (clivus) of sphenoid bone.
- *Lateral portions* (2): bilateral to foramen magnum; occipital condyles, hypoglossal canals, and jugular foramina located here.
- *Foramen magnum:* large opening; transmits inferior portion of brain (medulla oblongata), which is continuous with spinal cord.
- *Squammosal portion:* posterior, superior portion; presents the external occipital protuberance (inion, occiput).

Temporal bones

- Irregularly shaped bones forming lateral aspects of cranium.
- Located between greater wings of sphenoid bone and occipital bone (Figs. 6–57 and 6–59A and B).
- Dense, *petrous portions* form ridges and contain the organs of hearing.
- Contain internal auditory meati and carotid canals.
- *Zygomatic processes:* extend from flat, squammous portion; articulate with zygomatic (facial) bones.
- *Mandibular fossae:* articulate with mandibular condyles to form temporomandibular joints (TMJs).
- *Temporal styloid processes:* sharp, slender processes extending anteriorly and inferiorly to mastoid processes.
- *External auditory meatus (EAM):* external openings of the ear canal.
- *Mastoid processes:* inferior to EAM; contain numerous air cells; communicate with tympanic cavity (middle ear) at mastoid antrum.

b. Facial Bones

Nasal bones

- Small, rectangular (Fig. 6–57).
- Form bridge of nose.
- Movable part of nose is composed of cartilage.
- Articulate with each other at midline to form nasal suture.
- Frontonasal suture: formed by articulation with frontal bone; corresponds to nasion externally.

Lacrimal bones

- Smallest of facial bones.
- Form part of medial orbital wall (Fig. 6–57).
- Lacrimal groove: accommodates lacrimal (tear) duct.

Zygomatic (malar) bones

- Inferior and lateral to outer canthus of eye; cheek bones.
- Have four processes: frontosphenoidal, orbital, temporal, and maxillary (Fig. 6–57).

Maxillae

- Second largest of facial bones (Fig. 6–57 and 6–59).
- Articulate with each other to form most of upper jaw (hard palate).
- *Palatine processes:* plates of bone that articulate at midline to form two thirds of the hard palate.
- Form most of roof of mouth (hard palate) and floor of nasal cavity.
- Contain the maxillary sinuses (maxillary antra; antra of Highmore) just superior to bicuspid teeth; the thin floor of the maxillary sinus is formed by the alveolar process.
- *Alveolar ridge/process:* contains sockets for teeth; spongy ridge of bone.
- *Anterior nasal spine:* corresponds to *acanthion* externally.
- *Infraorbital foramen:* located below orbit, lateral to nasal cavity.

Facial Bones (14)

(2) Nasal
(2) Lacrimal (smallest)
(2) Palatine
(2) Inferior nasal conchae
(2) Zygomatic
(2) Maxillae
(1) Vomer
(1) Mandible (largest; only movable)
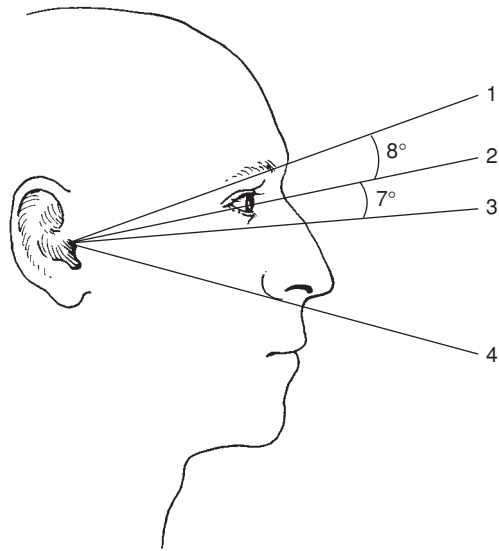
Figure 6–61. Four fundamental baselines are used in skull radiography: (1) the glabellomeatal (GML), (2) the orbitomeatal (OML, also known as canthomeatal or radiographic baseline), (3) the infraorbitomeatal (IOML), and (4) the acanthiomeatal line. There is approximately a 7° difference between the OML and IOML and 8° between the OML and GML.

Figure 6–62. PA skull radiograph; the correct amount of flexion places the petrous pyramids within the orbits. (Courtesy of Stamford Hospital, Department of Radiology.)

Palatine bones
- Small bones; form posterior one third of hard palate (Fig. 6–59).
- L-shaped; have vertical and horizontal processes.
- *Horizontal parts:* articulate with palatine processes of maxillae to complete the hard palate.
- *Vertical parts:* project superiorly from horizontal part to articulate with the sphenoid bones.

Inferior conchae (nasal turbinates)
- Completely osseous (Fig. 6–57).
- Placed inferiorly on each lateral wall of nasal cavity.

Vomer
- Inferior to perpendicular plate of ethmoid bone.
- Forms posterior bony septum (Fig. 6–57A).
- *Choanae:* posterior opening into nasopharynx; separated by posterior portion of vomer.

Mandible
- U-shaped bone; largest facial bone (Fig. 6–57).
- Only movable facial bone.
- *Mandibular symphysis:* where two halves fuse after birth.
- *Mental tubercles:* prominences at inferolateral margin of symphysis.
- *Mental protuberance:* protuberance at lower portion of symphysis.
- *Alveolar process/ridge:* spongy ridge of bone with sockets for teeth.
- *Body:* horizontal position.
- *Ramus:* posterior vertical portion.
- *Angle:* junction of vertical and horizontal parts: corresponds to external landmark: *gonion.*
- *TMJ:* articulation of head of condyle with mandibular fossa of temporal bone; only movable articulation in skull.
- *Coronoid process:* extends anterior and superior from ramus and has no articulation; serves as muscle attachment.
- *Mandibular notch:* deep notch between condyloid and coronoid processes.
- *Mental foramen:* small opening on outer surface of body, approximately below second premolar; passage for mandibular nerve.
- *Mandibular foramen:* opening on inner side of ramus for mandibular nerve.

2. Cranium

CRANIUM	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	Patient prone, MSP ⊥ midtable, OML ⊥ IR (see Fig. 6–62)	⊥ nasion	PA proj of skull, *petrous pyramids should fill the orbits;* demonstrates frontal bone, lateral cranial walls, frontal sinuses, crista galli (see Fig. 6–62)

(continued)

CRANIUM (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN

Note: *General survey cranium* can be obtained with CR∠ed 15° caudad to nasion (ridges fill lower 1/3 orbits). *Similar projections* of the same structures may be obtained in the AP position with the OML vertical if the CR is directed in the opposite direction. Anterior structures will be somewhat *magnified* and *eye dose will be greater.*

CRANIUM (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA axial (Caldwell)	Patient PA, MSP centered to grid, OML ⊥ grid, IR centered to nasion	15° caudad to nasion	PA axial of cranium, petrous portions in lower third of orbits (see Fig. 6–70)
AP axial (Towne)	Patient supine, MSP midtable, OML vertical, top of IR 1.5″ below vertex	30° caudad to a point ≈1.5″ above glabella (or 37° to IOML)	AP axial of skull, especially for *occipital bone*, symmetrical proj of petrous pyramids, projects dorsum sella and posterior clinoid processes within the foramen magnum (Fig. 6–63A)

Note: Excessive tube/or neck flexion will project posterior arch of C1 in foramen magnum. A collimated proj of the *sella turcica* can be obtained in this proj; an AP axial of the *zygomatic arches* can be obtained by directing the CR to the glabella and decreasing the technical factors. Similar results can be obtained in the PA position (PA axial; Haas method) with the CR∠ed 25° cephalad to the OML—the CR enters 1½″ below the inion and exits 1½″ above the nasion; it is particularly useful for hypersthenic or kyphotic patients although some magnification of the occipital bone must be expected.

(continued)

A

B

Figure 6–63. **(A)** AP axial (Towne method) projection of the skull; demonstrates the dorsum sella and posterior clinoid processes within the foramen magnum; useful for demonstration of the occipital bone. **(B)** Lateral projection of the skull. (Courtesy of Stamford Hospital, Department of Radiology.)

CRANIUM (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat	Patient PA oblique w/skull MSP ∥ grid, interpupillary line vertical, IOML ∥ transverse axis of IR	⊥ a point 2″ superior to EAM	lat proj of skull demonstrating superimposed cranial and facial structures; anterior and posterior clinoid processes and supraorbital margins should be superimposed (see Fig. 6–63B)
Full Basal proj Submento-vertical (SMV)	Patient supine or seated AP, neck hyperextended to place IOML ∥ IR and ⊥ CR, MSP ⊥ IR	⊥ IOML and IR, enters MSP at level of sella	Full basal proj of skull, useful for many foramina (spinosum, ovale, carotid canals), sphenoid and maxillary sinuses, dens through foramen magnum, symmetrical proj of petrous pyramids w/mandibular condyles projected anterior to petrosae and symphysis superimposed on frontal bone (see Figs. 6–59B and 6–64)

Note: A decrease of 10 kV will demonstrate a bilateral axial projection of the zygomatic arches (see Figs. 6–64B and 6–65).

(continued)
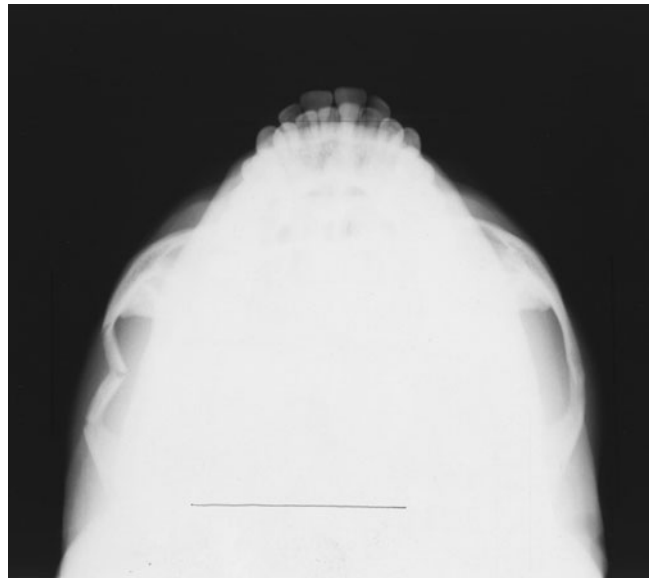
Figure 6–64. **(A)** Submentovertical (SMV) skull. The success of this projection depends on positioning the CR ⊥ the IOML and IR. **(B)** SMV projection of the skull, collimated and exposure factors adjusted to demonstrate zygomatic arches. Note fracture of left zygomatic arch. (Courtesy of Stamford Hospital, Department of Radiology.)
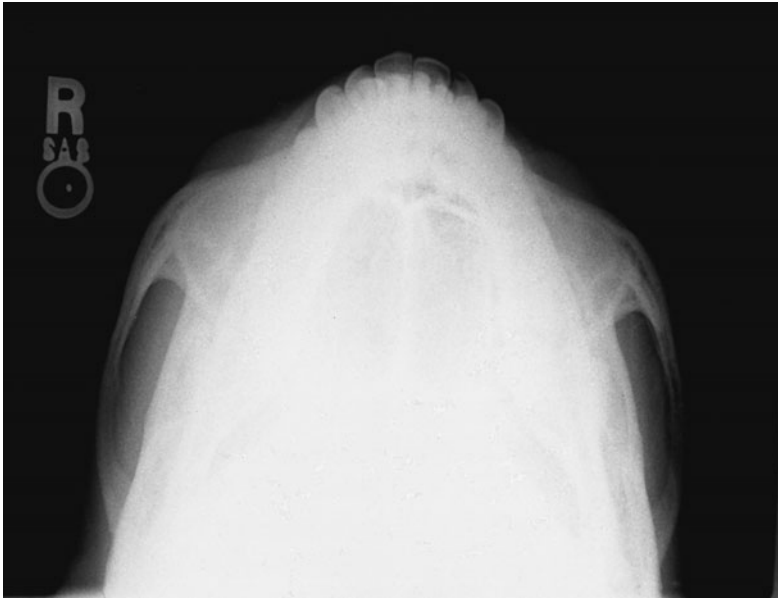
Figure 6–65. SMV projection of bilateral zygomatic arches. (Courtesy of Stamford Hospital, Department of Radiology.)

CRANIUM (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP (*trauma*)	Patient supine, MSP ⊥ mid-table, OML ⊥ IR	⊥ nasion	AP proj of skull, petrous pyramids should fill the orbits
AP axial (*trauma*)	Patient AP, MSP centered to grid, OML ⊥ grid, IR centered to nasion	15° cephalad to nasion	AP axial of cranium, petrous portions in lower third of orbits; facial structures somewhat magnified
lat (*trauma*)	Patient supine, head supported on sponge, grid IR vertical adjacent to side of interest. MSP ⊥ interpupillary line ⊥ IR.	⊥ IR, 2″ superior to EAM.	lat proj of skull in dorsal decubitus position; can demonstrate sphenoid sinus effusion as the only sign of basal skull fx

3. Orbits. The orbital cavities are formed by seven bones (frontal, sphenoid, ethmoid, maxilla, palatine, zygoma/malar, and lacrimal). The orbital walls are fragile and the orbital floor is subject to traumatic *blowout* fractures. Orbital floor fractures can be demonstrated using the *parietoacanthial (Waters)* projection; conventional tomography and CT is often indicated for further evaluation.

ORBITS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Parieto- acanthial (*Waters*)	Patient PA, MSP ⊥ centered to grid, chin extended so OML is 37° to IR	⊥ to parietal region, exiting at acanthion	Axial proj of facial bones, especially orbits, zygomas, and maxillae; best single proj for *facial bones*

Note: X-ray beam may be collimated to orbital region, with CR passing through MSP, and exiting midorbits.

ORBITS *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA axial *(Caldwell)*	Patient PA, skull MSP centered to grid, OML ⊥ grid, IR centered to nasion	15° caudad to nasion	PA axial of orbits, nasal septum, maxillae, and zygomas. Petrous pyramids are seen in the *lower one third of the orbits*

Note: X-ray beam may be collimated to orbital region, with CR passing through MSP, and exiting midorbits.

lat	Patient PA oblique w/skull MSP ∥ grid, interpupillary line vertical, IOML ∥ transverse axis of IR	⊥ a point 2″ superior to EAM	lat proj of skull demonstrating superimposed cranial and facial structures; anterior and posterior clinoid processes and supraorbital margins should be superimposed

Note: X-ray beam may be collimated to orbital region, with CR passing parallel to interpupillary line.

4. Facial Bones, Zygomatic Arches, and Nasal Bones

FACIAL BONES	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Parietoacanthial *(Waters)*	Patient PA, MSP ⊥ centered to grid, chin extended so OML is 37° to IR	⊥ to parietal region, exiting at acanthion	Axial proj of facial bones, especially orbits, zygomas, and maxillae; best single proj for *facial bones*

Note: Patient should be upright to demonstrate air/fluid levels.

lat	Patient recumbent prone, MSP of skull ∥ table, interpupillary line ⊥ IOML parallel to transverse axis of IR	⊥ a point 3/4″ dist to nasion; include nasofrontal suture through anterior nasal spine of maxilla	lat proj of superimposed nasal bones and their associated soft tissue (see Fig. 6–66)
PA axial *(Caldwell)*	Patient PA, MSP centered to grid, OML ⊥ grid, IR centered to nasion	15° caudad to nasion	PA axial of facial bones, petrous portions in lower third of orbits
AP axial *trauma* *(Reverse Waters)*	Patient supine, MSP ⊥ midtable	30° ∥ mentomeatal line, entering acanthion	Axial, but *magnified*, proj of facial bones
lat *trauma*	Patient supine, performed "crosstable," horizontal beam	CR enters 2″ superior to EAM; grid cassette placed adjacent to lateral aspect of patient skull	
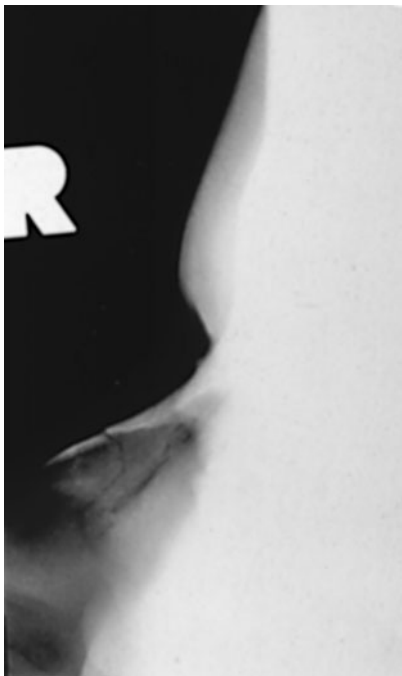
Figure 6–66. Lateral nasal bones demonstrating fracture. (Courtesy of Stamford Hospital, Department of Radiology.)

ZYGOMATIC ARCHES	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Full basal proj submen-tovertical	Patient supine or seated AP, neck hyperextended to place IOML ∥ IR and ⊥ CR, MSP ⊥ IR	⊥ IOML and IR, enters MSP at level of sella	Full basal proj of skull, useful for many foramina, sphenoid and maxillary sinuses; a decrease of 10 kV will demonstrate a bilateral axial projection of the zygomatic arches (Figs. 6–64B and 6–65)

Note: In this projection, the skull may be rotated 15° *toward the affected side* to better "open up" the zygomatic arches in individuals having flat cheekbones or a depressed fx.

AP axial (*Towne*)	Patient supine, MSP ⊥ midtable, OML vertical	30° caudad to glabella (or 37° to IOML)	AP axial of zygomatic arches free of superimposition
Parietoa-canthial (*Waters*)	Patient PA, MSP ⊥ centered to grid, chin extended so OML is 37° to IR	⊥ to parietal region, exiting at acanthion	Axial proj of facial bones, especially orbits, zygomas, and maxillae; best single proj for *facial bones*

Note: Patient could be examined in the upright position to demonstrate air/fluid levels.

NASAL BONES	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat	Patient PA obl, MSP of skull ∥ table, interpupillary line ⊥ IOML ∥ to transverse axis of IR	⊥ zygoma	lat proj of superimposed facial bones

NOTE: The *parietoacanthial* (modified Waters) and *PA axial* (Caldwell) from *facial bone* series are most often included in the *nasal bone* series.

5. Mandible and Temporomandibular Joints (TMJs)

MANDIBLE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	Patient PA, nose and forehead on table, MSP ⊥ IR centered to tip of nose	⊥ the lips	PA proj of mandible, especially body and rami (Fig. 6–67A)
PA axial	Patient PA, nose and forehead on table, MSP ⊥ IR centered to glabella	20°–25° cephalad to center of IR	PA axial mandible, especially for rami and condyles

(continued)

A

B
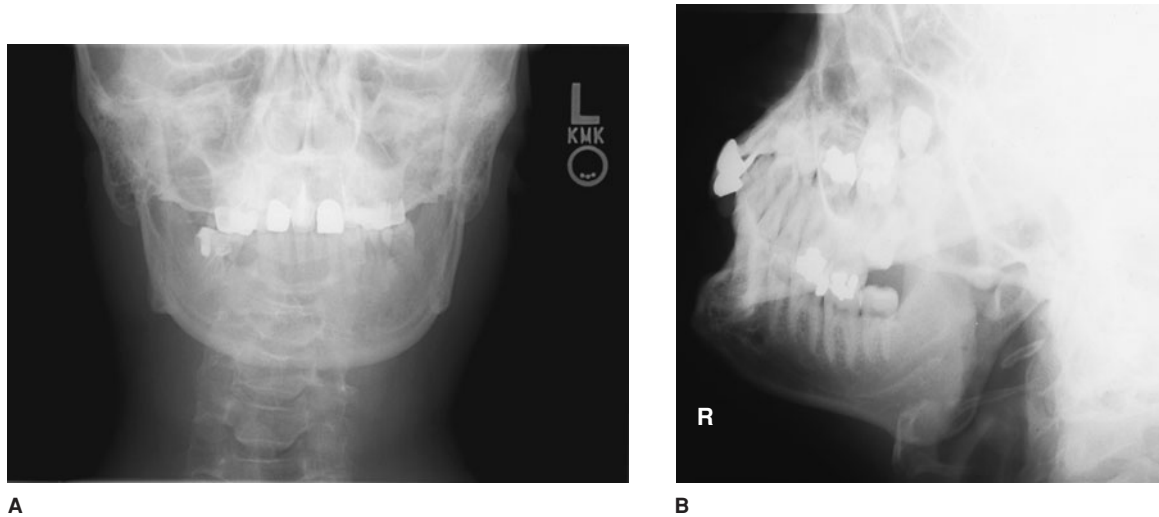
Figure 6–67. (**A**) PA mandible. (**B**) Axiolateral mandible, projects body, and ramus for visualization. (Courtesy of Stamford Hospital, Department of Radiology.)

MANDIBLE (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
Axio-lateral oblique	Patient PA, MSP of skull ‖, IR centered 1/2″ anterior and 1″ inferior to the EAM	25° cephalad, enters at mandibular angle of unaffected side	Axiolateral mandible, especially for body and ramus; rotate MSP 15° forward to better demonstrate body (see Fig. 6–67B)
AP axial (*Towne*)	Patient supine, MSP ⊥ midtable, OML vertical	30° caudad through mid-ramus (or 37° to IOML)	AP axial of mandibular rami free of superimposition
Basal proj submen-tovertical (SMV)	Patient supine or seated AP, neck hyperextended to place IOML ‖ IR and ⊥ CR, MSP ⊥ IR	⊥ IOML and IR, enters MSP at level of sella	Full basal proj of skull; useful for odontoid process through foramen magnum, symmetrical proj of petrous pyramids w/mandibular condyles projected anterior to petrosae and symphysis superimposed on frontal bone (see Fig. 6–64)

TMJ	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP axial (*Towne*)	Patient AP, MSP ⊥ mid-IR, OML ⊥ table	30° caudad, enters ≈3″ above nasion	AP axial proj of condyloid processes and their articulations; *unless contraindicated*, another exposure is made with the *mouth open* (Fig. 6–68)

(continued)

A   B
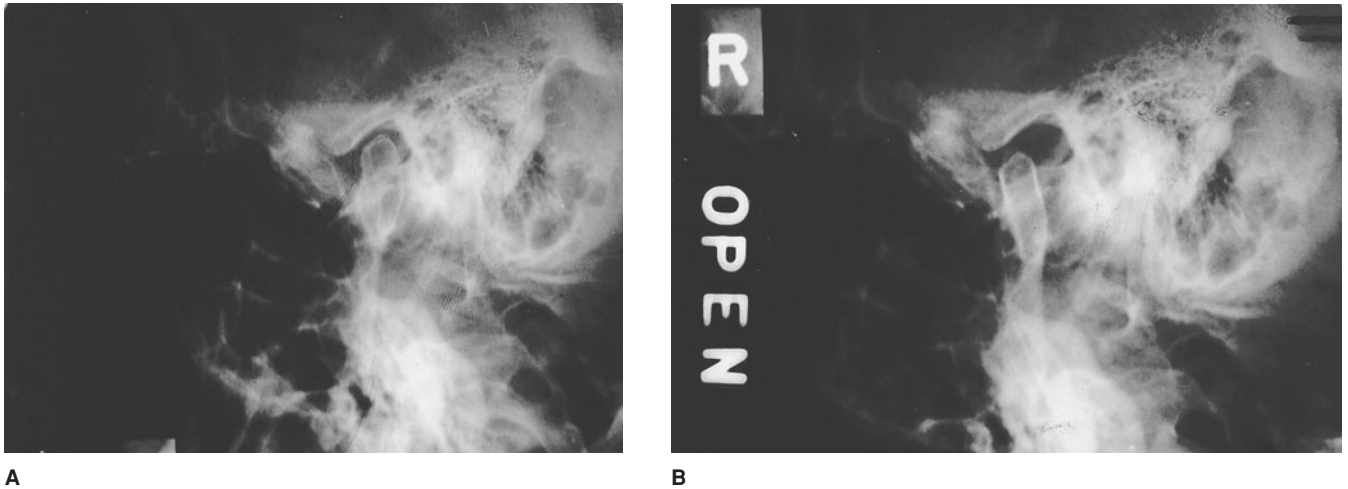
Figure 6–68. **(A)** Radiograph demonstrates the oblique lateral projection of the TMJ in the closed-mouth position. **(B)** The open-mouth position. (Courtesy of Stamford Hospital, Department of Radiology.)

TMJ *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat (*Schüller*)	Patient PA oblique w/skull MSP ‖ grid, interpupillary line vertical, IOML ‖ transverse axis of IR	25° caudad, exiting lower-most TMJ	Axiolateral TMJ *unless contraindicated, a second exposure is made with the mouth open*
Axiolat (*Law*)	Patient PA oblique w/IOML ‖ IR and MSP ‖. Rotate MSP down 15° *toward* grid	15° caudad, enters 1 1/2″ superior to uppermost EAM, exiting lowermost TMJ	Axiolateral TMJ of side down; *unless contraindicated, a second exposure is made with the mouth open*

6. Paranasal Sinuses. There are four paired *paranasal sinuses: frontal, ethmoidal, maxillary,* and *sphenoidal* (Fig. 6–69); they vary greatly in their size and shape. The left and right frontal sinuses are usually asymmetrical. They are located behind the glabella and superciliary arches of the frontal bone. The frontal sinuses are not present in young children and reach their adult size in the 15th or 16th year. The ethmoidal sinuses are composed of 6 to 18 thin-walled air cells that occupy the bony labyrinth of the ethmoid bone. The ethmoidal sinuses of children are very small and do not fully develop until after the 14th year. The maxillary sinuses (maxillary antra/antra of Highmore) are the largest of the paranasal sinuses and are located in the body of the maxillae. The *maxillary* antra are particularly prone to infection and collections of stagnant mucus. The maxillary antra reach their adult size around the 12th year. The sphenoidal sinuses are located in the body of the sphenoid bone and are usually asymmetrical. They generally reach adult size by the 14th year.

Anterior view of skull   **Lateral view of skull**

A   **B**
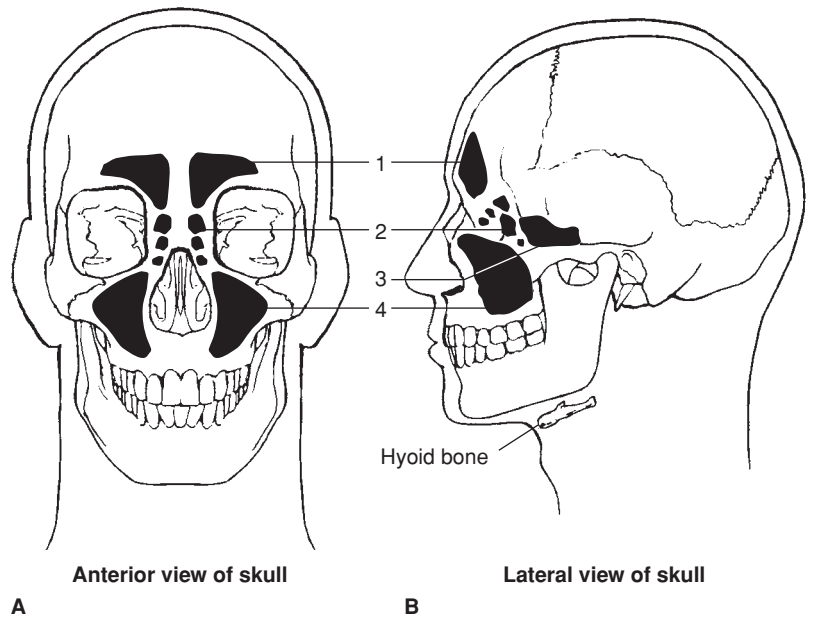
Figure 6–69. The paranasal sinuses, AP, and lateral views.

Radiography of the paranasal sinuses must be performed in the erect position so that any *fluid levels* may be demonstrated and to distinguish between fluid and other pathology such as *polyps.*

To demonstrate air and fluid levels *the CR must always be directed parallel to the floor*, even if the patient is not completely erect (just as in chest radiography). If the CR is angled to parallel the plane of the body, any fluid levels will be distorted or actually obliterated.

PARANASAL SINUSES	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA axial (*Caldwell*)	Patient PA, skull MSP centered to grid, elevate chin to place OML 15°w/ horizontal	⊥ to nasion	PA axial of *frontal* and *anterior ethmoid* sinuses, petrous pyramids are seen in the *lower one third of the orbits* (see Fig. 6–70)
Parietoa-canthial (*Waters*)	Patient PA, skull MSP centered to grid, OML 37° to IR centered to acanthion	⊥ enters parietal region and exits acanthion	Parietoacanthial proj of *maxillary* sinuses projected *above petrous pyramids* (see Fig. 6–71)

Note: Insufficient neck extension results in petrosae superimposed on floor of maxillary sinus; distorted projection of frontal and ethmoid. A modification of this projection made with the *mouth open* will demonstrate the *sphenoid sinuses* through the open mouth.

lat	Patient PA obl, skull MSP ‖ to IR centered 1″ posterior to outer canthus, interpupillary line vertical	⊥ mid-IR, enters 1″ posterior to outer canthus	lat proj of all paranasal sinuses (see Fig. 6–72)

(continued)

Figure 6–70. PA axial projection (Caldwell position) of the frontal and anterior ethmoid sinuses. The caudal angulation is somewhat excessive because the petrous pyramids are seen at the lowermost portion of the orbits. Correct angulation places the petrous pyramids in the lower one third of the orbits. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 6–71. Parietoacanthial projection (Water's method). The sinuses are centered to the image receptor. The chin is adequately extended and the petrous pyramids are seen below the floor of the maxillary sinuses. The parietoacanthial projection provides a fore-shortened view of the frontal and ethmoid sinuses. In a modification of this projection, the sphenoid sinuses would be seen through the open mouth. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 6–72. Lateral projection of the paranasal sinuses. All paranasal sinuses are demonstrated on the lateral projection. (Courtesy of Stamford Hospital, Department of Radiology.)

PARANASAL SINUSES (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
SMV (full basal)	Patient AP erect, neck hyperextended to place IOML ∥ IR and ⊥ CR, MSP ⊥ IR	⊥ IOML and IR, enters MSP at level of sella	Basal proj of sphenoid and ethmoid sinuses; mandibular symphysis should be super-imposed on frontal bone (see Fig. 6–73)

Figure 6–73. SMV projection of paranasal sinuses. Sphenoid and posterior ethmoid are demonstrated.
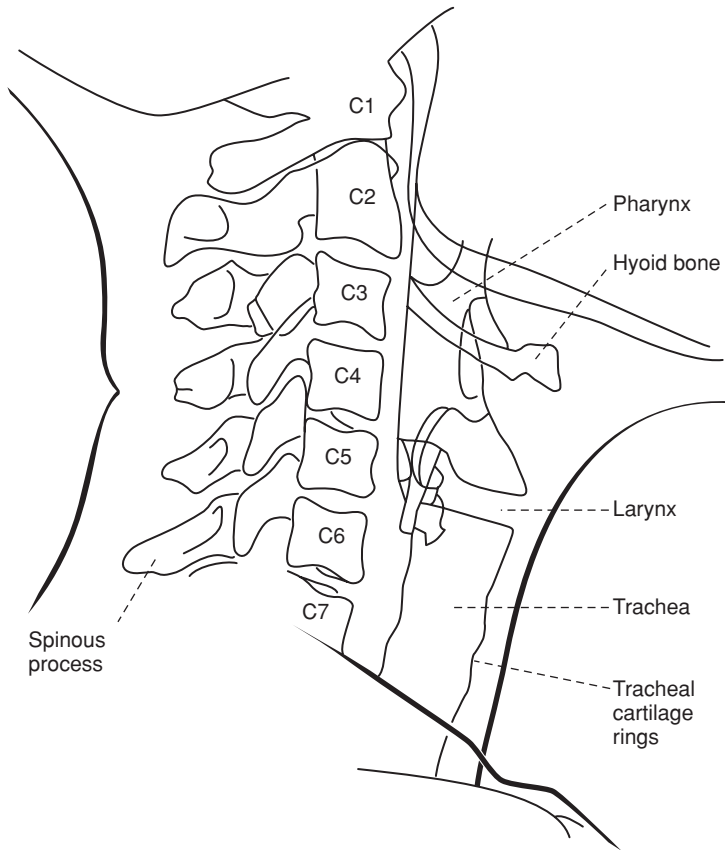
Figure 6–74. Anatomy of the neck, especially structures demonstrated in soft tissue study.

7. Soft Tissue Neck. The *upper airway* (Fig. 6–74) can be examined in the *AP* and *lateral* positions. These projections are used to demonstrate hypertrophy of the pharyngeal tonsils or adenoids. It is desired to see the nasopharynx *filled with air* to provide adequate contrast; therefore, the exposure must be made on *slow nasal inspiration*.

UPPER AIRWAY	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient AP supine or erect, MSP ⊥ IR	⊥ to IR at level of EAM; expose on slow nasal inspiration	Air-filled nasopharynx/ upper airway
lat	Patient Lateral preferably erect, MSP ∥ IR	⊥ to IR at level of EAM; expose on slow nasal inspiration	Air-filled nasopharynx/ upper airway (Fig. 6–75)

Figure 6–75. Lateral projection, soft tissue neck study.

Chapter Review Questions

☆ ***Congratulations!*** *You have completed a large portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.*

1. In the AP axial projection (Towne method) of the skull, with the central ray directed 30° caudad to the OML and passing midway between the external auditory meati, which of the following is best demonstrated?
   (A) facial bones
   (B) frontal bone
   (C) occipital bone
   (D) basal foramina

2. All of the following statements regarding a PA projection of the skull, with central ray perpendicular to the IR are true, *except*:
   (A) orbitomeatal line is perpendicular to the IR
   (B) petrous pyramids fill the lower third of the orbits
   (C) midsagittal plane (MSP) is perpendicular to the IR
   (D) central ray exits at the nasion

3. Which of the following is demonstrated in a 25° RPO position and the central ray entering 1-inch medial to the elevated ASIS?
   (A) left sacroiliac joint
   (B) right sacroiliac joint
   (C) left ilium
   (D) right ilium

4. Which of the following is (are) demonstrated in the lateral projection of the thoracic spine?
     1. intervertebral joints
     2. apophyseal joints
     3. intervertebral foramina
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 2 and 3 only

5. The thoracic vertebrae are unique in that they participate in the following articulations:
     1. costovertebral
     2. costotransverse
     3. costochondral
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

6. With the body in the supine position, the diaphragm moves:
    (A) 2 to 4 inches higher than when erect
    (B) 2 to 4 inches lower than when erect
    (C) 2 to 4 inches inferiorly
    (D) unpredictably

7. Which of the following is a functional study used to demonstrate the degree of AP motion present in the cervical spine?
    (A) open-mount projection
    (B) moving mandible AP
    (C) flexion and extension laterals
    (D) right and left bending

8. Which of the following statements is (are) correct regarding the parietoacanthial projection (Water's method) of the sinuses?
        1. patient should be examined erect
        2. OML is perpendicular to the IR
        3. petrosae should be projected below the maxillary antra
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

9. The intervertebral foramina of the lumbar spine are demonstrated with the:
    (A) coronal plane 45° to the IR
    (B) midsagittal plane 45° to the IR
    (C) coronal plane 70° to the IR
    (D) midsagittal plane parallel to the IR

10. To better demonstrate the mandibular rami in the PA position, the:
    (A) skull is obliqued toward the affected side
    (B) skull is obliqued away from the affected side
    (C) central ray is angled cephalad
    (D) central ray is angled caudad

Answers and Explanations

1. (C) The AP axial position projects the anterior structures (frontal and facial bones) downward, thus permitting visualization of the *occipital bone* without superimposition (Towne method). The dorsum sella and posterior clinoid processes of the sphenoid bone should be visualized within the foramen magnum. This projection may also be obtained by angling the central ray 30° caudad to the OML (Fig. 6-63A). The *frontal bone* is best shown with the patient PA and a perpendicular central ray. The parietoacanthial projection is the single best position for *facial bones. Basal foramina* are well demonstrated in the submentovertical projection.

2. (B) In the "true" PA projection of the skull with perpendicular central ray exiting the nasion, the petrous pyramids should *fill* the orbits. As the central ray (CR) is angled caudally, the petrous pyramids are projected lower in the orbits, and at approximately 25° to 30°, they are below the orbits. The orbitomeatal line (OML) must be perpendicular to the image receptor, or the

petrous pyramids will not be projected into the expected location in the angled projection. The midsagittal plane (MSP) must be perpendicular to the image receptor or the skull will be rotated.

3. (A) The sacroiliac joints angle posteriorly and medially 25° to the midsagittal plane (MSP). Therefore, to demonstrate them with the patient in the anteroposterior (AP) position (RPO, LPO), the *affected* side must be elevated 25°. This places the joint space perpendicular to the IR and parallel to the central ray. When performed with the posteroanterior (PA) position (right anterior oblique [RAO], left anterior oblique [LAO], the *unaffected* side will be elevated 25°.

4. (C) Intervertebral joints are well visualized in the lateral projection of all the vertebral groups. Thoracic and lumbar intervertebral foramina are well demonstrated in the lateral projection. Thoracic and lumbar apophyseal joints are demonstrated in an oblique position—thoracic requires a 70° oblique, lumbar requires a 45° oblique. Cervical articular facets (forming apophyseal joints) are 90° to the midsagittal plane (MSP) and are therefore well demonstrated in the lateral projection. The cervical intervertebral foramina lie 45° to the MSP (and 15°–20° to a transverse plane) and are therefore demonstrated in the oblique position.

5. (B) There are 12 thoracic vertebrae, which are larger in size than cervical vertebrae and which increase in size as they progress inferiorly toward the lumbar region. Thoracic spinous processes are fairly long and are sharply angled caudally. The bodies and transverse processes have *articular facets* for the *diarthrotic* rib articulations (*see Fig. 6–48).* These structures form the *costovertebral* (head of rib with body of vertebra) and *costotransverse* (tubercle of rib with transverse process of vertebra) articulations. The *costochondral* articulation describes where the anterior end of the rib articulates with its costal cartilage.

6. (A) With the body in the supine position, the abdominal viscera exert greater pressure on the diaphragm and it usually assumes a position 2 to 4 inches higher than when erect. When the body is erect, the diaphragm is more easily moved to a lower position during inspiration. For this reason, chest radiography is performed erect to allow maximum lung expansion.

7. (C) The degree of anterior and posterior motion is occasionally diminished with a "whiplash"-type injury. Anterior (forward, flexion) and posterior (backward, extension) motion is evaluated in the lateral position with the patient assuming flexion and extension as best as possible. Left and right bending images of the vertebral column are frequently obtained to evaluate scoliosis.

8. (C) The parietocanthial projection (Water's method) of the skull is valuable for the demonstration of facial bones or maxillary sinuses. The head is rested on extended chin so that the orbitomeatal line (OML) forms a 37° angle with the image receptor. This projects the petrous pyramids below the floor of the maxillary sinuses and provides an oblique frontal view of the facial bones.

9. (D) The thoracic *intervertebral foramina* are demonstrated in the lateral projection. The midsagittal plane (MSP) is parallel to the image receptor; the midcoronal plane (MCP) is perpendicular to the image receptor. The thoracic *apophyseal joints* are demonstrated in an oblique position with the coronal plane 70° to the image receptor (MSP 20° to the image receptor). The apophyseal joints closest to the image receptor are demonstrated in the posteroanterior (PA) (right/left anterior oblique [RAO/LAO]) oblique and those away from the image receptor in the anteroposterior (AP) (left/right posterior oblique [LPO/RPO]) oblique.

10. (C) The straight posteroanterior (PA) (0°) projection effectively demonstrates the mandibular body but the rami and condyles are superimposed on the occipital bone and petrous portion of the temporal bone. To better visualize the rami and condyles, the central ray is directed cephalad 20° to 30°. This projects the temporal and occipital bones above the area of interest.

IV. BODY SYSTEMS

A. Respiratory System

1. Introduction. The principal structures of the respiratory system are the *lungs*, which function to supply oxygen to the blood and relieve the body of carbon dioxide (Fig. 6–76). Pulmonary function depends on the processes of *ventilation* and *alveolar gas exchange*. The right lung is shorter because the liver is below it; the left lung is narrower because the heart occupies a portion of the lung's left side. The lungs have a somewhat conical shape; their narrow upper portion is called the *apex*, and their wide *base* is defined by the *diaphragmatic surface*. Structures such as the mainstem bronchi and pulmonary artery and veins enter and leave the lungs at the *hilum*. The right main bronchus is wider and more vertical, therefore aspirated foreign bodies are more likely to enter it than the left main bronchus, which is narrower and angles more sharply from the trachea. The *right lung* has *three lobes*; the upper and middle lobes are separated by the horizontal fissure, and the middle and lower lobes are separated by the oblique fissure. The *left lung* has *two lobes*; the upper and lower lobes are separated by the oblique fissure (Fig. 6–76).

The lungs are enclosed in a serous membrane, the *parietal pleura*. The *visceral pleura* lines the inner thoracic wall and covers the superior surface of the diaphragm; the potential space between the two layers of pleura is the *pleural cavity*.
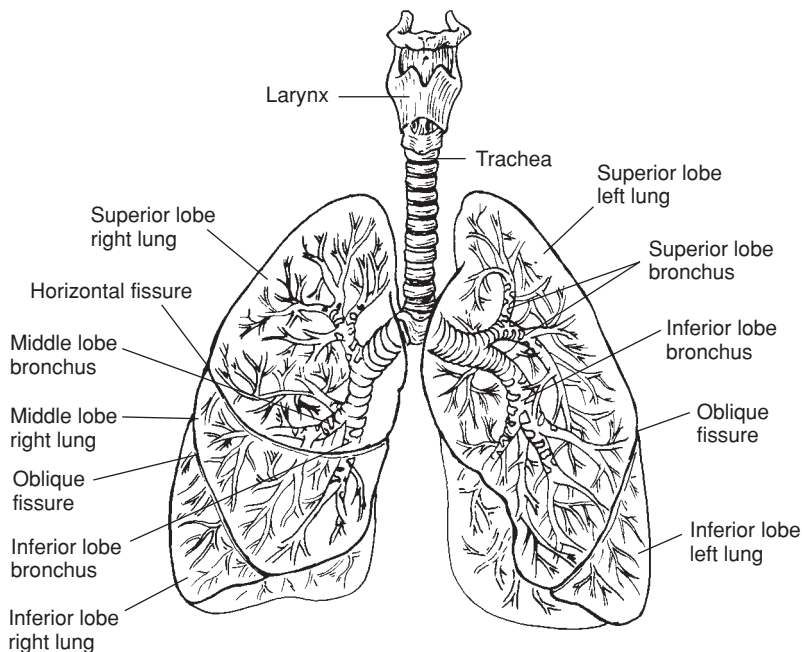
Figure 6–76. Trachea and bronchi (anterior view).

Pneumothorax is the presence of air in the pleural cavity. A large pneumothorax is usually accompanied by a partial or complete collapse of the lung (atelectasis). Radiographic indications of atelectasis include elevation of the *hemidiaphragm* of the affected side and an increase in (tissue) density of the collapsed lung. *Thoracentesis* is the procedure required to remove significant amounts of air, blood, or other fluids in the pleural cavity.

One of the most diagnostically useful and frequently performed radiographic examinations is the chest x-ray examination. During the course of their illness and recovery, patients often need successive chest examinations to monitor their progress, and reproduction of quality images is an important part of quality control. Accurate positioning and selection of technical factors is critical to the diagnostic value of the radiographic images. *Even slight rotation or leaning can cause significant distortion of the size and shape of the heart.* Consistent and accurate positioning is essential to radiographic quality.

The radiographer must take careful note of each patient's apparel, body type, and clinical information. Important considerations include removal of any radiopaque clothing and accessories, placing the IR transversely for broad-chested individuals (in order to include the *costophrenic angles*—blunting of the costophrenic angles is often a result of pleural effusion), instructing female patients with large breasts to move them up and laterally for the PA projection, exposing on the second inspiration for hypersthenic individuals, and adjusting exposure factors for various pathologic conditions. Appropriate radiation protection measures must always be provided.

Mobile chest radiography often brings the radiographer into contact with seriously ill patients. The radiographer must be very cautious when positioning these patients for there are often numerous tubes (e.g., chest tubes, endotracheal tubes, electrocardiographic [ECG] leads, Swan–Ganz lines, urinary catheters) associated with maintaining the patient's airway or reinflating a collapsed lung, removing fluid or air from the pleural cavity, administering medications, measuring central venous pressure, or measuring urine output (Fig. 6–77).

The following tables provide a summary of routine projections and frequently performed special projections.

2. Chest: PA, Lateral, and Obliques

CHEST	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	Patient erect PA, MSP exactly ⊥ IR, shoulders depressed and rolled forward w/back of hands on hips, top of IR 1.5 to 2″ above shoulders	⊥ T7	PA proj of thoracic viscera and skeletal anatomy; *inspiration* demonstrates air-filled trachea and lungs, 10 posterior ribs; *expiration* shows pulmonary vascular markings; *inspiration and expiration* are done for pneumothorax, foreign body, diaphragm excursion, and atelectasis (Fig. 6–78A)

(continued)
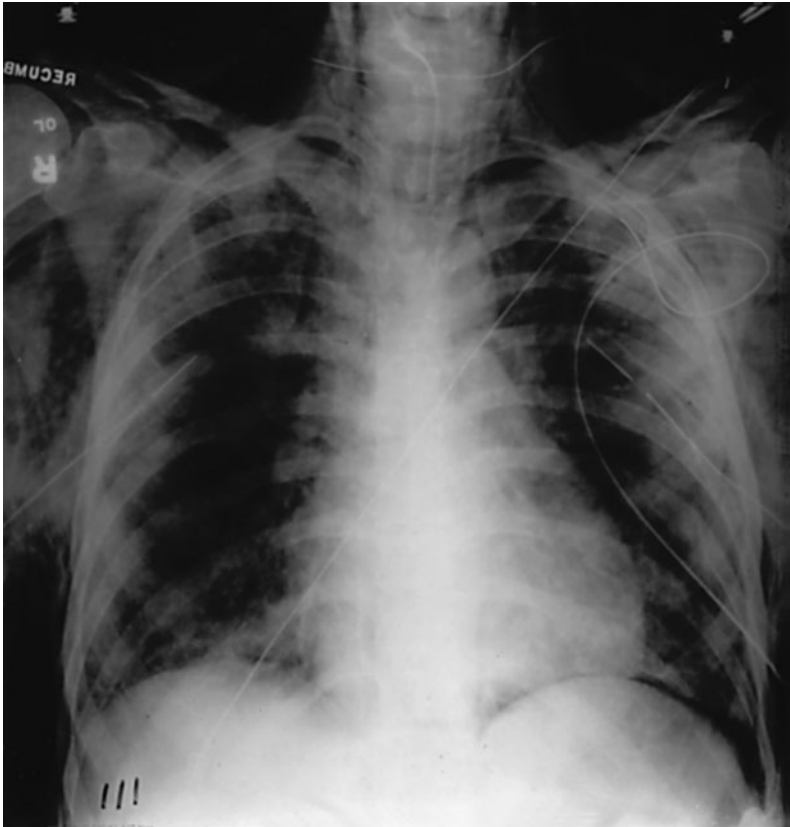
Figure 6–77. Mobile AP chest radiograph. Observe an endotracheal tube, ECG leads, one chest tube on the right and two on the left. The patient has extensive soft-tissue emphysema. Radiographers must exercise particular care when working around various patient tubes. (From the American College of Radiology Learning File. Courtesy of the ACR.)
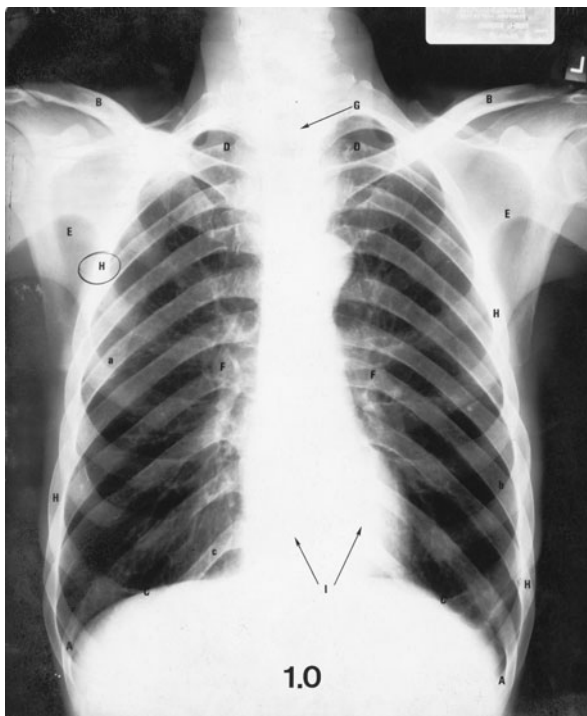
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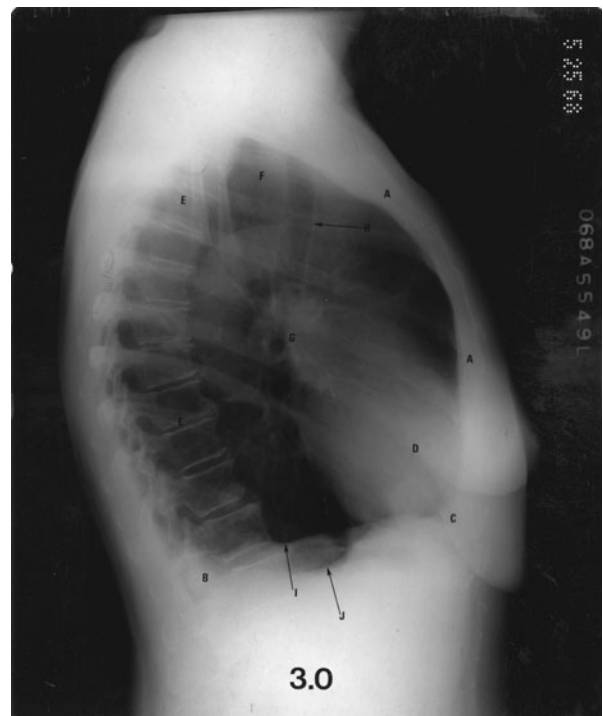
B

Figure 6–78. (**A**) PA projection of the chest. Identify the lettered structures. (Courtesy of Bob Wong, RT.) (**B**) Lateral projection of the chest. Identify the lettered structures. (Courtesy of Bob Wong, RT.)

CHEST (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN

Note: Chest radiography is performed *erect* whenever possible to demonstrate air/fluid levels. The MSP must be exactly vertical; any *rotation can cause significant distortion* and misrepresentation of the visceral structures (see Fig. 6–79A). *Rotation is detected on the PA radiograph by asymmetrical distance between the sternal ends of the clavicles and the lateral border of the thoracic vertebrae.* The shoulders are rolled forward to remove the scapulae from superimposition on the lung fields. Superiorly, the *pulmonary apices* must be seen; inferiorly the *costophrenic angles* must be seen in their entirety. *Inspiration must be adequate to demonstrate 10 posterior ribs.* A 72″ SID is recommended to decrease *magnification* of the heart. *Oblique* projections of the chest are occasionally performed as supplemental views. The *LAO* and *RAO* positions are performed with the MSP at 45° to the IR.

lat	Patient erect L lat, MSP ∥ IR, arms over head, top of IR 1.5 to 2″ above shoulders	⊥ IR, enters at level of T7	lat proj of chest particularly useful for heart, aorta, L lung and its fissures, and other left-sided structures/pathology; L lat usually done to place heart closer to IR (Fig. 6–78B)

Note: The MSP must be *exactly vertical*; any lateral leaning can cause significant distortion and misrepresentation of the visceral structures. *Rotation* is detected on the lateral radiograph by superimposition of ribs on sternum or vertebrae. Pulmonary apices and angles must be visualized (see Fig. 6–79B).
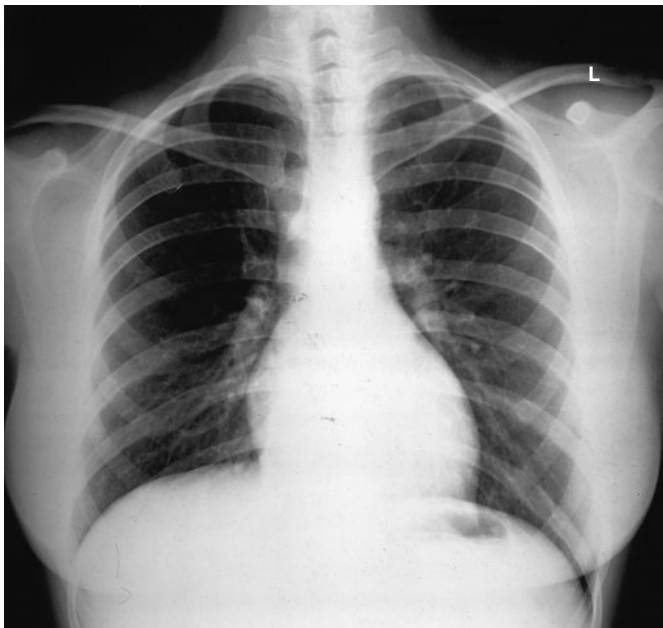
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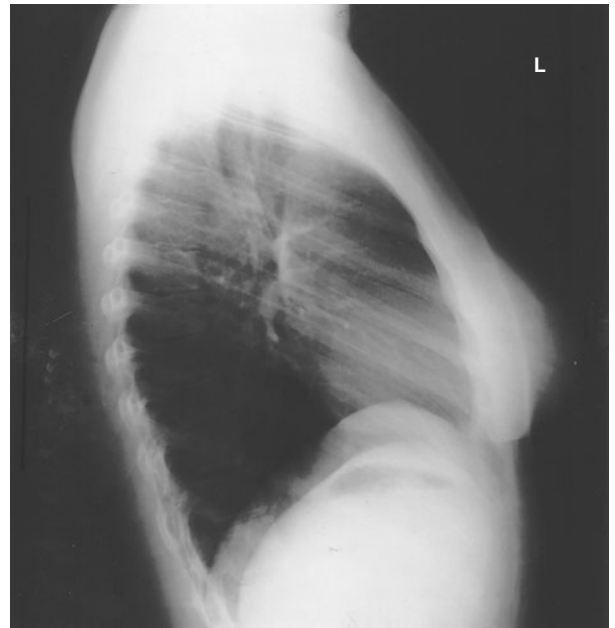
B

Figure 6–79. (**A**) PA projection of the chest of a normal, healthy adult *demonstrating the importance of positioning accuracy.* Slight rotation has made the manubrium visible at the site of the right sternoclavicular joint, providing a density very similar to that created by a paraspinous or mediastinal mass. (From the American College of Radiology Learning File. Courtesy of the ACR.) (**B**) Lateral projection of the same chest as Fig. 6–72 and without rotation. The sternum is seen free of superimposed ribs, the thoracic and lumbar vertebral spinous processes are seen. (From the American College of Radiology Learning File. Courtesy of the ACR.)

3. Chest: Axial and Decubitus

CHEST	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP Axial (*lordotic*)	Patient erect AP, MSP ⊥ mid-IR at level of T2	15°–20° cephalad to T2	AP axial (lordotic) proj of pulmonary apices projected below clavicles (can also be done with patient leaning back and CR ⊥ IR)
Decubitus (*L and R lat*)	Patient recumbent lat on affected or unaffected side as indicated by hx; anterior or posterior surface adjacent to IR. MSP ⊥ mid-IR w/top of IR 1.5″ above shoulders	⊥ mid-IR	Frontal (AP or PA) proj of the chest useful for demonstration of air or fluid levels

Note: If free *air* is suspected, the affected side must be *up*; if *fluid* is suspected, the affected side must be placed *down*.

4. Airway. AP and lateral projections of the airway and larynx are occasionally required to rule out *foreign body*, *polyps*, *tumors*, or any other condition suspected of causing some airway obstruction.

The AP is positioned as for an AP cervical spine with the CR perpendicular to the *laryngeal prominence*. The lateral is positioned as for a lateral cervical spine and centered to the coronal plane passing through the trachea (anterior to the cervical spine) at the level of the laryngeal prominence. *Exposures are made on slow inspiration* to visualize air-filled structures.

Depending on the structure(s) of interest being examined, these positions may be performed with barium and/or during performance of the *Valsalva/modified Valsalva maneuver*. Tomograms may be performed during phonation of vowel sounds to demonstrate more superior structures such as the larynx and/or vocal cords.

5. Terminology and Pathology. The following is a list of radiographically significant conditions and devices with which the student radiographer should be familiar:

Asthma

Atelectasis

Bronchiectasis

Bronchitis

Central venous pressure line

Chest tube (see Fig. 6–77)

Chronic obstructive pulmonary disease

Cystic fibrosis

Emphysema (see Fig. 6–80)

Empyema

Endotracheal tube (see Fig. 6–77)

Hemothorax

Hickman catheter

Pleural effusion (see Fig. 6–81)

Pneumoconiosis

Pneumonia

Pneumothorax

Swan–Ganz catheter

Thoracentesis

Tuberculosis

Figure 6–80. PA chest radiograph demonstrates the characteristic irreversible trapping of air found in emphysema, which gradually increases and overexpands the lungs, thus producing the *characteristic flattening of the diaphragm* and *widening of the intercostal spaces.* The increased air content of the lungs requires a compensating decrease in technical factors. (From the American College of Radiology Learning File. Courtesy of the ACR.)

Figure 6–81. PA chest demonstrating pleural effusion secondary to heart failure. (Reproduced with permission, from Doherty GM, ed. *Current Surgical Diagnosis & Treatment*, 12th ed. New York, NY: McGraw-Hill, 2006:341.)

Chapter Review Questions

⭐ ***Congratulations!*** *You have completed your review of a large portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.*

1. Aspirated foreign bodies in older children and adults are most likely to lodge in the:
   (A) right main bronchus
   (B) left main bronchus
   (C) esophagus
   (D) proximal stomach

2. Which of the following is (are) important when positioning the patient for a PA projection of the chest?
   1. the patient should be examined erect
   2. clavicles should be brought above the apices
   3. scapulae should be brought lateral to the lung fields
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

3. Chest radiography should be performed using 72 inches SID whenever possible in order to:
   1. maximize magnification of the heart
   2. obtain better lung detail
   3. visualize vascular markings
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

4. Blunting of the costophrenic angles seen on a PA projection of the chest can be an indication of:
   (A) pleural effusion
   (B) ascites
   (C) bronchitis
   (D) emphysema

5. Which of the following conditions is characterized by widening of the intercostal spaces?
   (A) emphysema
   (B) empyema
   (C) atelectasis
   (D) pneumonia

6. Inspiration and expiration projections of the chest may be performed to demonstrate:
    1. pneumothorax
    2. diaphragm excursion
    3. bronchitis
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

7. Which of the following criteria are used to evaluate a good PA projection of the chest?
    1. 10 posterior ribs should be visualized
    2. sternoclavicular joints should be symmetrical
    3. scapulae should be outside the lung fields
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

8. All of the following statements regarding respiratory structures are true, *except:*
    (A) the right lung has two lobes
    (B) the uppermost portion of the lung is the apex
    (C) each lung is enclosed in pleura
    (D) the trachea bifurcates into mainstem bronchi

9. To demonstrate the pulmonary apices below the level of the clavicles in the AP position, the CR should be directed:
    (A) perpendicular
    (B) 15° to 20° caudad
    (C) 15° to 20° cephalad
    (D) 40° cephalad

10. With the body in the erect position, the diaphragm moves:
    (A) 2 to 4 inches higher than when recumbent
    (B) 2 to 4 inches lower than when recumbent
    (C) very little
    (D) intermittently

Answers and Explanations

1. (A) Because the right main bronchus is wider and more vertical, aspirated foreign bodies are more likely to enter it than the left main bronchus, which is narrower and angles more sharply from the trachea. An aspirated foreign body does not enter the esophagus or stomach, as they are digestive, not respiratory, structures.

2. (C) The chest should be examined in the *erect* position whenever possible to demonstrate any air or fluid levels. The shoulders should be relaxed and depressed to move the clavicles *below* the lung apices. The shoulders should be rolled forward to move the *scapulae* out of the lung fields.

3. (C) Chest radiographs are performed in the erect position at 72 inches SID whenever possible. The long source-to-image receptor distance (SID) is easily achieved with a minimum

patient exposure due to the low tissue densities being examined (ribs and lungs). The longer SID *minimizes* magnification of the heart and provides better visualization of pulmonary vascular markings.

4. (A) Fluid in the thoracic cavity between the visceral and parietal pleura is called *pleural effusion.* In the erect position, fluid gravitates to the lowest point, settling in, and "blunting," the costophrenic angles. *Ascites* is an accumulation of serous fluid in the peritoneal cavity. *Bronchitis* is an inflammation of the bronchial tubes. Pulmonary *emphysema* is a chronic pulmonary disease characterized by increase beyond the normal in the size of air spaces distal to the terminal bronchiole, and with destructive changes in the walls of the bronchioles.

5. (A) *Emphysema* is characterized by irreversible trapping of air, which gradually increases and overexpands the lungs, thus producing the characteristic *flattening of the diaphragm* and *widening of the intercostal spaces* (see Fig. 6–80). The increased air content of the lungs requires a compensating *decrease in technical factors. Empyema* describes pus in the pleural cavity as a result of an infection of the lungs. *Atelectasis* is a collapsed or airless lung. *Pneumonia* is an inflammation of the lung; there are more than 50 causes of pneumonia.

6. (B) Phase of respiration is exceedingly important in thoracic radiography; lung expansion and the position of the diaphragm strongly influence the appearance of the finished radiograph. Inspiration and expiration radiographs of the chest are taken to demonstrate air in the pleural cavity (pneumothorax), to demonstrate degree of diaphragm excursion, or to detect the presence of foreign body. The expiration image will require a somewhat greater exposure (6–8 kV or more) to compensate for the diminished quantity of air in the lungs.

7. (D) To evaluate sufficient inspiration and lung expansion, 10 posterior ribs should be visualized. Sternoclavicular joints should be symmetrical; any loss of symmetry indicates rotation. Accurate positioning and selection of technical factors is critical to the diagnostic value of the radiographic images. Even slight rotation or leaning can cause significant distortion of the heart size and shape. To visualize maximum lung area, the shoulders are rolled forward to remove the scapulae from the lung fields.

8. (A) The trachea (windpipe) bifurcates into left and right mainstem bronchi, each entering its respective lung hilum. The left bronchus divides into two portions, one for each lobe of the left lung. *The right bronchus divides into three portions, one for each lobe of the right lung.* The lungs are conical in shape, consisting of upper pointed portions, termed the *apices* (singular: apex), and the broad lower portions (or *bases*). The lungs are enclosed in a double-walled serous membrane called the pleura.

9. (C) When the shoulders are relaxed, the clavicles are usually carried below the pulmonary apices. To examine the portions of lungs lying behind the clavicles, the CR is directed cephalad 15° to 20° to project the *clavicles above the apices*, when the patient is examined in the AP position.

10. (B) When the body is erect, the diaphragm is more easily moved to a lower position during inspiration. For this reason, chest radiography is performed erect to allow maximum lung expansion. With the body in the supine position, the abdominal viscera exert greater pressure on the diaphragm and it usually assumes a position 2 to 4 inches higher than when erect.
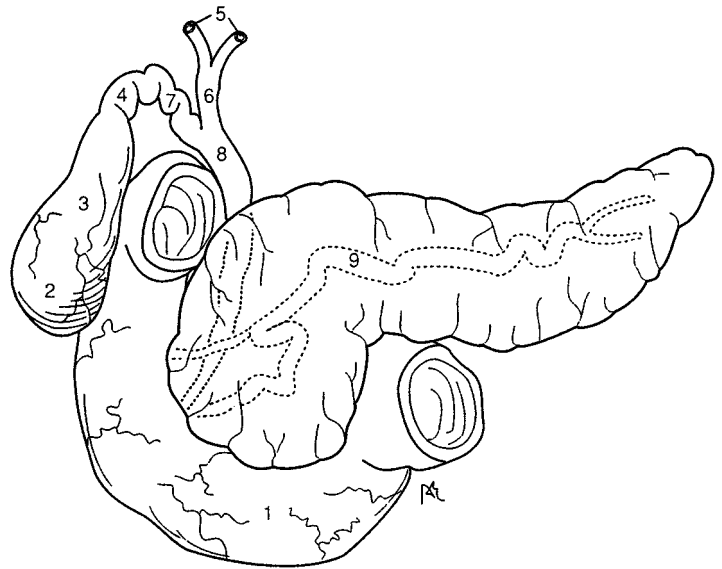
Figure 6–82. This illustrates the main hepatic and biliary ducts, gallbladder, and pancreas within the duodenal loop. Be able to identify the labeled structures.

B. BILIARY SYSTEM

1. Introduction. The biliary tree consists of the left and right hepatic ducts, common hepatic duct, cystic duct, common bile duct, and the gallbladder (GB) (Fig. 6–82). The hepatic ducts leave the liver and join to form the *common hepatic duct.* The short *cystic duct* continues to the GB. The common hepatic and cystic ducts unite to form the long *common bile duct,* which joints with the pancreatic duct to form the short *hepatopancreatic ampulla (of Vater).* The ampulla opens into the descending duodenum through the *duodenal papilla,* which is surrounded by the *hepatopancreatic sphincter (of Oddi).*

The *gallbladder* is located in a shallow fossa on the inferior surface of the liver between its right and quadrate lobes. Small gallstones are able to pass out the GB through the cystic duct; those that are too large irritate the GB mucosa, resulting in *cholecystitis. Gallstones* can also lodge in ducts. If a stone lodges in the cystic duct, cholecystitis without *jaundice* is the result, because bile can still drain into the duodenum. A stone lodged in the common bile duct will result in jaundice as well as cholecystitis. A "gallbladder attack" is the painful result of fatty chyme stimulating the release of *cholecystokinin,* which elevates pressure within the stone-laden GB.

Radiographic examinations of the biliary system include *oral cholecystography, operative cholangiography, T-tube cholangiography,* and *endoscopic retrograde cholangiopancreatography (ERCP).* Each of these examinations requires the use of a contrast agent. With the exception of the ERCP, few of these examinations are performed today, but rather are imaged via *sonography* (Fig. 6–83).

Figure 6–83. A sonogram of the gallbladder demonstrating the presence of gallstones. (Courtesy of Stamford Hospital, Department of Radiology.)

2. Patient Preparation. For *oral cholecystograms* (OCG), iodinated tablets are taken the evening before the examination. The GB stores and concentrates the contrast-laden bile, rendering the GB radiopaque. The evening meal must be fat-free to prevent GB contraction and subsequent release of the radiopaque bile. Oral cholecystography is used to evaluate the function of the biliary system as well as demonstrate the structure and contents of the GB.

Operative cholangiography is used to examine the bile ducts and frequently follows a *cholecystectomy*. An iodinated contrast agent is introduced into the common bile duct to evaluate biliary patency and that of the hepatopancreatic ampulla. Any calculi can be detected and removed before completion of surgery.

Occasionally, a T-shaped tube is left in the common bile duct for postsurgical drainage. T-tube cholangiography is performed by injecting a contrast agent through the tube to detect any remaining calculi and evaluate the biliary tree patency.

ERCP is a specialized procedure used to evaluate suspected biliary and/or pancreatic conditions. An *endoscope* is passed through the mouth, esophagus, and stomach, and into the descending duodenum to the orifice of the hepatopancreatic ampulla. Contrast material is injected into the common bile duct for evaluation of the biliary system.

3. Gallbladder. An oral cholecystogram frequently begins with a prone 14 × 17-inch image of the abdomen to check *opacification* and location of the GB as well as patient preparation and technical factors. Collimated recumbent PA and oblique, and erect or decubitus radiographs follow. In the absence of gallstones, a fatty meal may then be given to the patient and another similar series of images taken 20 to 30 minutes later. The fatty meal is used to check GB function: in the presence of fat the GB should contract and evacuate its bile. Fluoroscopic images may be taken in addition to, or in place of, the postfat radiographs.

The gallbladder of the average build patient is located between the 10th and 12th ribs on the right, midway between the vertebral column and lateral border of the body. *Hypersthenic* individuals usually require centering about 2 inches higher and more laterally, while centering for *asthenic* individuals is usually 2 inches lower and more midline. In the *erect* position, the GB of an asthenic patient can be as low as the iliac fossa.

OCG	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	Prone or PA erect, sagittal plane passing m/w b/w spine and R lat border of body, at level of 9th rib centered to grid (CR lower when done erect)	⊥ center of IR	PA recumbent or erect proj of GB. *The erect position will demonstrate layering of any* gallstones (Fig. 6–84A)
obl (*LAO*)	Recumbent LAO, sagittal plane passing m/w b/w spine and R lat border of body centered to grid at level of 9th rib	⊥ center of IR	obl GB, with less foreshortening and self-superimposition than in PA. *Greater obliquity (40°) for asthenic patients* than for hypersthenic (15°) (Fig. 6–84B)

(continued)

A   B   C
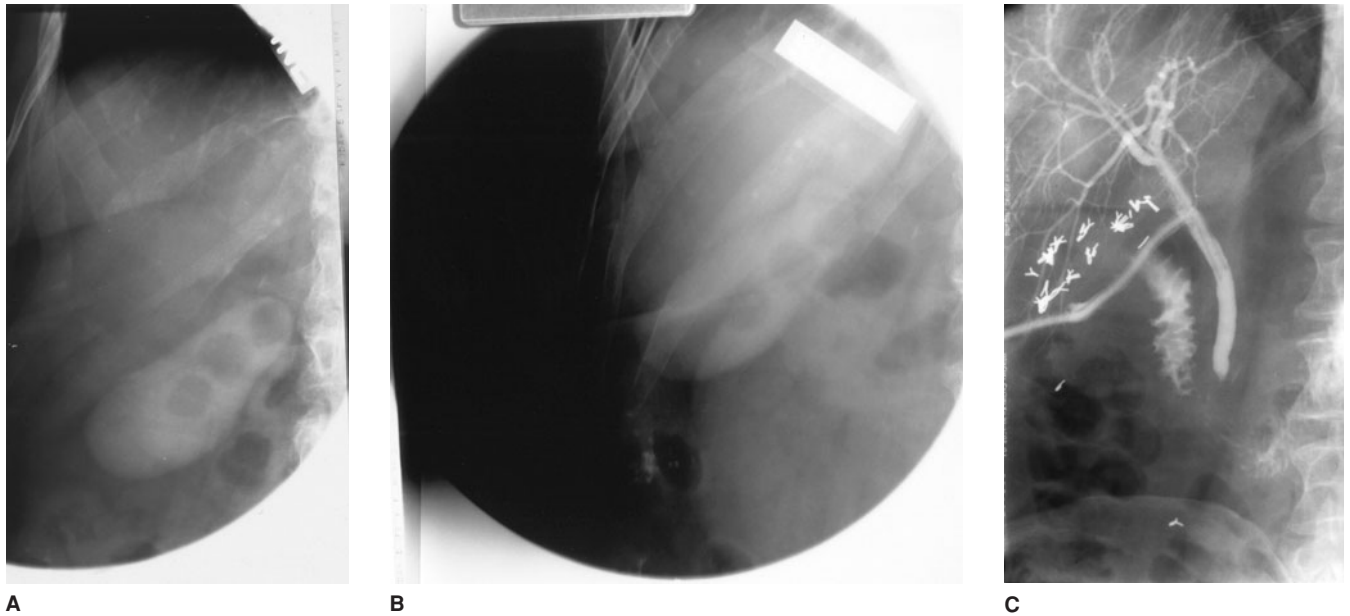
Figure 6–84. (**A**) PA projection of GB (with gallstones). (**B**) LAO of same GB. Oblique position moves GB away from vertebrae. (**C**) T-tube cholangiogram. (Courtesy of Stamford Hospital, Department of Radiology.)

OCG (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
R lat Decubitus	Patient recumbent R lat, posterior surface adjacent to upright grid and centered to level of gallbladder	⊥ center of IR	R lat decubitus of gallbladder useful for *stratification* (layering) of gallstones (Fig. 6–84) and the GB free of superimposed bowel loops

4. Cholangiography: Surgical and T-tube

SURGICAL/ T-TUBE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine	⊥ center of IR	AP of biliary tree and gallbladder area; to evaluate the hepatopancreatic ampulla and biliary tree for calculi or other pathology (following injection of contrast into common bile duct) (Fig. 6–84C)

Note: Can be performed RPO with L side elevated 15°–20°, R upper quadrant centered to grid.

5. ERCP. Following *canalization* of the hepatopancreatic ampulla, fluoroscopic images are made in the AP (RPO) or PA (LAO) position.

Imaging procedure should immediately follow injection since, under normal conditions, contrast will empty from the biliary ducts in approximately 5 minutes (Fig. 6–85).

6. Terminology and Pathology. The following is a list of radiographically significant conditions with which the student radiographer should be familiar:

Cholecystitis   Hepatitis
Cholelithiasis   Jaundice
Cirrhosis   Pancreatitis

C. DIGESTIVE SYSTEM

1. Introduction. The major portion of the GI tract lies within the abdominopelvic cavity. Its principal functions are the chemical breakdown and absorption of nutrients. The digestive system (Fig. 6–86) consists of the *gastrointestinal (GI) tract* and *accessory organs*. The *gastrointestinal tract*, or *alimentary canal*, is a continuous tube of varying dimensions consisting of the esophagus, stomach, and small and large intestines. The teeth, tongue, salivary glands, liver, gallbladder, and pancreas are *accessory organs* that aid in the mechanical and chemical breakdown of food.

The lobulated salivary glands encircle the entrance to the oropharynx. The largest of the salivary glands is the *parotid* gland. The parotid is located just anterior to the ear and above the mandibular angle and is emptied by Stenson's duct. The *submandibular* glands are located near the inner surface of the mandibular body, and empty their digestive juices into the mouth via Wharton's duct. The *sublingual* gland is located in the floor of the mouth and opens into the mouth by way of multiple ducts of Rivinas—the largest of these is Bartholins duct.

Salivary glands can be investigated radiographically (termed *sialography*) via injection of contrast material for demonstration of glandular disorders such as tumors, calculi, or fistula formation following trauma to the area. Sialography involves cannulation of the ostium of the parotid duct (Stenson's) or the submandibular duct (Wharton's). Figure 6–87 illustrates submandibular sialography.

The *esophagus* functions to propel a food bolus toward the stomach through *peristaltic* motion. The *cardiac sphincter* is located at the distal end of the esophagus. "Heartburn" is an inflammation of the esophageal *mucosa* as a result of gastric *reflux* of acidic material into the esophagus. *Esophageal varices* are dilated, *tortuous* veins directly beneath the esophageal mucosa. A hiatal hernia is a herniation of the stomach through the esophageal hiatus of the diaphragm, producing a sac-like dilatation above the diaphragm (Fig. 6–88A and B). The presence of reflux, varices, or herniation can be detected radiographically with the use of barium sulfate.

The *stomach* is the dilated, sac-like portion of the GI tract. When the stomach is empty, its mucosal lining forms soft folds called *rugae* (Fig. 6–89A). *Gastritis* is an inflammation of the gastric mucosa that can be caused by excessive secretion of acids or by ingestion of irritants such as aspirin or corticosteroids. Exteriorly, it presents a *greater curvature* on its lateral surface and a *lesser curvature* on its medial surface. The proximal opening of the stomach, at the *gastroesophageal*

Figure 6–85. Fluoroscopic image of a normal ERCP. The pancreatic and common bile ducts are clearly delineated. (Courtesy of Stamford Hospital, Department of Radiology.)

Tongue

Parotid gland

Parotid (Stensen) duct

Pharynx

Salivary glands — Sublingual
Submaxillary

Esophagus

Right lobe of liver

Fundus of stomach

Left lobe of liver

Spleen

Gallbladder

Body of stomach

Pylorus

Pancreas

Left colic flexure

Right colic flexure

Transverse colon

Ascending colon

Descending colon

Cecum

Small intestines
(duodenum, jejunum
and ileum)

Appendix

Rectum
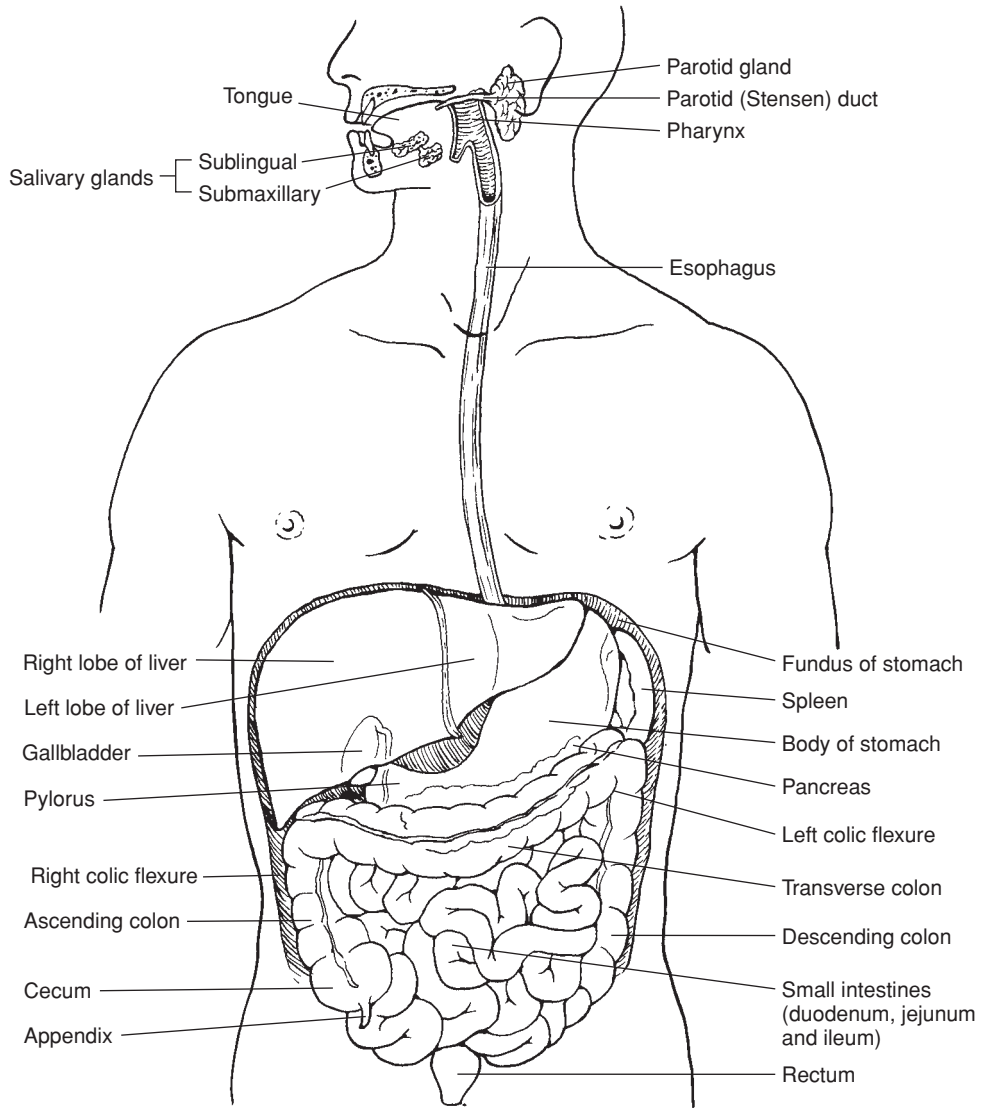
Figure 6–86. The digestive system.
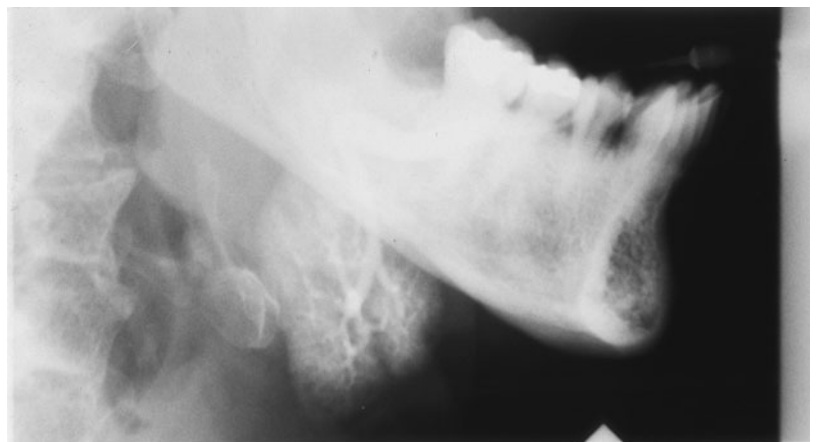
Figure 6–87. Submandibular sialogram
(Courtesy of Stamford Hospital, Department
of Radiology.)
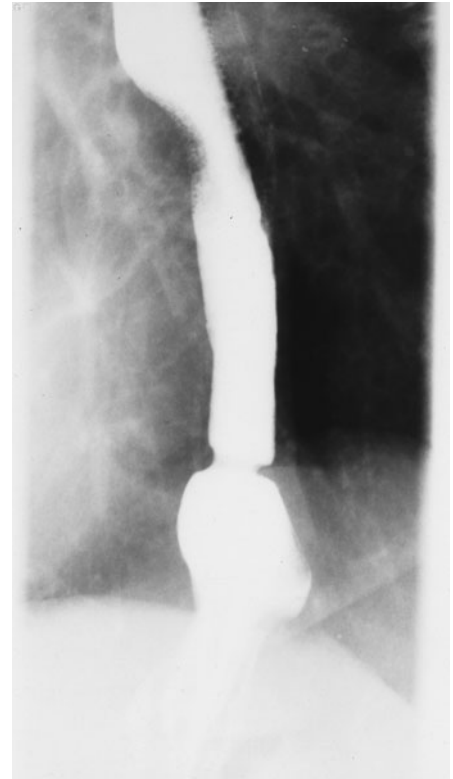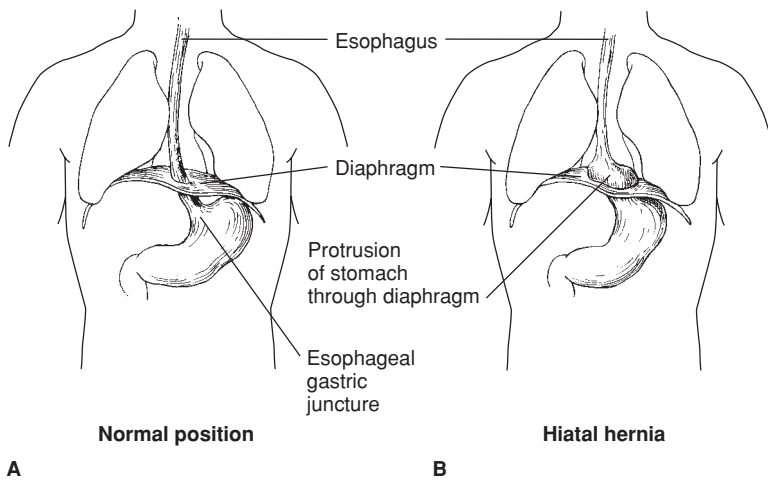
Figure 6–88. (**A**) Normal position of the stomach. (**B**) Note protrusion of stomach through esophageal hiatus (hiatal hernia). (**C**) Esophagram demonstrating hiatal hernia (with Schatzki's ring). (Courtesy of Stamford Hospital, Department of Radiology.)
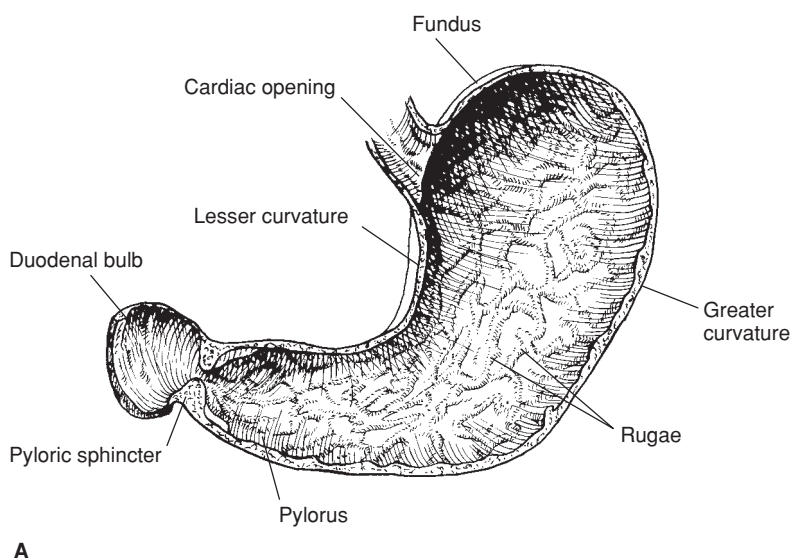
Figure 6–89. (**A**) Stomach (internal aspect). (**B**) Barium-filled duodenal loop; duodenal bulb, descending, transverse, and ascending duodenum are well demonstrated. (Courtesy of Stamford Hospital, Department of Radiology.)

junction (GEJ), is the *cardiac sphincter*; the *pyloric sphincter* is located at its distal end. The portion of the stomach around the distal esophagus is called the *cardia*; that portion superior to the esophageal juncture is the *fundus*. The sharp angle between the esophagus and fundus is the *cardiac notch*. The major portion of the stomach is the *body*; the distal portion is the *pylorus*. The *incisura angularis* is located on the lesser curvature and marks the beginning of the pylorus. The distal portion of the pylorus is marked by the *pyloric sphincter*.

The *small intestine* is composed of the duodenum, jejunum, and ileum. The *duodenum* is the shortest portion. It begins just beyond the pyloric sphincter and is divided into four portions: the duodenal cap or bulb, descending duodenum, transverse duodenum, and ascending duodenum. These portions form a C-shaped loop (*duodenal loop*) that is occupied by the head of the pancreas (Fig. 6–89B). The descending portion receives the hepatopancreatic ampulla and duodenal papilla (see "Biliary System" section). The ascending portion terminates at the duodenojejunal flexure (angle of Treitz). While the position of the short (9 inches) duodenum is fixed, the *jejunum* (9 feet) and *ileum* (13 feet) are very mobile. Twisting of the small intestine is called *volvulus* and can cause compression of blood vessels, leading to loss of blood supply, *ischemia*, and *infarct* of the affected area. The small intestine terminates at the *ileocecal valve*.

The approximately 5-foot-long *large intestine (colon)* (Fig. 6–90A) functions in the formation, transport, and evacuation of feces. The colon begins at the terminus of the small intestine; its first portion is the dilated sac-like *cecum*, located inferior to the ileocecal valve (Fig. 6–90A and B). Projecting posteromedially from the cecum is the short (approximately 3.5 inches) *vermiform appendix*. Its lumen is
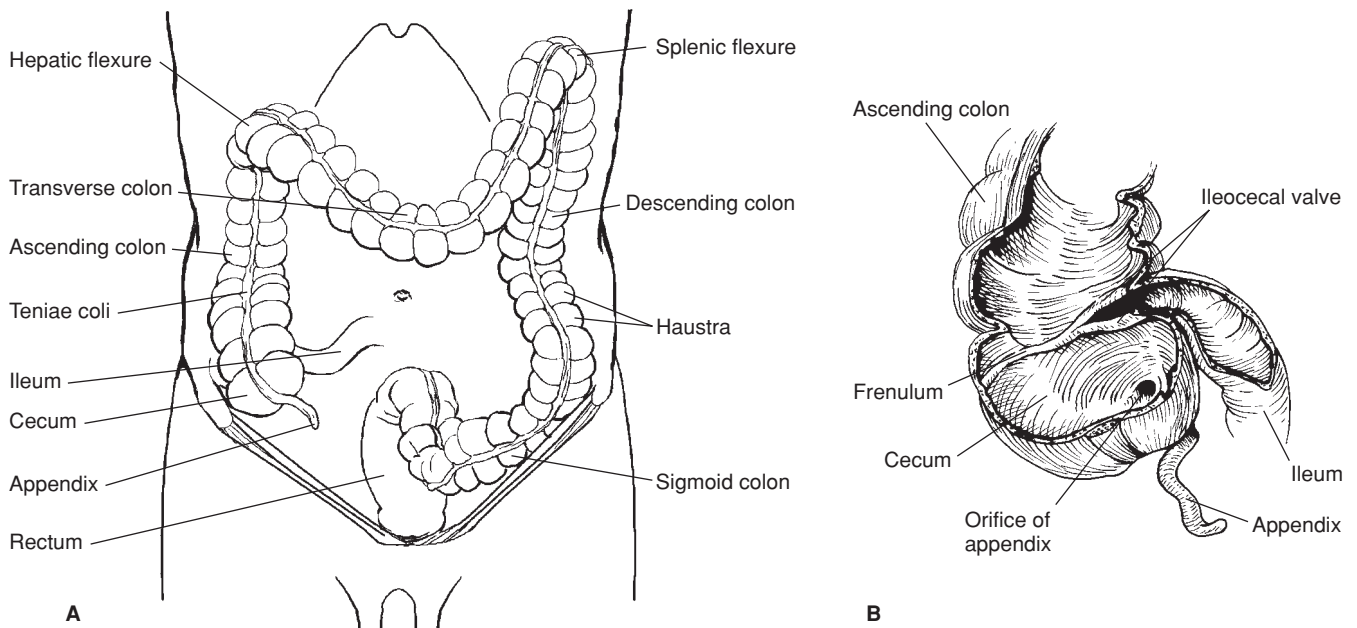
Figure 6–90. (**A**) The colon. (**B**) The ileocecal valve.

particularly narrow in adolescents and young adults and may become occluded by a fecalith and result in inflammation (appendicitis).

The *ascending colon* is continuous with the cecum and is located along the right side of the abdominal cavity. It bends medially and anteriorly in the right hypochondrium, forming the *right colic (hepatic) flexure*. The colon traverses the abdomen as the *transverse colon* and bends posteriorly and inferiorly in the left hypochondrium, forming the *left colic (splenic) flexure*. The *descending colon* continues down the left side of the abdominal cavity and, at about the level of the pelvic brim, the colon moves medially to form the S-shaped *sigmoid colon*. The *rectum* is that part of the large intestine, approximately 5 inches in length, between the sigmoid and the anal canal.

Diverticula are small saccular protrusions of intestinal mucosa through the intestinal wall. They are most commonly associated with the sigmoid colon and can become occluded by fecaliths and subsequently inflamed (diverticulitis). If an inflamed diverticulum perforates, it can result in severe bleeding and peritonitis.

2. Patient Preparation.

Preliminary patient preparation is generally required of patients undergoing radiographic examinations of various portions of the digestive system. The upper GI tract (stomach and small intestine) must be empty and the lower tract (large intestine) must be cleansed of any gas and fecal material. Patients should be questioned about their preparation and a preliminary "scout" image taken to check abdominal contents and for any radiopaque (e.g., gallstones, residual barium) material.

To make up for the lack of subject contrast, radiography of the digestive system most often requires the use of artificial contrast media in the form of barium sulfate suspension or water-soluble iodine and, frequently, air. *Double-contrast studies* of the stomach and large intestine are frequently performed. Barium sulfate functions to coat the organ with radiopaque material, while air inflates the structure. This permits visualization of the shape of the structure as well as *visualization of pathology within its lumen*. Thus, conditions such as *polyps* can be seen projecting within the air-filled lumen. A barium-filled *lumen* would make visualization of anything but the organ shape virtually impossible.

The speed with which barium sulfate passes through the alimentary canal depends on patient habitus (hypersthenic usually fastest) and the concentration of the barium suspension.

When performing examinations on patients suspected or known to have stomach or intestinal perforation, *water-soluble* iodinated contrast media should be used instead of barium sulfate. If the water-soluble medium leaks through a perforation into the peritoneal cavity, it will simply be absorbed and excreted by the kidneys. Water-soluble contrast media are excreted more rapidly than are barium sulfate preparations.

These studies are far from pleasant for patients and the radiographer should make every effort to fully explain the procedure while endeavoring to expedite the examination and make the patient as comfortable as possible.

With the increased use of digital fluoroscopy, fewer "overhead" radiographs are done today. A summary of the most frequently performed projections follows.

Figure 6–91. AP projection of the abdomen. (Courtesy of Conrad P. Ehrlich, M.D.)

3. Abdomen

ABDOMEN	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Supine, MSP centered to grid, IR centered to iliac crest (see Fig. 6–91)	⊥ to midline at level of crest	AP proj often used as "scout" image preliminary to contrast studies; shows size and shape of kidneys, liver, and spleen, psoas muscles, as well as any calcifications or masses
Erect	AP erect, MSP centered to grid, IR centered ≈2″ above iliac crest	⊥ to mid-IR	AP erect proj used to demonstrate air/fluid levels; both hemidia-phragms should be included (see Fig. 6–92)
lat Decubitus	Patient lat recumbent (AP or PA) MSP ⊥ and centered to upright grid, cassette centered ≈2″ above iliac crest	Horizontal and ⊥ mid-IR	Usually *left* lat decubitus of abdomen to demonstrate air/fluid levels in patients unable to assume the erect position; both hemidiaphragms should be included

Note: A *dorsal decubitus* can also be a valuable supplement to show air/fluid levels. The patient is placed in the dorsal decubitus (supine) position and a horizontal x-ray beam is used.
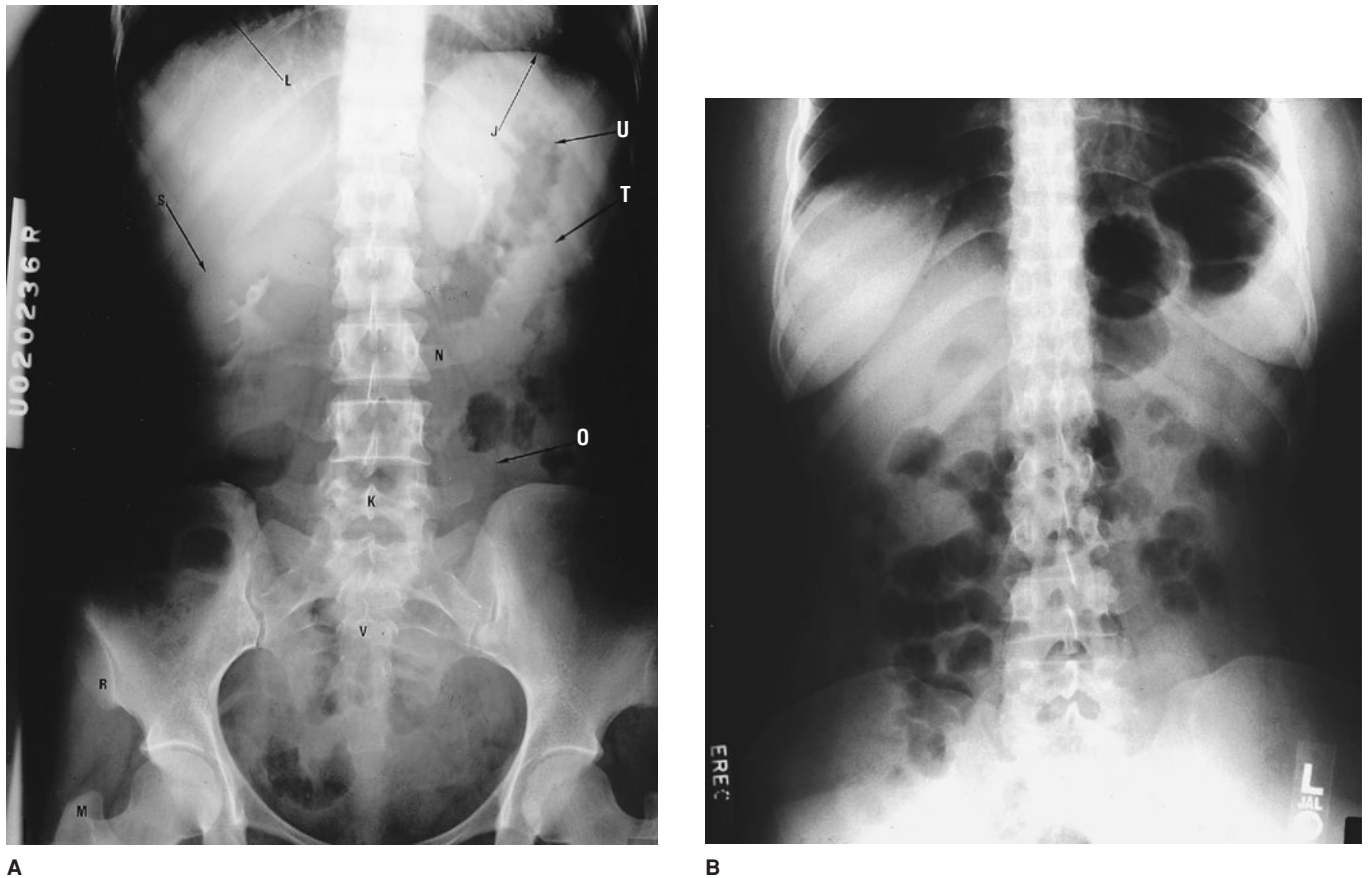
Figure 6–92. Observe the differences between these two x-ray images. **(A)** Part of an intravenous urogram (IVU) examination made in the recumbent position. (Courtesy of Bob Wong, RT.) **(B)** Part of an abdominal survey made in the erect position. Observe the change in appearance and radiographic density, especially of the lower abdomen, as the patient is moved erect and the abdominal viscera assume a lower position; the lower abdomen essentially becomes "thicker" and radiographic density decreases. Each hemidiaphragm must be observed on the erect abdomen. (From the American College of Radiology Learning File. Courtesy of the ACR.)

A *three-way abdomen* study is often performed to evaluate possible obstruction (Fig. 6–93) or free air and fluid within the abdomen and usually consists of AP recumbent, AP erect, and L lateral decubitus projections of the abdomen.

4. Esophagus

ESOPHAGUS	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Supine, MSP centered and ⊥ table, IR top 1″–2″ above shoulders, patient swallowing barium during (<0.1 sec)	⊥ mid-IR, ≈T6–T7	Barium-filled esophagus in AP proj

(continued)

Figure 6–93. Small-bowel obstruction indicated by the dilated bowel loops having a ladder-like pattern. Patient is recumbent; therefore, air/fluid levels are not demonstrated. (Reproduced with permission, from Doherty GM, ed. *Current Surgical Diagnosis & Treatment.* 12th ed. New York, NY: McGraw-Hill, 2006:666.)

ESOPHAGUS *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
RAO	Prone obl, 35°–40° RAO, IR top 1″ to 2″ above shoulders, patient swallowing barium during exposure	⊥ mid-IR, ≈T6–T7	Barium-filled esophagus in RAO proj, demonstrated b/w vertebrae and heart; best single proj of barium-filled esophagus (see Fig. 6–94)
lat (L or R)	Recumbent lat, MCP centered to grid, top of IR just above shoulders, patient swallowing during exposure	⊥ mid-IR	Barium-filled esophagus in lat proj

Note: Esophagus for demonstration of *varices* must be performed in the *recumbent* position; table slightly Trendelenburg and/or performance of the Valsalva maneuver is also helpful. Exposure times of 0.1 second or less should be used to avoid motion; however, respiration normally stops during and shortly after the act of swallowing, so that patients need not be instructed to stop breathing.

5. Stomach and Small Intestine.

Radiologic examination of the stomach and/or small bowel generally begins with fluoroscopic examination. The fluoroscopist observes the swallowing mechanism, mucosal lining (rugae) of the stomach, and the filling and emptying mechanisms of the stomach and proximal small bowel in various positions. The patient is turned and rotated in various positions so that all aspects of the stomach and any abnormalities such as hiatal hernia (see Fig. 6–88C) can be visualized. Double-contrast examinations of the upper GI system are performed frequently. Occasionally, glucagon or another similar drug will be given the patient (IV or IM) prior to the examination to relax the GI tract and permit more complete filling. Various images will be made by the fluoroscopist and the radiographer may take supplemental "overhead" projections. *Small-bowel series* examinations require that successive images be made of the abdomen at specified intervals; an additional fluoroscopic image is made when barium reaches the *ileocecal valve*.

Contrast material (usually water soluble) may occasionally be instilled through a gastrointestinal (GI) tube for visualization of the GI tract. GI tubes can be used therapeutically to siphon gas and fluid from the GI tract or diagnostically, using contrast agent, to locate the site of obstruction or pathology.

STOMACH	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
LPO	Supine, obliqued ≈40° to left, centered mid-way b/w vertebrae and L abdominal wall at level of L1	⊥ mid-IR (at level of L1)	Barium-filled fundus good position for *double contrast* of body, pylorus, and duodenal bulb (see Fig. 6–95)

Note: As the fundus is the most *posterior* portion of stomach, it readily fills w/barium in AP position and moves more superiorly.

STOMACH (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
lat	Recumbent lateral (usually R), center m/w b/w MCP and anterior abdominal wall to IR at level of L2	⊥ mid-IR (at level of L2)	lat stomach and prox small bowel demonstrating anterior and posterior aspects of stomach, retrogastric space, pyloric canal, duodenal loop (see Fig. 6–96)

Note: This projection provides the best visualization of the pyloric canal and duodenal bulb in the hypersthenic patient.

RAO	Recumbent PA obliqued 40°–70°, centered m/w b/w vertebrae and lateral abdominal wall at level of L2	⊥ mid-IR (at level of L2)	Right PA obl proj of stomach barium-filled pyloric canal and duodenal loop; demonstrates stomach's emptying mechanism, because *peristaltic activity is greatest in this position*

(continued)

Figure 6–94. RAO of a barium-filled esophagus. The esophagus has three normal constrictions at the levels of the cricoid cartilage, the left bronchus, and the esophageal hiatus of the diaphragm. (Courtesy of Stamford Hospital, Department of Radiology.)
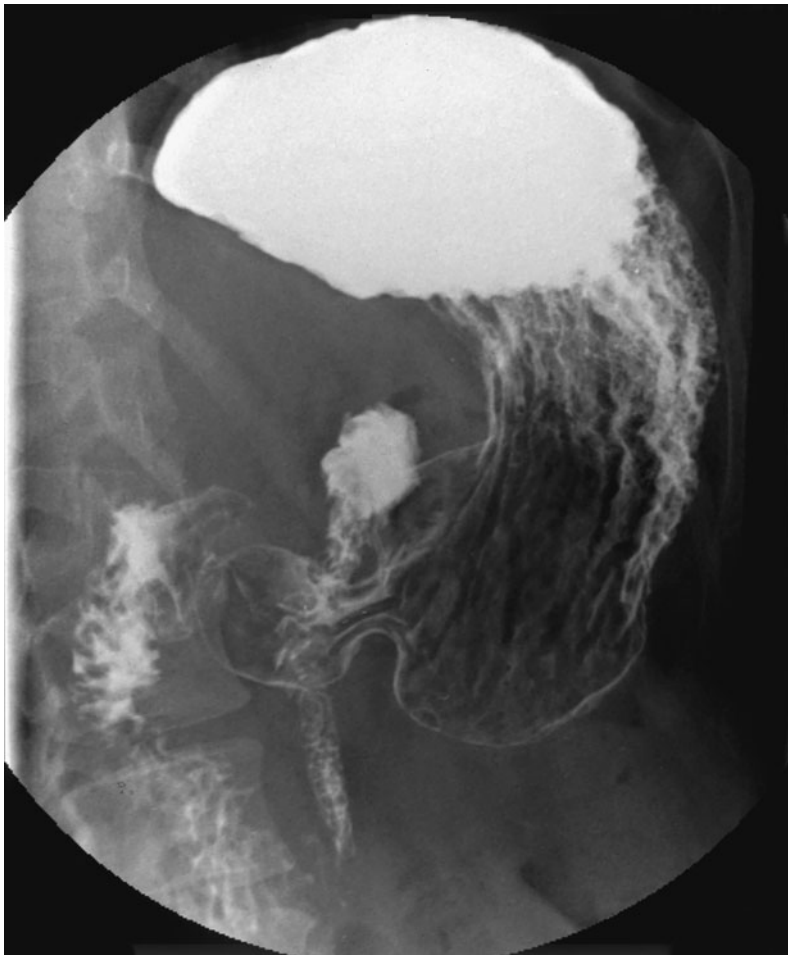
Figure 6–95. LPO of the stomach. In this position, air replaces the barium that drains from the duodenal bulb and pylorus, thus providing double-contrast visualization of these structures. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 6–96. Lateral projection demonstrates the anterior and posterior stomach surfaces and the retrogastric space. (Courtesy of Stamford Hospital, Department of Radiology.)

STOMACH (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
PA	Prone, MSP centered to IR, at level of L2	⊥ mid-IR (at level of L2)	PA proj of transversely spread stomach, demonstrating contours, greater and lesser curvatures (Fig. 6–97) *(continued)*

Figure 6–97. PA projection of the stomach. Note barium in body and pylorus. (Courtesy of Stamford Hospital, Department of Radiology.)

STOMACH *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN

Note: Hypersthenic patients frequently have high, transverse stomachs with indistinguishable curvatures. The adult hypersthenic stomach can be "opened" and its *contours* made readily visible by angling the CR 35° to 45° cephalad. The top edge of a lengthwise 14″ × 17″ IR is placed level with the patient's chin and the CR directed to mid-IR.

STOMACH *(con't)*	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP/PA Small Bowel	Patient supine, MSP centered to grid, IR centered to level of L2	⊥ mid-IR	AP proj of dist esophagus area, stomach, and proximal small bowel; demonstrates hiatal hernias w/patient in Trendelenburg position

Note: This position is used to record progress of the barium column in *small bowel* examinations. The first radiograph is usually made 15 minutes after ingestion of the barium drink and centered at level of L2. Subsequent radiographs are made at 15- to 30-minute intervals (and centered at level of crest), according to the individual patient and how quickly or slowly the barium progresses. Spot images are usually taken when the barium column reaches the ileocecal valve.

Barium sulfate is *contraindicated* if a *perforation* is suspected somewhere along the course of the GI tract (e.g., a perforated diverticulum or gastric ulcer); a water-soluble (absorbable) iodinated contrast medium is generally used instead. A patient with a nasogastric (NG) tube can have the contrast medium administered through it for the purpose of locating and studying any site of obstruction. This procedure is called *enteroclysis*.

6. Large Intestine. The lower GI tract is most often examined by *retrograde* filling with barium sulfate and, frequently, air. The fluoroscopist observes filling of the large bowel in various positions and makes images as indicated. Much of the barium is then drained from the intestine, and air is introduced. The objective is to coat the bowel with barium, then distend its lumen with air. The double-contrast method is ideal for demonstration of intraluminal lesions, such as polyps.

The success of the barium enema examination depends on several factors, but without proper patient preparation a diagnostic examination is often impossible. *Poor preparation resulting in retained fecal material in the colon can mimic or conceal pathologic conditions.*

The barium enema is most easily tolerated and retained by the patient if it is cool or actually cold (≈40–45°F). There is probably no radiographic examination that causes more embarrassment and anxiety than the barium-enema and air-contrast procedure. The radiographer must be sensitive to the concerns and needs of the patient by providing a complete explanation of the procedure and by providing for the patient's modesty as much as possible.

The table below summarizes frequently performed BE projections taken following the fluoroscopic procedure.

Figure 6–98. Double-contrast PA axial projection of the rectum and sigmoid. The caudal tube angulation serves to "open" the redundant S-shaped sigmoid colon. Similar results may be obtained in the AP position with a cephalad tube angle. (Courtesy of Stamford Hospital, Department of Radiology.)

BE	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Supine, MSP centered to IR at level of iliac crest	⊥ mid-IR	AP proj of entire contrast-filled large intestine

Note: The large intestine of hypersthenic patients is high and around the periphery of the abdomen; hence, they may require that the AP and PA be done on (2) 14″ × 17″, IRs placed crosswise in the Bucky tray. In contrast, the colon of the asthenic patient is low, redundant, and more midline.

PA	Prone, MSP centered to IR at level of iliac	⊥ mid-IR	PA proj of entire contrast-filled large intestine; AP or PA erect may be used to demonstrate double-contrast *flexures*
PA Axial	Prone, MSP centered to IR at level of pubic symphysis	35° caudad to midline at level of ASIS	PA axial proj of *sigmoid colon*; angulation opens the length of the S-shaped colon (see Fig. 6–98)

Note: AP axial may be performed to show similar structures; CR is directed 35° cephalad.

RAO	PA, obl ≈40°, centered to midline, cassette centered to level of iliac crest	⊥ mid-IR	Right PA obl proj of the colon, demonstrates *ascending colon and hepatic flexure* (see Fig. 6–99)

(continued)
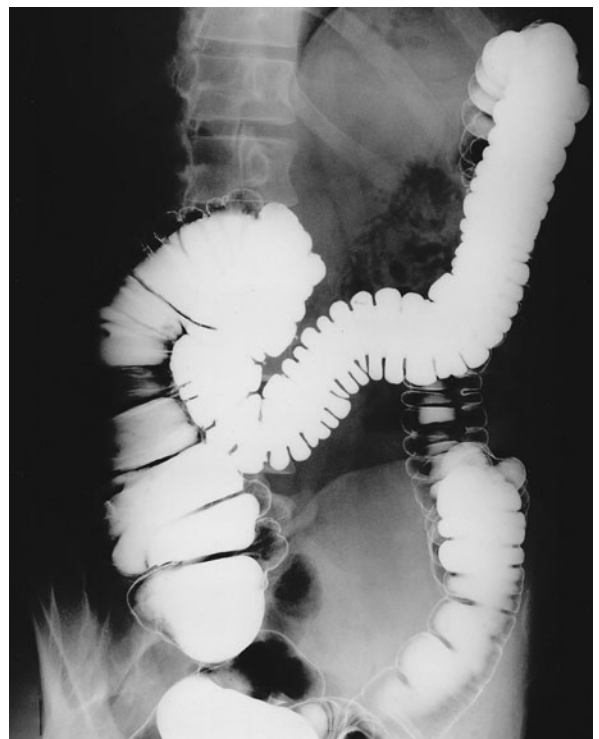
Figure 6–99. RAO of the barium and air-filled large bowel. Note that the hepatic flexure is "opened" for better visualization. An LPO would provide similar results. The opposite obliques (LAO, RPO) are used to demonstrate the splenic flexure and descending colon. (Courtesy of Stamford Hospital, Department of Radiology.)

BE (con't)	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
LAO	PA obl ≈40°, centered to midline, cassette centered to level of iliac crest	⊥ mid-IR	Left PA obl proj of the colon, demonstrates *descending colon and splenic flexure*

Note: *RPO* will demonstrate *descending colon and splenic flexure; LPO* will demonstrate *ascending colon and hepatic flexure.*

Lat	Lat recumbent, MCP centered to grid, IR centered at level of ASIS	⊥ mid-IR	L or R Lat proj, especially for *rectum* and *rectosigmoid* area
Lat Decubitus (R and L)	Lat recumbent, (AP or PA), MSP ⊥ and centered to upright grid at level of iliac crest	Horizontal and ⊥ mid-IR	Air rises to provide double-contrast delineation of lat walls of colon; both decubitus are routinely performed (see Fig. 6–100)

Note: A *postevacuation* PA or AP projection is usually performed to demonstrate large bowel mucosa.

Figure 6–100. Right lateral decubitus view of the air- and barium-filled colon. The heavier barium sulfate moves toward the dependent side, while air rises to fill the remainder of the barium-coated lumen. Thus, the *right lateral decubitus demonstrates double contrast of the "left-sided walls" of the ascending and descending colons* (i.e., lateral side of descending colon and medial side of ascending colon). (Courtesy of Stamford Hospital, Department of Radiology.)

7. Terminology and Pathology. The following is a list of radiographically significant abdominal and digestive conditions and devices with which the student radiographer should be familiar:

Achalasia	Gastroenteritis
Appendicitis	Hiatal hernia (see Fig. 6–101)
Ascites	Ileostomy
Colostomy	Intussusception
Crohn's disease	Irritable-bowel syndrome
Diverticulitis	Peptic ulcer
Diverticulosis	Peritonitis
Dysphagia	Polyp
Enteritis	Pyloric stenosis
Esophageal reflux	Ulcerative colitis
Esophageal varices	Volvulus

Chapter Review Questions

⭐ *Congratulations! You have completed a large portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.*

1. During a gastrointestinal examination, the AP recumbent projection of a stomach of average size and shape will usually demonstrate:
    1. barium-filled fundus
    2. double contrast of distal stomach portions
    3. barium-filled duodenum and pylorus
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

2. During a GI examination, the AP recumbent projection of a stomach of average shape will usually demonstrate:
    1. anterior and posterior aspects of the stomach
    2. barium-filled fundus
    3. double-contrast body and antral portions
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

3. Which of the following projections of the abdomen should be used to demonstrate air or fluid levels when the erect position cannot be obtained?
    1. AP Trendelenburg
    2. dorsal decubitus
    3. lateral decubitus

(A) 1 only

(B) 1 and 2 only

(C) 2 and 3 only

(D) 1, 2, and 3

4. Which of the following best describes the relationship between the esophagus and trachea?

(A) esophagus is posterior to the trachea

(B) trachea is posterior to the esophagus

(C) esophagus is lateral to the trachea

(D) trachea is lateral to the esophagus

5. To demonstrate esophageal varices, the patient must be examined in the:

(A) recumbent position

(B) erect position

(C) anatomic position

(D) Fowler's position

6. The usual preparation for an upper GI series is:

(A) clear fluids 8 hours prior to examination

(B) NPO after midnight

(C) enemas until clear before examination

(D) light breakfast day of the examination

7. Which of the following positions would best demonstrate a double contrast of the hepatic and splenic flexures?

(A) left lateral decubitus

(B) AP recumbent

(C) right lateral decubitus

(D) AP erect

8. In which of the following positions are a barium-filled pyloric canal and duodenal bulb best demonstrated during a GI series?

(A) RAO

(B) left lateral

(C) recumbent PA

(D) recumbent AP

9. What position is frequently used to project the GB away from the vertebrae in the asthenic patient?

(A) RAO

(B) LAO

(C) left lateral decubitus

(D) PA erect

10. Which of the following barium-/air-filled anatomic structures is best demonstrated in the RAO position?

(A) splenic flexure

(B) hepatic flexure

(C) sigmoid colon

(D) ileocecal valve

Answers and Explanations

1. (B) With the body in the anteroposterior (AP) recumbent position, barium flows easily into the fundus of the stomach, displacing it somewhat superiorly. The fundus, then, is filled with barium, while the air that had been in the fundus is displaced into the gastric body, pylorus, and duodenum, illustrating them in double-contrast fashion. Air-contrast delineation of these structures allows us to see through the stomach to retrogastric areas and structures. Barium-filled duodenum and pylorus is best demonstrated in the right anterior oblique (RAO) position.

2. (C) With the body in the AP recumbent position, *barium* flows easily into the *fundus* of the stomach, displacing the stomach somewhat superiorly. The fundus, then, is filled with barium, while the *air* that had been in the fundus is displaced into the *gastric body, pylorus,* and *duodenum,* illustrating them in double-contrast fashion. Air-contrast delineation of these structures allows us to see through the stomach to the retrogastric areas and structures. *Anterior and posterior aspects* of the stomach are visualized in the *lateral* position; medial and lateral aspects of the stomach are visualized in the AP projection.

3. (C) Air or fluid levels will be clearly demonstrated only if the central ray is directed parallel to them. Therefore, to demonstrate air or fluid levels, erect or decubitus positions should be used. A "three-way abdomen" study is often performed to evaluate possible obstruction or free air or fluid within the abdomen and usually consists of anteroposterior (AP) recumbent, AP erect, and left lateral decubitus projections of the abdomen.

4. (A) The trachea (windpipe) is a tube-like passageway for air that is supported by C-shaped cartilaginous rings. The trachea is part of the respiratory system and is continuous with the main stem bronchi. The esophagus, part of the alimentary canal, is a hollow tube-like structure connecting the mouth and stomach, and lies posterior to the trachea. If one inadvertently aspirates food or drink into the trachea, choking occurs.

5. (A) Esophageal varices are tortuous dilatations of the esophageal veins. They are much less pronounced in the erect position and must always be examined with the patient recumbent. The recumbent position affords more complete filling of the veins, as blood flows against gravity.

6. (B) The upper gastrointestinal (GI) tract must be empty for best x-ray evaluation. Any food or liquid mixed with the barium sulfate suspension can simulate pathology. Preparation therefore is to withhold food and fluids for 8 to 9 hours before the examination, typically after midnight, as fasting examinations are usually performed first thing in the morning.

7. (D) To demonstrate structures via double contrast, the barium must be moved away from the area and replaced with air. The *anteroposterior (AP) erect position* will accomplish that for both the colic flexures. The erect position allows barium to move downward, while air rises to fill the flexures. The decubitus positions are useful to demonstrate the lateral and medial walls of the ascending and descending colon.

8. (A) The right anterior oblique (RAO) position affords a good view of the pyloric canal and duodenal bulb. It is also a good position for the barium-filled esophagus, projecting it between the vertebrae and heart. The left lateral projection of the stomach demonstrates the

left retrogastric space; the recumbent posteroanterior (PA) is used as a general survey of the gastric surfaces, and the recumbent anteroposterior (AP) with a slight left oblique affords a double contrast of the pylorus and duodenum.

9. (B) There are four types of body habitus. Listed from largest to smallest, they are hypersthenic, sthenic, hyposthenic, and asthenic. The position, shape, and motility of various organs can differ greatly from one body type to another. The typical asthenic gallbladder (GB) is situated low and medial, often very close to the midline. To move the GB away from the midline, left anterior oblique (LAO) position is used. The GB of hypersthenic individuals occupies a high lateral, and transverse position.

10. (B) In the prone oblique positions (right/left anterior oblique [RAO/LAO]) the flexure disclosed is the one closer to the IR. Therefore, the RAO position will open up the hepatic flexure. The anteroposterior (AP) oblique positions (right/left posterior oblique [RPO/LPO]) demonstrate the side away from the IR.

D. Urinary System

1. Introduction. Two of the functions of the urinary system (Fig. 6–101) are to *remove wastes from the blood* and *eliminate it in the form of urine*. The tiny units within the renal substance that perform these functions are called *nephrons*. The major components of the urinary system are the *kidneys*, *ureters*, and *bladder*.

The paired *kidneys* are *retroperitoneal* and embedded in adipose tissue between the vertebral levels of T12 and L3. The right kidney is usually 1 to 2 inches lower than the left because of the presence of the liver on the right. The kidneys move inferiorly 1 to 3 inches when the body assumes an erect position; they move inferiorly and superiorly during respiration. The slit-like opening on the medial renal surface of each kidney is the *hilum*, which opens into a space called the *renal sinus* (Fig. 6–102). The renal artery and vein pass through the hilum. The upper, expanded portion of the ureter is called the *renal pelvis*,
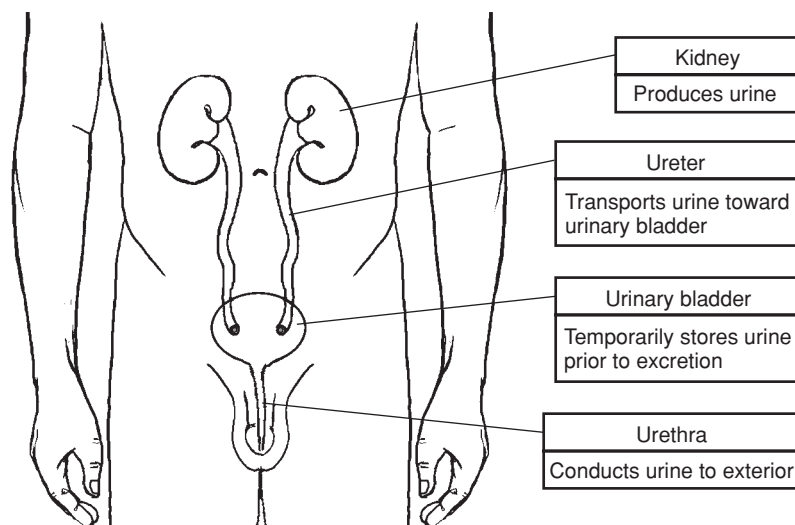
Figure 6–101. Components of the urinary system.
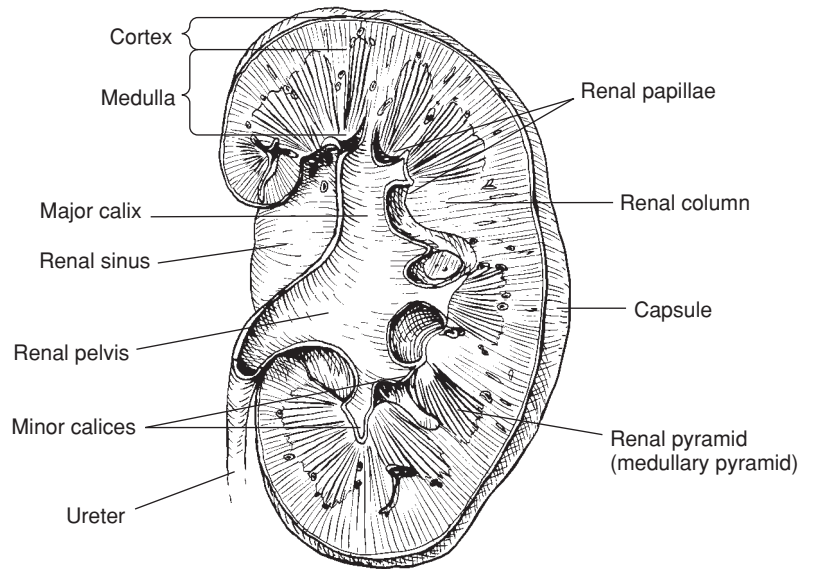
Figure 6–102. Section through the left renal pelvis.

or *infundibulum*, and also passes through the hilum; it is continuous with the major and minor calyces within the kidney.

Within each kidney, the renal *parenchyma* is divided into two parts: the outer *cortex* and inner *medulla*. The cortex is compact and has a grainy appearance as a result of the many *glomeruli* within its tissues. The medulla contains 10 to 14 *renal pyramids* with a characteristic striated appearance that is due to the *collecting tubules* within (see Fig. 6–102).

The proximal portion of each *ureter* is at the renal pelvis. As the ureter passes inferiorly, three normal constrictions can be observed: at the ureteropelvic junction, at the pelvic brim, and at the ureterovesicular junction. The ureters lie in a plane anterior to the kidneys, ureteral filling with contrast media is best achieved using the PA projection. Urine is carried through the ureters by peristaltic activity. If a ureter is obstructed by a kidney stone, *hydronephrosis* occurs. The ureters enter the *urinary bladder* posteroinferiorly (Fig. 6–103). The base of the
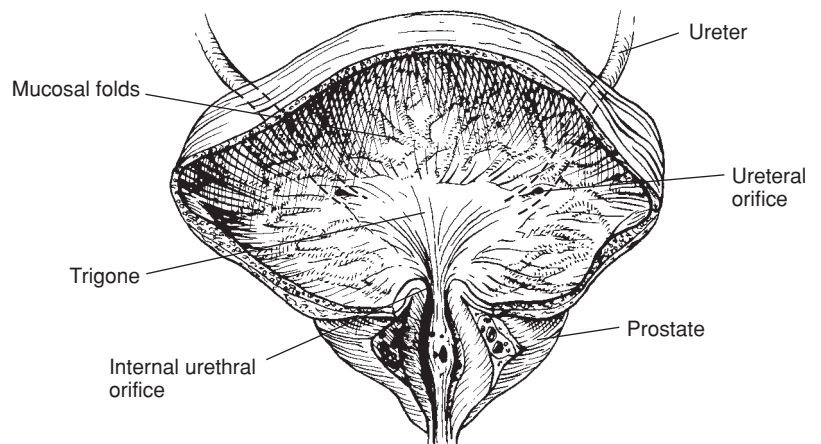
Figure 6–103. Bladder trigone (anterior portion of bladder removed).

bladder rests on the pelvic floor. The triangular-shaped area formed by the *ureteral* and *urethral orifices* is called the *trigone*. Micturition is the process of emptying the urinary bladder of its contents through the *urethra*. The male urethra is about 7 to 8 inches long and is divided into prostatic, membranous, and penile portions. The female urethra is about 1.5 inches in length.

A common complication of regional enteritis or diverticular disease is the formation of a *fistula* between the urinary bladder and small or large intestine. Fistulous tracts may often be evaluated radiographically with contrast media.

Routine radiographic procedures of the urinary system are generally performed via the IV route. When performed in the retrograde manner, *cystoscopy* is required.

Though the numbers of urinary system x-ray examinations have been steadily decreasing, and are infrequently performed in many institutions today, a review of these examinations follows.

2. Patient Preparation and Procedure.
Investigation of the urinary tract requires patient preparation sufficient to rid the intestinal tract of gas and fecal material. Typical preparation usually begins the evening before the examination with a light dinner, a gentle laxative, and nothing to eat or drink (NPO; non per os [nothing by mouth]) after midnight. Immediately before beginning the IVU, the patient must be instructed to empty his or her bladder; this prevents dilution of opacified urine in the bladder. If the patient has a urinary catheter, it is generally clamped just before the injection and unclamped before the postvoid image. The IVU is preceded by a preliminary scout image of the abdomen to evaluate patient preparation and reveal any calcifications (renal or gallstones), position of kidneys, and accuracy of technical factor selection (Fig. 6–104).

Because the urinary structures have so little subject contrast, artificial contrast material must be employed for better visualization of these structures. Contrast agents used for urographic procedures can have unpleasant and (rarely) even lethal, side effects. Intravenous injection of contrast frequently produces a warm, flushed feeling, a bitter or metallic taste, or mild nausea. These side effects are of short duration and usually pass as quickly as they come. More serious side effects include *urticaria*, respiratory discomfort and distress, and, rarely, *anaphylaxis*. An *antihistamine* is appropriate treatment for simple side effects, but the radiographer must always be prepared to deal quickly and efficiently with patients experiencing more serious reactions. *Nonionic* contrast agents are far less likely to produce side effects. Contrast agents and their side effects are more thoroughly discussed in Chapter 1.

The selected contrast agent is injected intravenously and successive radiographs are made at specified intervals. A time-interval marker must be included on each image to indicate the elapsed postinjection time. Injection and postinjection protocol varies with the institution, radiologist, patient condition, and diagnosis. The contrast may be rapidly injected in a *bolus* to obtain a 30-second *nephrogram*.

Compression over the distal ureters (delaying contrast or urine travel to bladder) may be required to more completely fill the kidneys with contrast medium or to visualize the contrast-filled kidneys for a longer period of time (Fig. 6–105). Maximum concentration of the

Figure 6–104. A preliminary or "scout" image of the abdomen is taken before the start of an IVU. The radiograph is checked for residual barium from previous contrast studies, patient preparation (including barium from previous studies; note residual barium in patient's appendix), location of kidneys, technical factors, and any calcifications. (Courtesy of Stamford Hospital, Department of Radiology.)
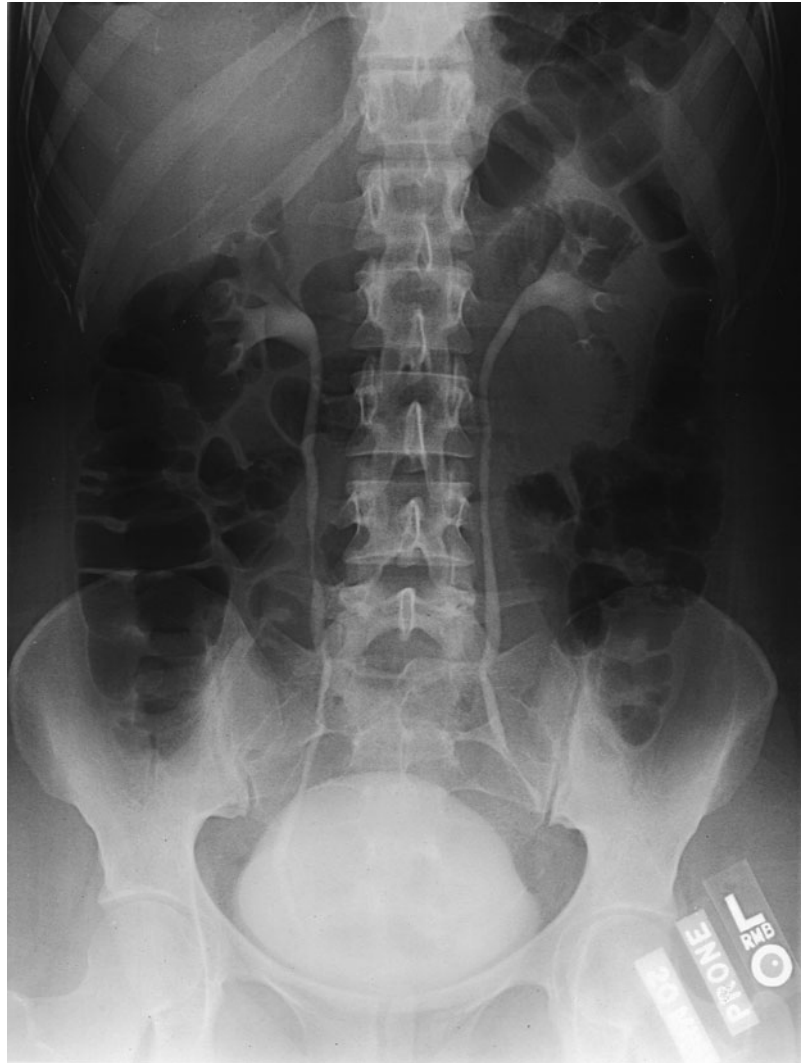
Figure 6–105. PA projection of IVU, demonstrating contrast-filled ureters. Since the ureters lie in a plane that is anterior to that of the kidneys, they are best demonstrated as contrast-filled structures in the *PA position.* The contrast material, which is heavier than urine, gravitates to fill the anterior ureters. (Courtesy of Stamford Hospital, Department of Radiology.)

contrast material usually occurs at 15 to 20 minutes after injection, but varies with degree of patient hydration.

Radiographs collimated to the kidneys (11 × 14 inches crosswise) may be required at 1, 3, and 5 minutes to evaluate a diagnosis of renal hypertension. Both obliques and tomograms may be required to evaluate a suspected tumor or lesion. AP and oblique kidney, ureter, and bladder images (KUBs) are usually required at 10 to 15 minutes after injection. A prone KUB is frequently requested at 20 minutes. Because the ureters lie in a plane anterior to the kidneys, *ureteral filling* with contrast media is best achieved using the PA projection (see Fig. 6–107).

3. Types of Examinations. Routine IV procedures are most correctly referred to as *intravenous urography* (IVU), or *excretory urography,* although they are still commonly referred to as intravenous *pyelography* (IVP) (*pyel* refers only to renal *pelvis*). Intravenous procedures demonstrate *function* of the urinary system. Retrograde studies demonstrate

Figure 6–106. When positioning the abdomen, it is important to position the patient's hands at his or her side or resting high on the chest. Note the position of the patient's right hand in this retrograde urogram. (From the American College of Radiology Learning File. Courtesy of the ACR.)

only the *structure* of the part and are generally performed to evaluate the lower urinary tract (lower ureters, bladder, and urethra).

Retrograde urograms (Fig. 6–106) require catheterization of the ureter(s). Radiographs that include the kidney(s) and ureter(s) in their entirety are made after retrograde filling of the structures. A cystogram or (voiding) *cystourethrogram* requires urethral catheterization only. Radiographs are made of the contrast-filled bladder and frequently of the contrast-filled urethra during voiding. *Cystoscopy* is required for location and catheterization of the vesicoureteral orifices.

Excretory and retrograde urography involve accurate positioning of the abdomen to include the kidneys, ureters, and bladder. If these structures cannot fit on a single image, a second radiograph is generally taken for the bladder. The following is a review of abdomen KUB positioning and an overview of bladder positioning.

4. KUB (Kidneys, Ureters, and Bladder)

KUB	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
	Patient supine, MSP ⊥ centered to grid, IR centered to iliac crest	⊥ to midline at level of crest	AP proj of abdomen shows size and shape of kidneys, liver, spleen, psoas muscles, and any calcifications or masses

Note: AP abdomen should include from top of kidneys through symphysis pubis (see Fig. 6–107); *obliques* are performed at 30°.
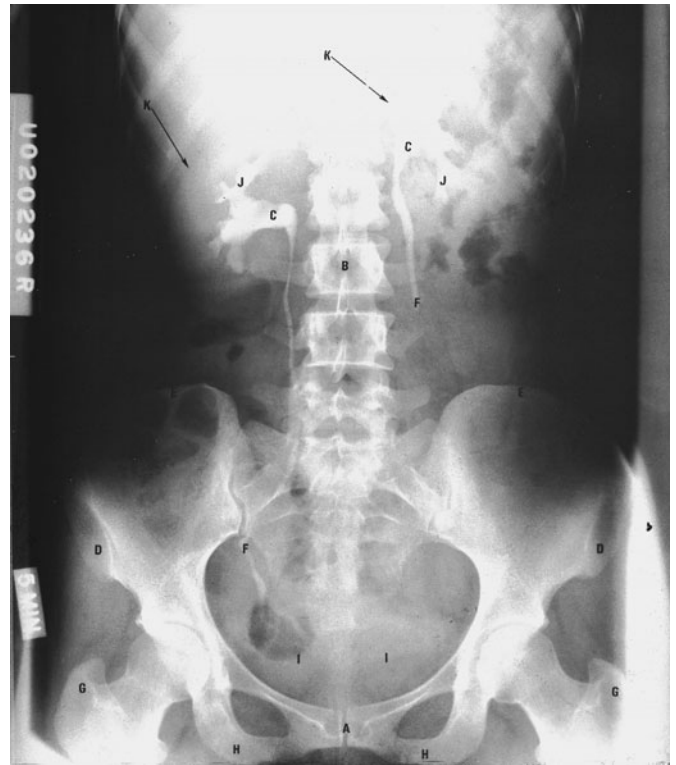
Figure 6–107. This KUB is a 5-minute IVU image. Good collimation is evident and the kidneys, ureters, and bladder are included in their entirety. *Review the contents of the abdominal cavity* by correcting identifying each of the lettered structures. (Courtesy of Bob Wong, RT.)

The PA projection will best demonstrate *contrast-filled ureters* (Fig. 6–106).

The 30° oblique KUB places the kidney of the *up* side *parallel* to the image receptor; the ureter of the side *down* parallel to the image receptor. Figure 6–108 is an RPO that places the left kidney and right ureter parallel to the image receptor.

5. Bladder

BLADDER	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
AP	Patient supine, MSP ⊥ centered to grid, lower edge of IR just below pubic symphysis	⊥ to center of IR	AP proj shows contrast-filled or postvoid bladder
AP (Voiding Studies)	Patient supine, MSP ⊥ centered to grid, IR centered to pubic symphysis	⊥ to midline at level of pubic symphysis	AP projection of bladder and proximal urethra; used for voiding cystourethrograms (see Fig. 6–109); a 5°∠caudad can be used for the female to place bladder neck and urethra below pubis

Note: *Oblique* projections are obtained at 40°–60° for the female and at 30° for the male.

Figure 6–108. Fifteen-minute RPO during IVU, demonstrating the left kidney and right ureter parallel to the image receptor. The 30° oblique KUB places the *kidney* of the *up* side *parallel* to the image receptor, and the *ureter* of the side *down* parallel to the image receptor. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 6–109. Voiding cystourethogram. (From the American College of Radiology Learning File. Courtesy of the ACR.)

A

B

Figure 6–110. Although radiograph **(A)** may appear to be part of an IVU examination, no contrast agent is associated with the opaque right kidney; the opaque area is due to formation of a *staghorn calculus.* Radiograph **(B)** is a 1-hour IVU demonstrating both collecting systems. Staghorn calculi are usually associated with chronic infection and alkaline urine. They may be associated with a single calyx or an entire renal pelvis, and may be unilateral or bilateral. Whenever possible, staghorn (named for their shape, resembling a stag's antlers) calculi are removed because they can cause partial obstruction of the calyces and/or ureteropelvic junction. (From the American College of Radiology Learning File. Courtesy of the ACR.)

6. Terminology and Pathology. The following is a list of radiographically significant urinary conditions and devices with which the student radiographer should be familiar:

Cystitis	Polycystic kidney
Double-collecting system	Prostatic hypertrophy
Double ureter	Pyelonephritis
Fistula	Renal calculi
Foley catheter	Renal hypotension
Horseshoe kidney	Staghorn calculus (see
Hydronephrosis	Fig. 6–110)
Hydroureter	Supernumerary kidney
Incontinence	Uremia
Nephroptosis	Ureteral stent
Nephrostomy tube	Ureterocele
Pelvic kidney	Vesicoureteral reflux
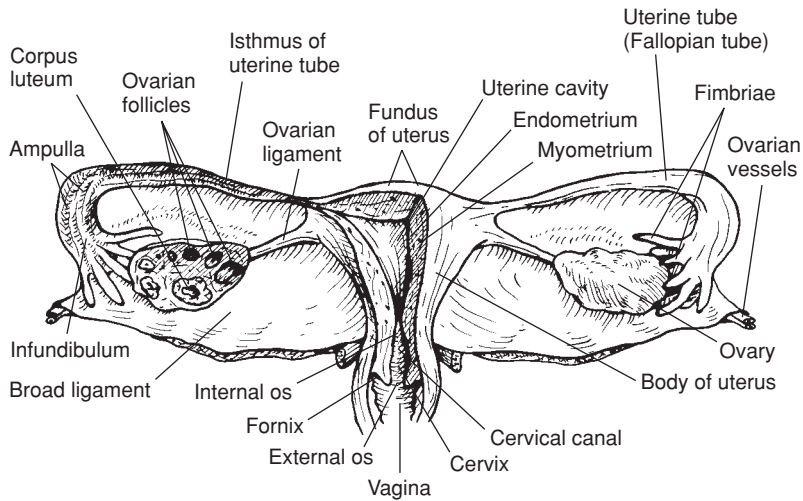
Figure 6–111. Uterus, uterine tubes (oviducts), and ovaries.

E. FEMALE REPRODUCTIVE SYSTEM

1. Introduction. The female reproductive system consists of the ovaries, oviducts, and uterus. The broad, suspensory, round, and ovarian ligaments are all associated with support of the reproductive organs.

The *ovaries* are the female gonads that function to release ova (female reproductive cells) during ovulation and produce various female hormones including estrogen and progesterone. The *oviducts*, or Fallopian tubes, are 3 to 5 inches long, arise from the uterine cornua (angles), and extend laterally to arch over each ovary. The oviduct lateral extremities are broader than their medial ends and are bordered by motile *fimbriae* (see Figs. 6–111 and 6–112A and B). The

A

B

Figure 6–112. (**A**) AP projection of hysterosalpingogram study. Contrast-filled uterus and oviducts are shown. (Courtesy of Stamford Hospital, Department of Radiology.) (**B**) Large mass distorting uterus.

fimbriae sweep over the ovary and function to collect the liberated ovum. *Fertilization* of the ovum usually occurs in the outer portion of the oviducts. Ova are propelled through the oviduct by peristaltic motion. *Salpingitis* is possibly the most common cause of female sterility; if fertilization does occur, the zygote is unable to traverse the oviduct due to its scarred or narrowed condition. Occasionally, a fertilized ovum will become implanted in the oviduct, a condition known as ectopic, or tubal, pregnancy. This condition is a gynecologic emergency because, if left untreated, the patient can die from internal hemorrhage.

The most superior, arched, portion of the *uterus* is the fundus. The angle on each side is the cornu and marks the point of entry of the oviducts. The *body* is the large central region and the narrow inferior portion is the *cervix.*

2. Hysterosalpingogram. The most commonly performed radiologic examination of the reproductive system is hysterosalpingography, which is employed for evaluation of the uterus, oviducts, and ovaries of the female reproductive system. The procedure serves to delineate the position, size, and shape of the structures, and demonstrates pathology such as *polyps, tumors*, and *fistulas*. However, it is most often used to demonstrate *patency* of the oviducts in cases of *infertility*, and is sometimes therapeutic in terms of opening a blocked oviduct.

Hysterosalpingograms should be *scheduled* about 10 days after the start of menstruation. This is the time just *before* ovulation, when there should be little chance of irradiating a newly fertilized ovum.

After the cervical canal is cannulated, an iodinated contrast agent is injected via the cannula into the uterine cavity. If the oviducts are patent, contrast will flow through them and into the peritoneal cavity. Fluoroscopy is performed during injection and spot images are taken. Overhead radiographs may be performed following the fluoroscopic procedure.

AP	POSITION OF PART	CENTRAL RAY DIRECTED	STRUCTURES INCLUDED/ BEST SEEN
	Patient supine, MSP centered to grid, and a point 2″ above the pubic symphysis centered to the IR	⊥ mid-IR	AP proj of uterus and oviducts; 30° obliques may be taken as required (see Fig. 6–112A and B)

3. Terminology and Pathology. The following is a list of radiographically significant reproductive conditions with which the student radiographer should be familiar:

Bicornuate uterus	Leiomyoma
Ectopic pregnancy	Pelvic inflammatory disease
Endometriosis	Placenta previa
Infertility	Salpingitis

Chapter Review Questions

Congratulations! You have completed your review of a large portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.

1. In what order should the following radiographs be performed?
   1. barium enema
   2. intravenous pyelogram
   3. upper GI
   (A) 3, 1, 2
   (B) 1, 3, 2
   (C) 2, 1, 3
   (D) 2, 3, 1

2. Which of the following will best demonstrate the size and shape of the liver and kidneys?
   (A) lateral abdomen
   (B) AP abdomen
   (C) dorsal decubitus abdomen
   (D) ventral decubitus abdomen

3. Which of the following examinations require(s) restriction of the patient's diet?
   1. GI series
   2. abdominal survey
   3. pyelogram
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

4. During IV urography, the prone position is generally recommended to demonstrate:
   1. filling of obstructed ureters
   2. the renal pelvis
   3. the superior calyces
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

5. Which of the following examinations require(s) catheterization of the ureters?
   1. retrograde urogram
   2. cystogram
   3. voiding cystogram
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

6. Some common mild side effects of intravenous administration of water-soluble iodinated contrast agents include:
   1. flushed feeling
   2. bitter taste
   3. urticaria
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

7. Hysterosalpingograms may be performed for the following reason(s):
   1. demonstration of fistulous tracts
   2. investigation of infertility
   3. demonstration of tubal patency
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

8. A postvoid image of the urinary bladder is usually requested at the completion of an IVP/IVU and may be helpful in demonstrating:
   1. residual urine
   2. prostate enlargement
   3. ureteral tortuosity
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

9. During routine intravenous urography, the oblique position demonstrates the:
   (A) kidney of the side up parallel to the IR
   (B) kidney of the side up perpendicular to the IR
   (C) urinary bladder parallel to the IR
   (D) urinary bladder perpendicular to the IR

10. To better demonstrate contrast-filled distal ureters during intravenous urography, it is helpful to:
    1. use a 15° AP Trendelenburg position
    2. apply compression to the proximal ureters
    3. apply compression to the distal ureters
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 1 and 3 only

Answers and Explanations

1. (C) When scheduling patient examinations, it is important to avoid the possibility of residual contrast medium covering areas of interest on later examinations. The intravenous

pyelogram (IVP) should be scheduled first because the contrast medium used is excreted rapidly. The barium enema (BE) should be scheduled next. The gastrointestinal (GI) series is scheduled last. Any barium remaining from the previous BE should not be enough to interfere with the stomach or duodenum, although a preliminary scout image should be taken in each case.

2. (B) The anteroposterior (AP) projection provides a survey of the abdomen, showing the size and shape of the liver, spleen, and kidneys. When performed erect, it should demonstrate both hemidiaphragms. The lateral projection is sometimes requested and is useful for evaluating the prevertebral space occupied by the aorta. Ventral and dorsal decubitus positions provide a lateral view of the abdomen useful for demonstration of air–fluid levels.

3. (C) A patient having a gastrointestinal (GI) series is required to be NPO (nothing by mouth) for at least 8 hours prior to the examination; food or drink in the stomach can simulate disease. A patient scheduled for a pyelogram must have the preceding meal withheld so as to avoid the possibility of aspirating vomitus in case of allergic reaction. An abdominal survey does not require the use of contrast medium and no patient preparation is required.

4. (B) The kidneys lie obliquely in the posterior portion of the trunk, with their superior portions angled posteriorly and their inferior portions and ureters angled anteriorly. Therefore, to facilitate filling of the most anteriorly placed structures, the patient is examined in the prone position. Opacified urine then flows to the most dependent part of the kidney and ureter—the ureteropelvic region, inferior calyces, and ureters.

5. (A) Retrograde urograms require catheterization of the urethra and/or ureter(s). Radiographs that include the kidney(s) and ureter(s) in their entirety are made after retrograde filling of the structures. A cystogram or (voiding) cystourethrogram requires *urethral* catheterization only. Radiographs are made of the contrast-filled bladder and frequently of the contrast-filled urethra during voiding. Cystoscopy is required for location and catheterization of the vesicoureteral orifices.

6. (B) Because the urinary structures have so little subject contrast, artificial contrast material must be employed for better visualization of these structures. Contrast agents used for urographic procedures can have unpleasant, and (rarely) even lethal, side effects. Intravenous injection of contrast frequently produces a warm, flushed feeling, a bitter or metallic taste, or mild nausea. These side effects are of short duration and usually pass as quickly as they come. More serious side effects include urticaria, respiratory discomfort/distress, and, rarely, anaphylaxis. An antihistamine is appropriate treatment for simple side effects, but the radiographer must always be prepared to deal quickly and efficiently with patients experiencing more serious reactions. Nonionic contrast agents are far less likely to produce side effects.

7. (D) The most commonly performed radiologic examination of the reproductive system is hysterosalpingography, which is employed for evaluation of the uterus, oviducts, and ovaries of the female reproductive system. The procedure serves to delineate the position, size, and shape of the structures, and demonstrate pathology such as polyps, tumors, and fistulas. However, it is most often used to demonstrate *patency* of the oviducts in cases of *infertility* and is sometimes therapeutic in terms of opening a blocked oviduct.

8. (B) An anteroposterior (AP) postvoid bladder image is usually required to detect any *residual urine* in the evaluation of *tumor masses* or *enlarged prostate glands.* An erect image is occasionally requested to demonstrate renal mobility and ureteral tortuosity.

9. (A) During intravenous urography, both oblique positions are generally obtained. The 30° oblique KUB (kidney, ureters, bladder) places the kidney of the side *away* from the x-ray table *parallel* to the IR. The kidney closer to the x-ray table is placed perpendicular to the IR. The oblique positions provide an oblique projection of the urinary bladder.

10. (A) A 15° to 20° anteroposterior (AP) Trendelenburg position during intravenous (IV) urography is often helpful in demonstrating filling of the distal ureters and the area of the vesicoureteral orifices. In this position, the contrast-filled urinary bladder moves superiorly, encouraging filling of the distal ureters and superior bladder, and provides better delineation of these areas. The central ray should be directed perpendicular to the IR. Compression of the *distal* ureters is used to prolong filling of the renal pelvis and calyces. Compression of the *proximal* ureters is not advocated.
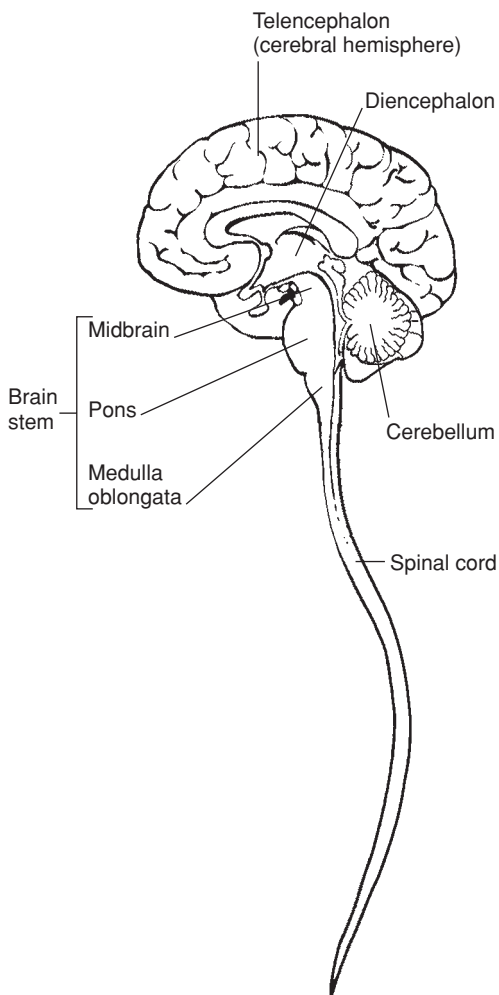
Figure 6–113. The CNS: brain and spinal cord.

F. CENTRAL NERVOUS SYSTEM

1. Introduction. The central nervous system (CNS) is composed of the *brain* and *spinal cord* (Fig. 6–113), enclosed within the bony skull and vertebral column. The brain consists of the cerebrum (largest part), *cerebellum, pons varolii*, and *medulla oblongata.* The *gray matter* of the brain consists of neuron cell bodies; the *white matter* consists of tracts (pathways) of axons. In transverse section, the spinal cord is seen to have an H-shaped configuration of gray matter internally, surrounded by white matter (Fig. 6–114). The brain and spinal cord work together in the perception of sensory stimuli, in integration and correlation of stimuli with memory, and in neural actions resulting in coordinated motor responses to stimuli.

The CNS is enclosed within three tissue membranes, the *meninges.* The *pia mater* is the innermost, vascular membrane, which is closely attached to the brain and spinal cord. The *arachnoid mater* is a thin layer outside the pia mater and attached to it by web-like fibers. The *subarachnoid space* is between the pia and arachnoid mater and is filled with cerebrospinal fluid (CSF). The brain and spinal cord float in CSF, which acts as a shock absorber.

Cerebral artery hemorrhage will leak blood into the CSF. *Lumbar puncture* is performed (between L3 and L4 or L4 and L5) to remove small quantities of CSF for testing and to introduce contrast medium during myelography. The *dura mater* is a double-layered fibrous membrane outside the arachnoid mater. The *subdural space* is located between the arachnoid and dura mater; it does not contain CSF. The *epidural space* is located between the two layers of dura mater.

The cylindrical spinal cord is a continuation of the medulla oblongata, extending through the foramen magnum and spinal canal to its termination at the *conus medullaris* (about the level of L1). The lumbar and sacral nerves have long roots that extend from the spinal cord as the *cauda equina* (horse's tail).

2. Procedures. Routine radiographic examination of the bony components of the CNS includes studies of the skull and vertebral column and, occasionally, tomography of these structures. Computerized tomography (CT) and magnetic resonance imaging (MRI) procedures have replaced many plain radiographic procedures in the diagnosis and management of traumatic injuries and pathologic processes of the brain and spinal cord.

3. Myelogram. Nevertheless, *myelography* remains a valuable diagnostic tool to demonstrate the site and extent of *spinal cord tumors* and *herniated intervertebral discs.* The intervertebral disc can ruputure due to trauma or degeneration. The *nucleus pulposus* protrudes posteriorly through a tear in the *annulus fibrosus* and impinges on nerve roots (Fig. 6–115). More than 90% of disc ruptures occur at the L4–L5 and L5–S1 interspaces. Narrowing of the affected disc space may often be detected radiographically and the defects caused by the rupture can generally be demonstrated through myelography, CT, or MRI.

Water-soluble nonionic iodinated contrast agents are the most widely used contrast media for myelography. Advantages of water-soluble contrast agents (over non–water-soluble) include better visualization of the nerve roots (see Fig. 6–116) and absorption properties that allow it to be left in the subarachnoid space after the examination (because it is easily absorbed by the body). However, the use of water-soluble contrast agents for myelography does require that radiographs be made accurately and without delay, because it is absorbed fairly quickly.

Foot and shoulder supports must be securely attached to the x-ray table. The patient should receive a complete explanation of the examination and must be instructed about the importance of keeping his or her chin extended when the table is lowered into the Trendelenburg position.

A lumbar puncture is performed (usually at the fourth intervertebral space with the patient in the prone or flexed lateral position), a small quantity of CSF is removed from the subarachnoid space and sent to the laboratory for testing, and an equal amount of contrast agent is injected intrathecally (i.e., into the subarachnoid space of the spinal canal). The position of the contrast column will change according to gravitational forces, and its movement is observed fluoroscopically as the x-ray table is angled to varying degrees of Trendelenburg position and Fowler's position. Fluoroscopic spot images are taken as needed, followed by overhead radiographs. Routine protocol generally includes an AP or PA and a horizontal beam (cross-table) lateral view of the vertebral area examined.

4. Terminology and Pathology. The following is a list of radiographically significant CNS conditions with which the student radiographer should be familiar:

Degenerative disc disease	Parkinson's disease
Herniated nucleus pulposus	Meningitis
Hydrocephalus	Meningomyelocele
Meningioma	Spondylosis
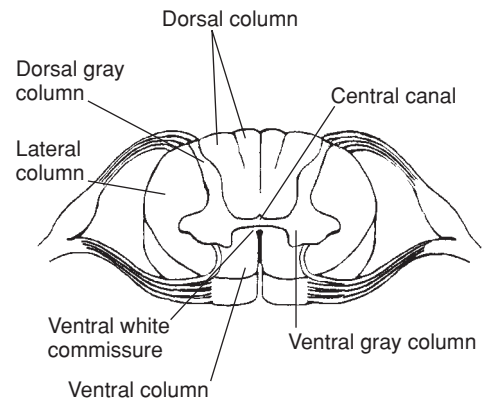
Figure 6–114. Cross section of the spinal cord.
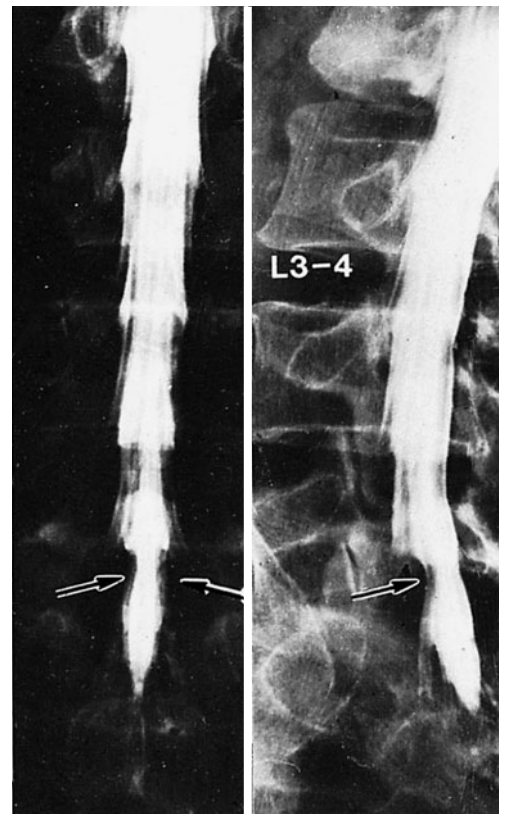
Figure 6–115. Myelograms demonstrating herniated L4–L5 disc. (Reproduced, with permission, from deGroot J. *Correlative Neuroanatomy*, 21st ed. East Norwalk, CT: Appleton & Lange, 1991.)

A   **B**
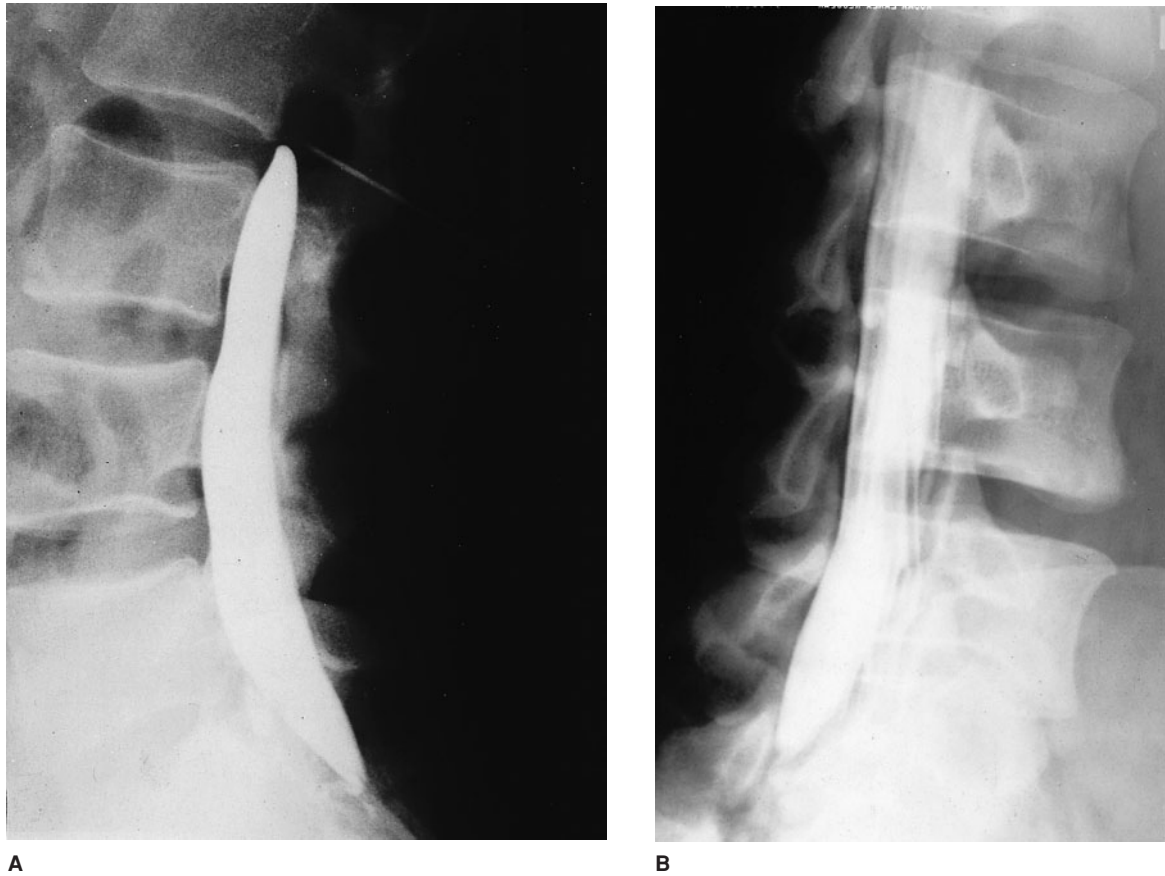
Figure 6–116. **(A)** Non–water-soluble contrast (Pantopaque) myelography. (Courtesy of Stamford Hospital, Department of Radiology.) **(B)** Water-soluble contrast myelography; observe improved visualization of nerve roots seen at the level of each pedicle as linear radiolucencies within the small inferolateral extensions of the contrast agent. (From the American College of Radiology Learning File. Courtesy of the ACR.)

G. Circulatory System

1. Introduction. The circulatory system consists of the *heart* and vessels (arteries, capillaries, veins) that distribute blood throughout the body (see Fig. 6–117). The heart is the muscular pump, the *arteries* conduct oxygenated blood throughout the body; the *capillaries* are responsible for diffusion of gases and exchange of nutrients and wastes; and the *veins* collect deoxygenated blood and return it to the heart and lungs.

Contraction of the heart muscle as it pumps blood is called *systole*; relaxation is called *diastole*; these values are measured with a *sphygmomanometer*. Accompanying the contraction and expansion of the heart is contraction and expansion of arterial walls, called *pulse*.

The heart wall is made up of the external *epicardium*, the middle *myocardium*, and the internal *endocardium*. The *pericardium* is the fibroserous sac enclosing the heart and roots of the great vessels. The heart has four chambers. The two upper chambers are the *atria* and the two lower chambers are the *ventricles*. The apex of the heart is the tip of the left ventricle.
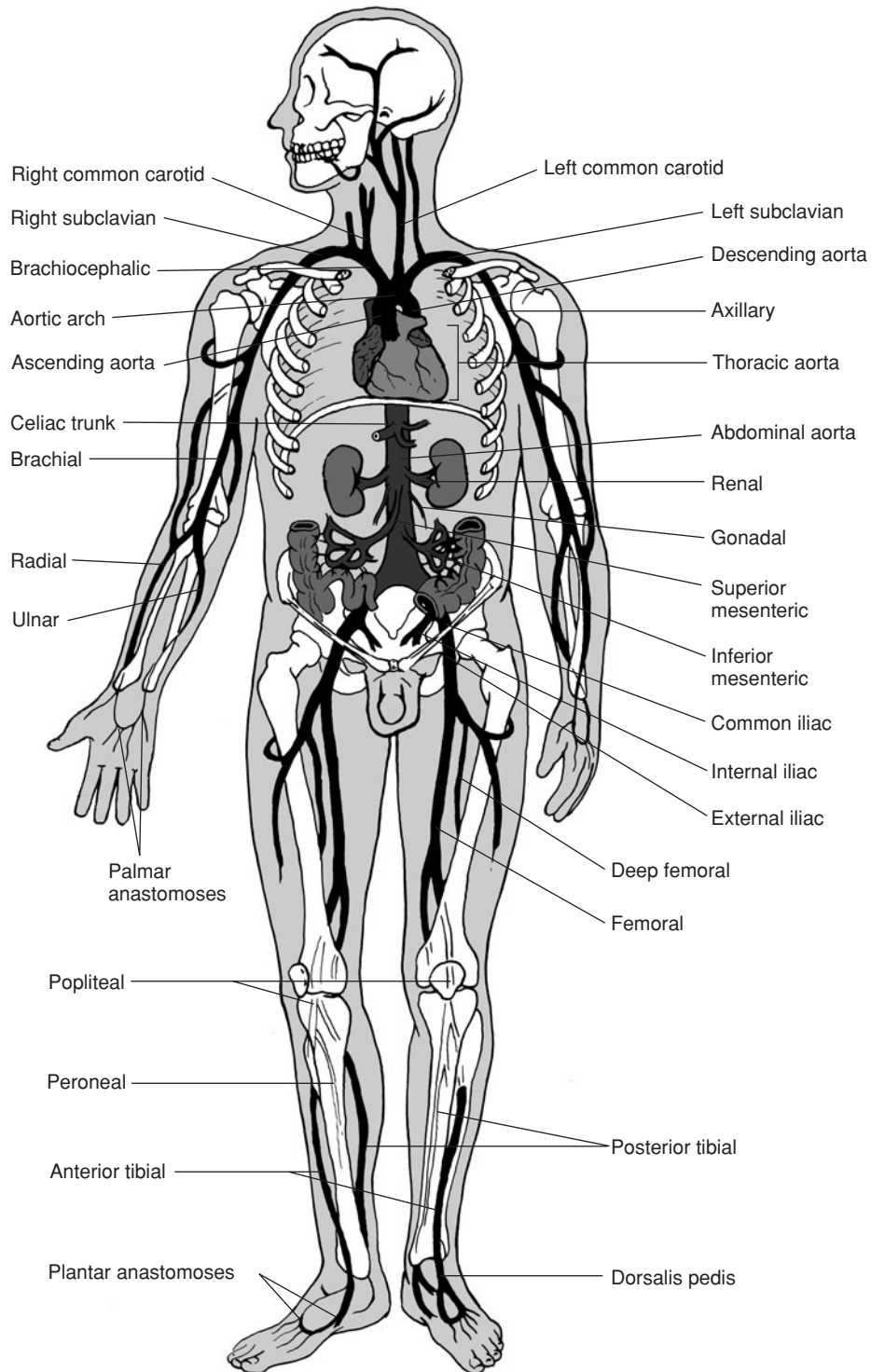
Figure 6–117. The major arteries of the cardiovascular system.
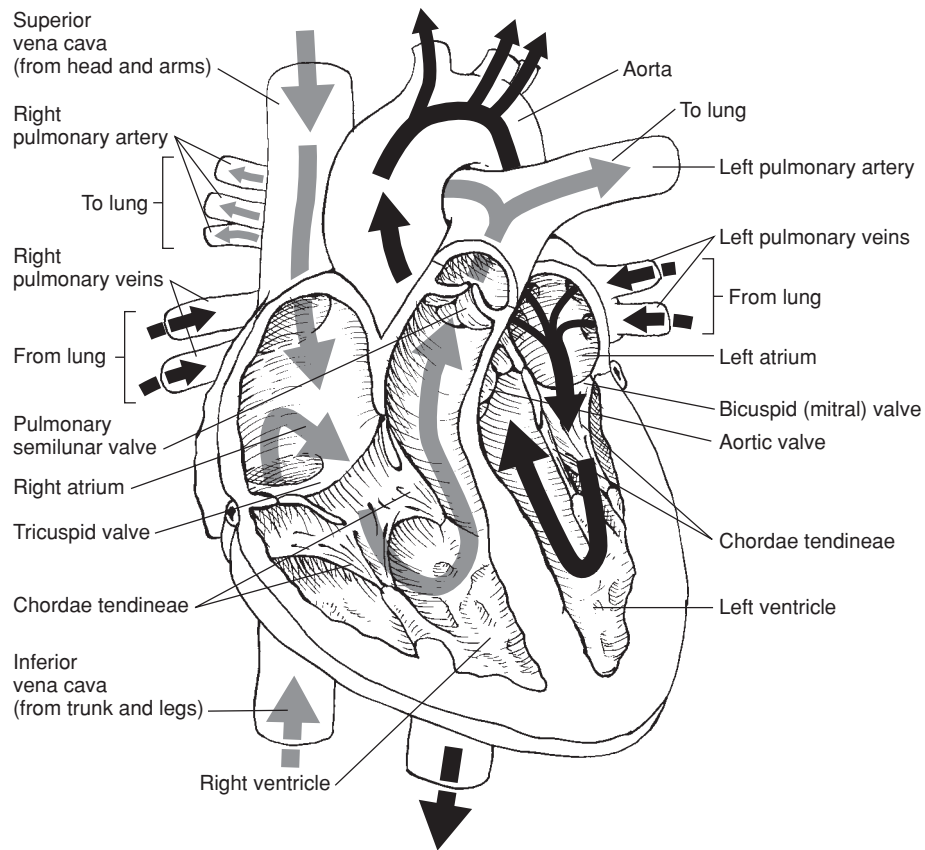
Figure 6–118. The four chambers of the heart and the major blood vessels. Directions of blood flow are indicated.

Venous blood is returned to the right atrium of the heart via the *superior* (from the upper part of the body) and *inferior* (from the lower body) *vena cavae* and the *coronary sinus* (from the heart substance; see Fig. 6–118). Upon atrial systole, the blood passes through the *tricuspid valve* into the right ventricle. During ventricular systole, the blood is pumped through the *pulmonary semilunar valve* into the *pulmonary artery* (the only artery to carry deoxygenated blood) to the lungs for oxygenation.

Blood is returned via the *pulmonary veins* (the only veins to carry oxygenated blood) to the left atrium. During atrial systole, blood passes through the *mitral* (bicuspid) *valve* into the left ventricle. During ventricular systole, the oxygenated blood is pumped through the *aortic semilunar valve* into the aorta. When blood pressure is reported, as for example "130 over 85," the top number (130) represents the systolic pressure and the lower number (85) represents the diastolic pressure.

The *aorta* is the trunk artery of the body; it is divided into the ascending aorta, aortic arch (see Fig. 6–119), descending thoracic aorta, and abdominal aorta. Many arteries arise from the aorta to supply destinations throughout the body. The *superior* and *inferior vena cavae* and the *coronary sinus* are the major veins, collecting venous blood from the upper and lower body areas and heart substance, respectively. The formation of sclerotic plaques (as in *atherosclerosis*) and other conditions that impair the flow of blood can lead to *ischemia* and tissue *infarction*. Atherosclerosis of the coronary arteries can cause *angina pectoris* and *myocardial infarction*.
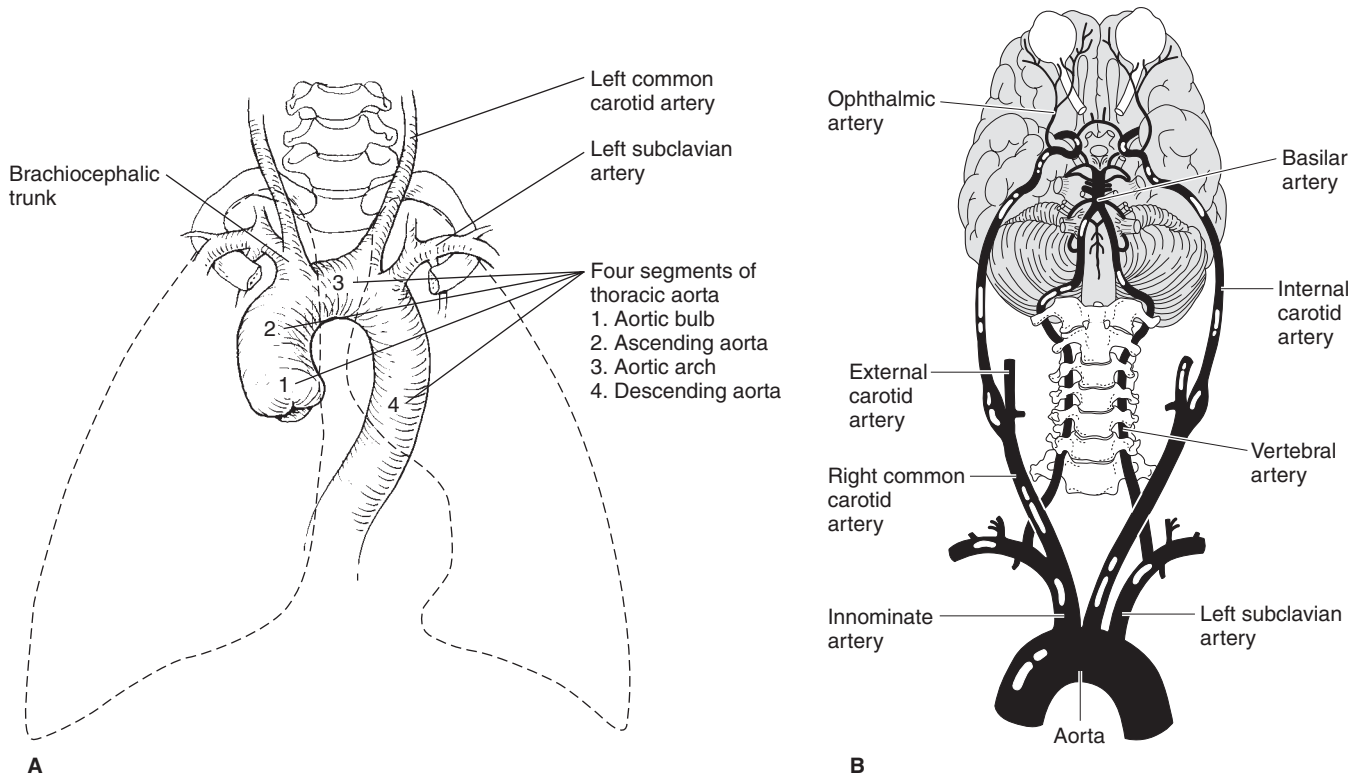
Figure 6–119. **(A)** Thoracic aorta illustrating major branches of aortic arch. **(B)** Blood supply to the brain. (Reproduced, with permission, from Doherty GM, ed. *Current Surgical Diagnosis & Treatment*, 12th ed. McGraw-Hill, New York, NY: 2006:824.)

The *four divisions* of the aorta and *their major branches* are as follows:

Ascending Aorta
• L and R coronary arteries

Aortic Arch (Fig. 6–119A)
• Brachiocephalic (innominate) artery gives rise to
  • R common carotid artery
  • R subclavian artery
• L common carotid artery
• L subclavian artery

Blood Supply to the Brain
Internal carotid arteries (Fig. 6–119B)
  • branch from common carotid arteries
  • supply anterior brain
Vertebral arteries
  • branch from subclavian arteries
  • supply posterior brain

Thoracic Aorta
• Intercostal arteries
• Superior phrenic arteries
• Bronchial arteries
• Esophageal arteries

Pulmonary Circulation
• Unoxygenated blood from the right side of the heart is directed to the lungs for oxygenation, then to the left side of the heart

Systemic Circulation
• Oxygenated blood from the left side of the heart is pumped to the body tissues then back to the right side of the heart

Abdominal Aorta

- Inferior phrenic arteries
- Celiac (axis) artery gives rise to
  - Common hepatic artery
  - L gastric artery
  - Splenic artery
- Superior mesenteric artery
- Suprarenal arteries
- Renal arteries
- Gonadal arteries (testicular or ovarian)
- Inferior mesenteric artery
- Common iliac arteries give rise to lower extremity arteries
  - Internal iliac arteries
  - External iliac (hypogastric) arteries

Arteries of the Lower Extremity

- Internal iliac arteries
- External iliac arteries
- Femoral arteries
- Popliteal arteries
- Anterior tibial arteries and posterior tibial arteries
- Dorsalis pedis, peroneal/fibular, medial, and lateral plantar arteries

The majority of peripheral and visceral angiographic procedures are performed in a specially equipped angiographic suite by cardiovascular–interventional technologists (Figs. 6–120 and 6–121). Many cardiovascular suites today use digital subtraction angiography (DSA). *Subtraction* is a technique that removes unnecessary structures

Figure 6–120. Lower extremity arteriogram subtraction demonstrating *aneurysm, before* **(A)** and *after* **(B)** repair. (Courtesy of Stamford Hospital, Department of Radiology.)
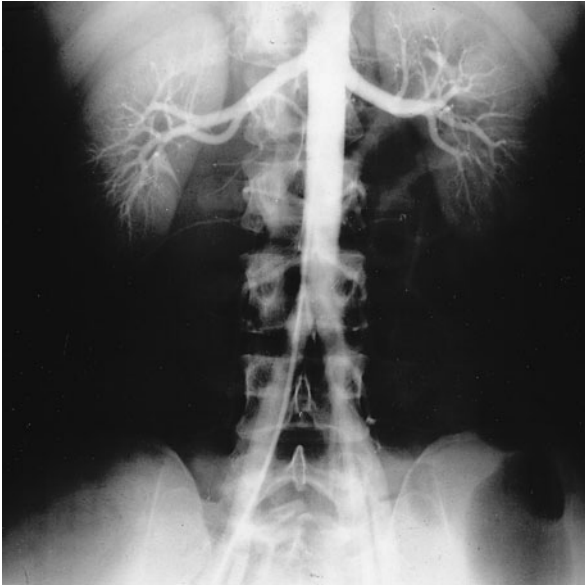
Figure 6–121. The renal arteriogram is one of many types of procedures performed by specially trained teams of health care professionals. (From the American College of Radiology Learning File. Courtesy of the ACR.)

such as bone from superimposition on contrast-filled blood vessels. DSA is subtraction achieved by means of a computer, which can also permit manipulation of contrast and other image characteristics by the technologist. The student radiographer, while not performing most of these examinations, should be familiar with the names of the most common procedures and the conditions and disorders for which they are performed.

2. Venogram. The one vascular procedure that might still be performed in general radiography is the lower extremity *venogram* (Fig. 6–122). This examination is generally performed to confirm a suspected deep vein thrombosis in an effort to avoid the complications of a pulmonary embolism.

The patient should be examined on a radiographic table that can be tilted to a semierect position of at least 45°. Tourniquets are used to force contrast medium into the deep veins. Sterile technique must be rigorously maintained. An injection of 50 to 100 mL at 1 to 2 mL/second is usually made through a superficial vein in the foot. Images are made at about 5- to 10-second intervals of the lower leg, thigh, and pelvis.

3. Terminology and Pathology. The following is a list of radiographically significant circulatory conditions with which the student radiographer should be familiar:

Aneurysm	Hypertension
Angina pectoris	Myocardial infarction
Atherosclerosis	Phlebitis
Atrial septal defect	Pulmonary edema
CVA (cerebrovascular accident)	Pulmonary embolism
Coarctation of aorta	Rheumatic heart disease
Congestive heart failure	Thrombophlebitis
Coronary artery disease	Ventricular septal defect

Figure 6–122. AP projection of a lower extremity venogram demonstrating multiple intraluminal filling defects. (Reproduced with permission, from Way LW, ed. *Current Surgical Diagnosis & Treatment.* 10th ed. East Norwalk, CT: Appleton & Lange, 1994.)

Chapter Review Questions

⭐ ***Congratulations!*** *You have completed your review of a large portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.*

1. Which of the following statement(s) regarding myelography is (are) correct?
    1. spinal puncture can be performed in the prone or flexed lateral position
    2. contrast medium distribution is regulated through table angulation
    3. the patient's head must be in acute flexion during Trendelenburg positions
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

2. The contraction and expansion of arterial walls in accordance with forceful contraction and relaxation of the heart is called:
    (A) hypertension
    (B) elasticity
    (C) pulse
    (D) pressure

3. The method by which contrast-filled vascular images are removed from superimposition upon bone is called:
    (A) positive masking
    (B) reversal
    (C) subtraction
    (D) registration

4. Indicate the correct sequence of oxygenated blood as it returns from the lungs to the heart:
    (A) pulmonary veins, left atrium, left ventricle, aortic valve
    (B) pulmonary artery, left atrium, left ventricle, aortic valve
    (C) pulmonary veins, right atrium, right ventricle, pulmonary semilunar valve
    (D) pulmonary artery, right atrium, right ventricle, pulmonary semilunar valve

5. In myelography, the contrast medium is generally injected into the:
    (A) cisterna magna
    (B) individual intervertebral discs
    (C) subarachnoid space between the first and second lumbar vertebrae
    (D) subarachnoid space between the third and fourth lumbar vertebrae

6. Lower extremity venography requires an injection of iodinated contrast medium into the:
    (A) superficial veins of the foot
    (B) deep veins of the foot
    (C) femoral vein
    (D) popliteal vein

7. Myelography is a diagnostic examination used to demonstrate:
    1. posterior protrusion of herniated intervertebral disc
    2. anterior protrusion of herniated intervertebral disc
    3. internal disc lesions
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 1 and 3 only

8. The four major arteries supplying the brain include the:
    1. brachiocephalic artery
    2. common carotid arteries
    3. vertebral arteries
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

9. Which of the following statement(s) is (are) true regarding lower extremity venography?
    1. the patient is often examined in the semierect position
    2. tourniquets are used to force contrast medium into the deep veins
    3. all radiographs are AP projections
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

10. The apex of the heart is formed by the:
    (A) left atrium
    (B) right atrium
    (C) left ventricle
    (D) right ventricle

Answers and Explanations

1. (B) Myelography is the radiologic examination of structures within the spinal canal. Opaque contrast medium is usually used. Following injection, the contrast medium is distributed to the vertebral region of interest by gravity; the x-ray table is angled Trendelenburg or visualization of the cervical region and in the Fowler's position for visualization of the thoracic and lumbar regions. While the table is Trendelenburg, care must be taken that the patient's head be kept in acute *extension* to compress the cisterna magna and keep contrast medium from traveling into the ventricles of the brain.

2. (C) As the heart contracts and relaxes while functioning to pump blood from the heart, those arteries that are large and those in closest proximity to the heart will feel the effect of the heart's forceful contractions in their walls. The arterial walls pulsate in unison with the heart's contractions. This movement may be detected with the fingers in various parts of the body and is referred to as the *pulse.*

3. (C) Superimposition of bony details frequently makes angiographic demonstration of blood vessels less than optimal. The method used to remove these superimposed bony details is called *subtraction. Digital* subtraction can accomplish this through the use of a computer, but *photographic* subtraction may also be performed using images from an angiographic series. *Registration* is the process of matching one series image exactly over another. A reversal image, or positive mask, is a reverse of the black and white radiographic tones.

4. (A) Deoxygenated blood is returned by way of the inferior and superior vena cava to the right side of the heart. The blood is emptied into the right atrium, passes through the tricuspid valve, and enters the right ventricle. It is forced through the pulmonary semilunar valve into the pulmonary artery (by contraction of the right ventricle) and passes to the lungs for reoxygenation. From the lungs it is collected by the *pulmonary* veins, which carry the oxygenated blood to the left atrium, where it travels through the mitral valve into the *left ventricle.* Upon contraction of the left ventricle, blood passes through the *aortic valve* into the aorta and to all parts of the body.

5. (D) Generally, contrast medium is injected into the subarachnoid space between the third and fourth lumbar vertebrae. Because the spinal cord ends at the level of the first or second lumbar vertebrae, this is considered to be a relatively safe injection site. The cisterna magna can be used, but the risk of contrast entering and causing side effects increases.

6. (A) Lower extremity venography requires an injection of contrast medium into the superficial veins of the foot. The skin on top of the patient's foot is very sensitive and every precaution should be taken to minimize the pain involved. Explain the procedure fully and soak the foot in warm water to make the veins more accessible for injection.

7. (A) An intervertebral disc can rupture due to trauma or degeneration. The nucleus pulposus protrudes *posteriorly* through a tear in the annulus fibrosus and impinges on nerve roots and can be demonstrated by placing positive or negative contrast media into the subarachnoid space. Internal disc lesions can be demonstrated only by injecting contrast into the individual discs (this procedure is termed *discography*). Anterior protrusion of a herniated intervertebral disc does not impinge on the spinal cord and is not demonstrated in myelography.

8. (C) Major branches of the common carotid arteries (internal carotids) function to supply the anterior brain, while the posterior brain is supplied by the vertebral arteries (branches of the subclavian arteries). The brachiocephalic (innominate) artery is unpaired and is one of three branches of the aortic arch, from which the right common carotid artery is derived. The left common carotid artery comes directly off the aortic arch.

9. (B) To increase the concentration of contrast medium in the deep veins of the leg, a Fowler's position is used with the table angle of approximately 45°. Tourniquets can also be used to force the contrast into the deep veins of the leg. Imaging may be performed with or without fluoroscopy and may include anteroposterior (AP), lateral, and 30° obliques of the lower leg in internal rotation.

10. (C) The heart wall is made up of the external epicardium, the middle myocardium, and the internal endocardium. The pericardium is the fibroserous sac enclosing the heart and roots of the great vessels. The heart has four chambers. The two upper chambers are the atria, and the two lower chambers are the ventricles. The *apex* of the heart is the tip of the left ventricle.

Chapter Exercises

☆ ***Congratulations!*** *You have completed the entire chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You can refer back to the indicated pages to check your answers and/or review the subject matter.*

1. Identify the bony structures composing the appendicular skeleton *(p. 91)*.

2. Describe the (a) method of positioning, (b) direction and point of entry of the CR, (c) principal structures visualized, and (d) pertinent traumatic or pathologic conditions and any technical adjustments they may necessitate relative to the appendicular skeleton, to include routine and special views of the:

    A. hand and wrist *(pp. 99–101)*.

    B. forearm and elbow *(pp. 102–104)*.

    C. humerus and shoulder *(pp. 104–106)*.

    D. clavicle and scapula *(pp. 106–108)*.

    E. foot and ankle *(pp. 117–121)*.

    F. lower leg and knee *(pp. 121–123)*.

    G. femur and hip *(pp. 124–126)*.

    H. pelvis and sacroiliac joints *(pp. 126–127)*.

    I. long bone measurement *(p. 128)*.

    J. arthrography *(pp. 128–129)*.

3. Identify the bony structures comprising the axial skeleton *(p. 136)*.

4. Describe the (a) method of positioning, (b) direction and point of entry of the CR, (c) principal structures visualized, and (d) pertinent traumatic and pathologic conditions and

any technical adjustments they may necessitate relative to the axial skeleton, to include routine and special views of the:

A. cervical spine *(pp. 139–141)*.

B. thoracic spine *(pp. 142–143)*.

C. lumbar spine *(pp. 143–145)*.

D. sacrum, coccyx *(pp. 146–148)*.

E. scoliosis series *(p. 148)*.

F. sternum and ribs *(pp. 149–151)*.

G. cranial and facial bones *(pp. 158–165)*.

H. paranasal sinuses; upper airway *(pp. 166–169)*.

5. Identify the principal structures comprising the respiratory system and their function(s) *(p. 173)*.

6. Describe the (a) method of positioning, (b) direction and point of entry of the CR, (c) principal structures visualized, and (d) pertinent traumatic and pathologic conditions and any technical adjustments that may be required relative to the routine and special views of the chest (PA, lateral, obl, lordotic, decubitus) and airway *(pp. 174–177)*.

7. Identify the principal structures comprising the biliary system and their function(s) *(p. 182)*.

8. Describe the (a) method of positioning, (b) direction and point of entry of the CR, (c) principal structures visualized, and (d) pertinent traumatic and pathologic conditions and any technical adjustments that may be required relative to the routine and special views of the biliary system, including:

A. OCG *(pp. 183–184)*.

B. Surgical and T-tube cholangiograms *(p. 184)*.

C. ERCP *(pp. 184–185)*.

9. Identify the principal structures comprising the digestive system and their function(s) *(p. 185)*.

10. Describe the (a) method of positioning, (b) direction and point of entry of the CR, (c) principal structures visualized, and (d) pertinent traumatic and pathologic conditions and

any technical adjustments that may be required relative to the routine and special views of the digestive system, to include:

A. abdomen *(p. 190).*

B. esophagus *(pp. 191–192).*

C. stomach and small intestine *(pp. 192–195).*

D. large intestine *(pp. 196–197).*

11. Identify the principal structures comprising the urinary system and their function(s) *(pp. 201–202).*

12. Describe the (a) method of positioning, (b) direction and point of entry of the CR, (c) principal structures visualized, and (d) pertinent traumatic and pathologic conditions and any technical adjustments that may be required relative to the routine and special views of the urinary system, to include:

A. KUB *(pp. 205–206).*

B. retrograde examinations *(p. 205).*

C. voiding examinations: male versus female *(p. 206).*

D. compression *(p. 203).*

D. bladder *(p. 206).*

13. Identify the principal structures comprising the female reproductive system and their function(s) *(p. 209).*

14. Describe the (a) method of positioning, (b) direction and point of entry of the CR, (c) principal structures visualized, and (d) pertinent traumatic and pathologic conditions and any technical adjustments that may be required in hysterosalpingography *(p. 210).*

15. Identify the principal structures comprising the CNS and their function(s) *(p. 214).*

16. Describe the (a) method of positioning, (b) direction and point of entry of the CR, (c) principal structures visualized, and (d) pertinent traumatic and pathologic conditions and any technical adjustments that may be required in myelography *(pp. 215–216).*

17. Identify the principal structures comprising the circulatory system and their function(s) *(pp. 216–220).*

18. List the kinds of specialized examinations that might be performed to demonstrate various traumatic and pathologic conditions of the circulatory system *(pp. 220–221).*

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part

III

Radiation Protection

Radiation Protection Considerations

I. IONIZING EFFECTS OF X-RADIATION

A. ELECTROMAGNETIC RADIATION

A review of electromagnetic radiation and energy is essential to the study of x-rays and other forms of ionizing radiation. *Electromagnetic radiation* can be described as wave-like fluctuations of electric and magnetic fields. There are many kinds of electromagnetic radiation. Figure 7–1 illustrates that visible light, microwaves, and radio waves, as well as x-ray and gamma rays, are all part of the *electromagnetic spectrum*. All the electromagnetic radiations have the same *velocity*, i.e., 3×10^8 m/s (186 000 miles per second); however, they differ greatly in *wavelength* and *frequency*.

Wavelength refers to the distance between two consecutive wave crests (Fig. 7–2). *Frequency* refers to the number of cycles per second; its unit of measurement is *hertz* (Hz), which is equal to 1 cycle per second.

Frequency and wavelength are closely associated with the relative *energy* of electromagnetic radiations. More energetic radiations have shorter wavelength and higher frequency. The relationship among frequency, wavelength, and energy is graphically illustrated in the electromagnetic spectrum (Fig. 7–1).
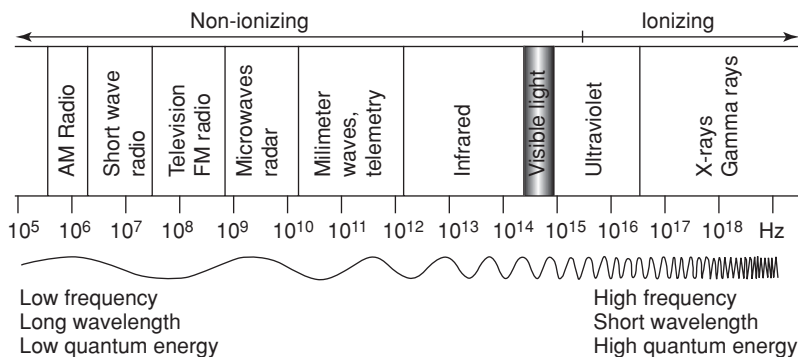
Figure 7–1. The electromagnetic spectrum. Frequency and photon energy are *directly* related; frequency and photon energy are *inversely* related to wavelength.
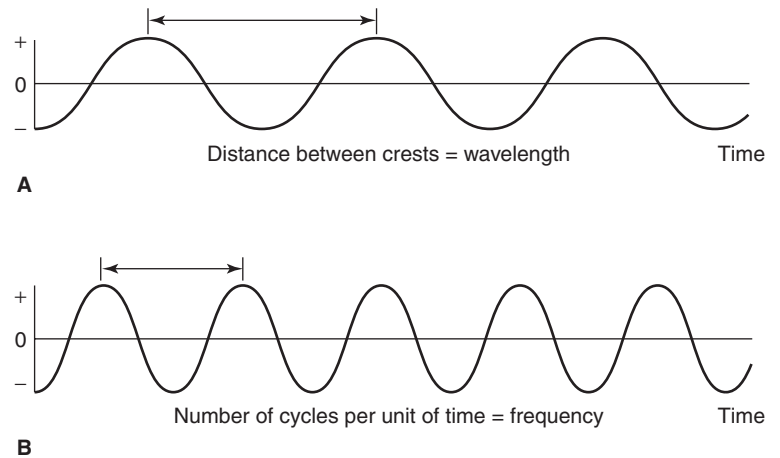
Figure 7–2. Wavelength versus frequency. *Wavelength* is described as the distance between successive crests. The shorter the wavelength, the more crests or cycles per unit of time (e.g., per second). Therefore, the shorter the wavelength the greater the *frequency* (number of cycles/s). Wavelength and frequency are *inversely* related.

Figure 7–3. The population's exposure to various sources of ionizing radiation. Natural background radiations (the earth, the sun, building materials) compose the majority of our exposure. Medical irradiation is the largest portion of our exposure to artificial sources of radiation. *Occupational radiation, nuclear energy, and fallout are responsible for only a minute portion of our total exposure.*

Some radiations are energetic enough to rearrange atoms in materials through which they pass, and they can therefore be hazardous to living tissue. These radiations are called *ionizing radiation* because they have the energetic potential to break apart electrically neutral atoms, resulting in the production of negative and/or positive *ions*. X-ray photons, having the dual nature of both particles and electromagnetic waves, are highly energetic ionizing radiation. Diagnostic x-rays are extremely short, between 10^{-8} and 10^{-12} meter in wavelength. The unit formerly used for such small dimensions is the Angstrom (Å); 1 Å is equal to 10^{-10} meter.

Humans have always been exposed to ionizing radiation. Some ionizing radiations (such as those emitted by uranium) occur naturally in the earth's crust and in its atmosphere (from the sun and cosmic reactions in space). These radiations are present in the structures in which we live and in the food we consume; radioactive gas is present in the air that we breathe, and there are traces of radioactive materials in our bodies. These radiations are referred to as *natural background* (environmental) *radiation.* The levels of natural background radiation vary greatly from one geographic location to another. *The greatest portion of our exposure to background radiation comes from naturally occurring sources such as these.*

In addition to natural background radiation, we are also exposed to sources of radiation created by humans. *Artificial* or *man-made background radiation* includes sources such as medical and dental x-rays, nuclear testing fallout, and radiation associated with nuclear power plants. Figure 7–3 illustrates the approximate quantity of radiation received from natural and artificial sources.

X-ray *photons* are infinitesimal bundles of energy that deposit some of their energy into matter as they travel through it. This deposition of energy and subsequent *ionization* has the potential to cause chemical and biologic damage.

B. PRODUCTION OF X-RAYS AT THE TUNGSTEN TARGET

Diagnostic x-rays are produced within the x-ray tube as high-speed *electrons* are rapidly decelerated by the tungsten target. The source of electrons is the heated cathode filament; the electrons are driven across to the anode's focal spot when thousands of volts (kV [kilovolts]) are applied. When the high-speed electrons are suddenly stopped at the

focal spot, their kinetic energy is converted to x-ray photon energy. This happens in the following two ways.

1. Bremsstrahlung (Brems) or "Braking" Radiation.

A high-speed electron is accelerated toward a tungsten atom within the anode focal track. The electron is attracted, and pulled off course, by the positively charged nucleus of the tungsten atom. The electron's deflection from its original course caused by the "braking" (slowing down) results in a loss of energy. *This energy loss is given up in the form of an x-ray photon: Brems or braking radiation* (Fig. 7–4). The electron might not give up all its kinetic energy in one such interaction; it might go on to have several more interactions deeper in the target, each time giving up an x-ray photon having less and less energy. This is one reason the x-ray beam is heterogeneous (polyenergetic), i.e., has a spectrum of energies. *Brems radiation comprises 70% to 90% of the x-ray beam.*

2. Characteristic Radiation.

In this case, a high-speed electron encounters a tungsten atom in the anode's focal track and ejects a K-shell electron (Fig. 7–5A), leaving a vacancy in the K shell (Fig. 7–5B). An electron from a shell above (e.g., the L shell) fills the vacancy. In doing so, because of the difference in energy level between the K and L shell, there is emitted a K-*characteristic primary ray* (Fig. 7–5C). The energy of the characteristic ray is equal to the difference in energy between the K and L shells. K-characteristic primary x-rays from a tungsten target x-ray tube have a 69 keV energy. Characteristic radiation comprises very little of the x-ray beam (10%–30%).

C. Interactions Between X-Ray Photons and Matter

The gradual decrease in exposure rate as ionizing radiation passes through tissues is called *attenuation*. Attenuation is principally attributable to the following two major types of interactions that occur between x-ray photons and tissue in the diagnostic x-ray range of energies.

1. Photoelectric Effect.

In the *photoelectric effect*, a relatively *low-energy* (low kV) x-ray photon interacts with tissue and uses all its energy (true/total absorption) to eject an *inner shell* electron. This leaves an inner shell orbital vacancy. An electron from the shell above drops down to fill the vacancy and, in doing so, gives up energy in the form of a *characteristic ray* (Fig. 7–6).

The photoelectric effect is more likely to occur in absorbers having *high atomic number* (e.g., bone, positive contrast media) and with *low-energy photons*. The photoelectric effect contributes significantly to patient dose, as all the x-ray photon energy is absorbed by the tissue (and, therefore, is responsible for the production of short-scale contrast). Its probability is Z^3/E^3 in the diagnostic energy range.

2. Compton Scatter.

In *Compton scatter*, a fairly *high*-energy (high kV) x-ray photon interacts with tissue and ejects an *outer shell* electron (Fig. 7–7). The ejected electron is called a *recoil electron*. The scattered x-ray photon is deflected with somewhat reduced energy ("modified scatter"). However, it retains most of its original energy and exits the body as an energetic scattered photon.
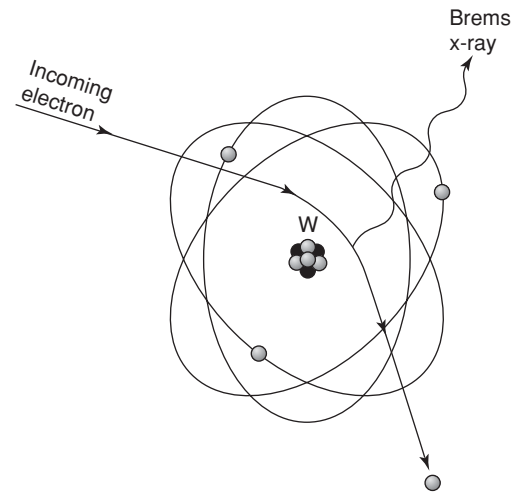
Figure 7–4. Production of Bremsstrahlung (Brems) radiation. A high-speed electron is deflected from its path and the loss of kinetic energy is emitted in the form of an x-ray photon.

A Incoming electron strikes K shell tungsten electron.

B Both electrons leave the shell.

Ejected electron

C The K vacancy is usually filled by an L-shell electron. The difference in energy levels (E = L − K) is represented by a K characteristic ray.

L shell electron files K vacancy
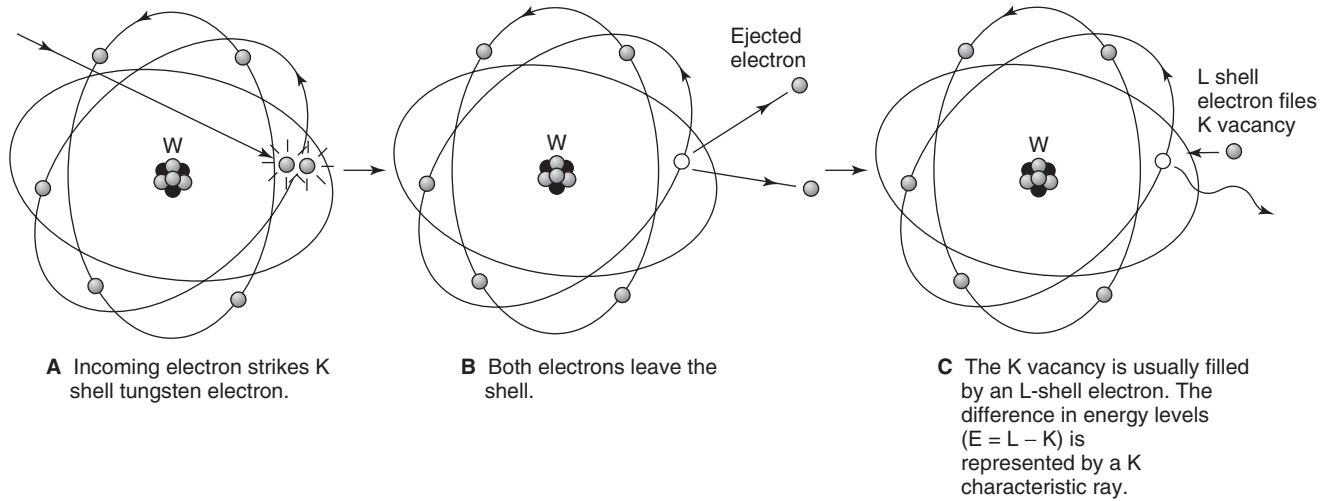
Figure 7–5. Production of characteristic radiation. A high-speed electron **(A)** ejects a tungsten K-shell electron, leaving a K-shell vacancy **(B)**. An electron from the L shell fills the vacancy and emits a K-characteristic ray **(C)**.

Ejected photoelectron

Incident photon (low energy)
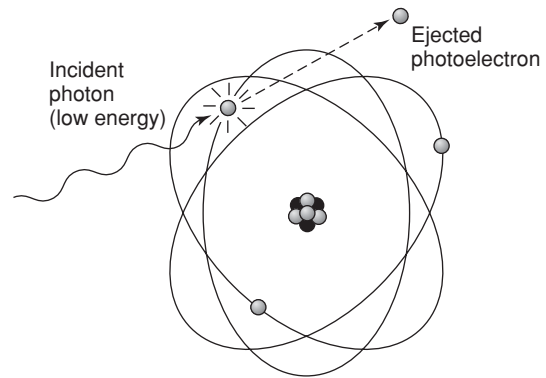
Figure 7–6. In the photoelectric effect, the incoming (low energy) photon releases *all* its energy as it ejects an inner shell electron from orbit.

Ejected Compton electron (outer shell)

Incident photon (high energy)

Scattered Compton photon
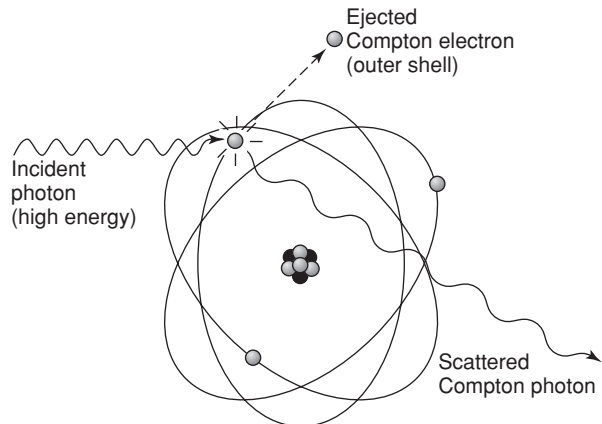
Figure 7–7. In Compton scatter, the incoming (high energy) photon uses *part* of its energy to eject an outer shell electron; in doing so, the photon changes direction (scatters) but retains much of its original energy.

Because the scattered photon exits the body, it does not pose a radiation hazard to the patient. It can, however, contribute to *image fog* and pose a *radiation hazard to personnel* (as in fluoroscopic procedures).

■ *SUMMARY*

- ■ The radiations of the electromagnetic spectrum all travel at the same velocity, 186 000 miles/sec, but differ in wavelength and frequency.
- ■ Wavelength is the distance between two consecutive wave crests. The number of cycles and crests per second is frequency; its unit of measurement is Hz.
- ■ Wavelength and frequency are inversely related.
- ■ Speed of light $=$ frequency $\times$ wavelength ($c = f\lambda$)
- ■ The two kinds of background radiation sources are natural background radiation and artificial/man-made background radiation; natural sources account for the largest human exposure to ionizing radiation.
- ■ Medical radiation exposure is the largest source of artificial/man-made ionizing radiation exposure to humans.
- ■ Ionization is caused by high-energy, short-wavelength electromagnetic radiations that break apart electrically neutral atoms.
- ■ Two types of x-radiation are produced at the anode through energy conversion processes: Brems radiation and characteristic radiation; Brems radiation predominates.
- ■ X-rays can interact with tissue cells and cause ionization; the interactions between x-rays and tissue cells that occur most often are Compton scatter and the photoelectric effect.
- ■ Characteristics of photoelectric effect
  - ■ Low-energy x-ray photon gives up all its energy ejecting an inner shell electron.
  - ■ Produces a characteristic ray.
  - ■ Major contributor to patient dose.
  - ■ Occurs in absorbers having high atomic number.
  - ■ Produces short-scale contrast.
- ■ Characteristics of Compton scatter
  - ■ The interaction that predominates in the diagnostic x-ray range.
  - ■ High-energy x-ray photon uses a portion of its energy to eject an outer shell electron.
  - ■ Responsible for scattered radiation fog to the image.
  - ■ Poses radiation hazard to personnel.
- ■ Exposure dose depends on beam attenuation and on which type of interaction occurs between x-ray photons and tissue. Exposure dose is, therefore, affected by radiation quality (kV) and the subject being irradiated (i.e., thickness and nature of part; atomic number of part).

Figure 7–8. Dose–effect curves. **(A)** Linear, nonthreshold. **(B)** Nonlinear, nonthreshold. **(C)** Nonlinear, threshold. **(D)** Linear, threshold.

II. DOSE–RESPONSE RELATIONSHIPS

A. DOSE–RESPONSE CURVES

The association between a dose of ionizing radiation and the magnitude of the resulting response or effect is referred to as a *dose–response, or dose–effect, relationship.*

Dose–response curves are used to illustrate the relationship between exposure to ionizing radiation and possible resultant biologic responses (Fig. 7–8). *Linear* (straight line) relationships are those in which the response is directly related to the dose received; that is, if the dose is increased, the biologic response is increased. In *nonlinear* relationships, the effects are not proportional to the dose. The term *threshold* refers to the dose below which no harmful effects are likely to occur, or, the point/dose at which a response first begins. The two most frequently used dose–response curves in radiation protection are the *linear, nonthreshold,* and the *nonlinear, threshold.* The Committee on Biologic Effects of Ionizing Radiation (BEIR) has evaluated the linear and linear quadratic nonthreshold curves and pronounced the *linear nonthreshold* relationship (the more conservative of the two) as *the curve of choice for radiation protection standards.*

B. LINEAR: THRESHOLD AND NONTHRESHOLD

The *linear threshold* curve is shown in Figure 7–8D and illustrates responses that are proportional to the radiation dose received only after some particular dose is received—below this "threshold" dose, no response/effect is likely to occur. The *linear nonthreshold* curve (Fig. 7–8A) is used to illustrate responses such as radiation-induced leukemia, cancer, and genetic effects. These are sometimes referred to as *stochastic effects.* Stochastic effects occur randomly and are "all or nothing" type effects; that is, they do not occur with degrees of severity. It must be noted that *in a nonthreshold curve there is no safe dose,* that is, no dose below which there will definitely be no biologic response—any dose can cause a biologic effect. Theoretically, even one x-ray photon can cause a biologic response. This is the curve of choice to predict effects of low-level (e.g., medical and occupational) exposure to ionizing radiation.

C. NONLINEAR: THRESHOLD AND NONTHRESHOLD

In *nonlinear* curves, the effects of radiation are not proportional to the dose received. *Figure 7–8B and C* illustrate nonlinear dose–response curves. In nonlinear curves, a considerable dose could be required before effects occur, and then effects might increase significantly with only a little more increase in dose. Response could level off at some point and further doses might have much less effect. Thus, the term *nonlinear.* Nonlinear curves can be threshold or nonthreshold. A familiar nonlinear curve is the *S,* or *sigmoid,* type seen in *Figure 7–8C.* The *nonlinear (sigmoid) threshold* curve is used to illustrate certain radiation-induced somatic conditions such as skin *erythema.* These responses are *predictable* and sometimes referred to as *nonstochastic effects.*

D. LATE EFFECTS

The Committee on the Biological Effects of Ionizing Radiation (BEIR) in 1990 reported in their revised risk estimates that effects of ionizing radiation exposure are approximately three to four times more than reported in the previous statement. Occupationally exposed individuals are concerned principally with *late* (i.e., *long-term* or *delayed*) effects of ionizing radiation such as radiation-induced *genetic effects*, *leukemia*, *cancers* (bone, lung, thyroid, breast), and *local effects* such as skin erythema, infertility, and cataracts—these can occur many years following initial exposure to low levels of ionizing radiation. These long-term/delayed effects are usually *chronic* and many are represented by the linear, nonthreshold dose–response curve.

History provides us with many examples of the delayed effects of ionizing radiation: many of the early radiologists and radiation scientists, A-bomb survivors of Hiroshima and Nagasaki, and patients with ankylosing spondylitis in Great Britain in the 1940s developed leukemia and other *life span–shortening* diseases as a result of exposure to varying quantities of ionizing radiation over a period of time. Some children irradiated in the 1940s for enlarged thymus glands developed thyroid cancer as adults 20 years later. Radium watch-dial painters in the 1920s developed a variety of bone cancers following a latent period of 20 to 30 years. These are all delayed effects of radiation and are represented by the linear, nonthreshold dose–response curve.

Cataractogenesis is another late effect of exposure to ionizing radiation, but is represented by the *nonlinear, threshold* dose–response curve. An acute dose of approximately 200 *rad* is required to cause radiogenic cataracts. A far greater occupational or otherwise fractionated dose of approximately 1000 rad is required to induce cataracts.

Early, or short-term, effects of radiation are those responses that occur very soon after exposure to ionizing radiation. Short-term effects are usually *acute effects* and occur only after exposure to a very large amount of radiation all at one time (and perhaps to the whole body) and therefore will not occur in diagnostic radiology.

■ SUMMARY

- ■ **Ionization of living tissue can cause chemical and biologic damage to somatic and/or genetic cells.**
- ■ **A nonthreshold dose–response relationship indicates that there is no safe dose of radiation; any dose can cause a biologic effect.**
- ■ **The linear nonthreshold dose–response relationship illustrates stochastic responses (cancer, genetic effects) and is the curve of choice for occupational exposure.**
- ■ **Occupationally exposed workers are concerned with late (i.e., long-term or delayed) effects of ionizing radiation such as radiation-induced genetic effects, leukemia, and cancers (bone, lung, thyroid, breast).**

III. BIOLOGIC EFFECTS OF IONIZING RADIATION

A. LAW OF BERGONIÉ AND TRIBONDEAU

Before beginning our review of somatic and genetic effects of ionizing radiation, a brief review of *radiobiology* is in order. Radiobiology is the study of the effects of ionizing radiation on biologic material at the cellular level.

In 1906, two scientists Bergonié and Tribondeau proposed that certain cellular qualities made tissues more or less radiosensitive. The Law of Bergonié and Tribondeau addresses relative tissue sensitivity and states that the following are particularly radiosensitive:

1. Stem (undifferentiated, or precursor) cells
2. Young, immature tissues
3. Highly mitotic cells

Thus, very young cells, undifferentiated cells (nonspecialized in structure and function), and cells having the most reproductive activity are highly *radiosensitive.* Examples of highly radiosensitive tissues are intestinal epithelial cells and cells of the rapidly developing embryo and fetus.

B. RADIATION WEIGHTING AND TISSUE WEIGHTING FACTORS

Ionization causes the removal of electrons from some atoms and the addition of electrons to other atoms. Thus, the stage is set for biologic effects; as a result of the ionization, appropriate chemical bonds cannot be maintained.

Similar absorbed doses of *different kinds* of radiation can cause different biologic effects to *tissues of differing radiosensitivity.* A *radiation weighting factor* (W_r) is a number assigned to different types of ionizing radiations so that their effect(s) may be better determined (e.g., x-ray vs. alpha particles). The W_r of different ionizing radiations is dependent on the linear energy transfer (LET) of that particular radiation. A *tissue weighting factor* (W_t) represents the relative tissue radiosensitivity of the irradiated material (e.g., muscle vs. intestinal epithelium vs. bone, etc.).

For example, to determine effective dose (*EfD*), the following formula is used:

$$\text{Effective dose } (EfD) = \text{Radiation weighting factor } (W_r) \\ \times \text{Tissue weighting factor } (W_t) \\ \times \text{Absorbed dose } (D)$$

C. LET AND RBE VS. BIOLOGIC DAMAGE

Radiation deposits energy as it passes through tissue. The rate at which this occurs is described as *linear energy transfer.* LET is another means of expressing radiation quality and determining the W_r. It expresses the ability of radiation to do damage. As the LET of radiation increases, the radiation's ability to produce biological damage also increases. This is described quantitatively by *relative biologic effectiveness (RBE)*; LET and RBE are directly related.

Diagnostic x-rays are considered low LET radiation; the approximate LET of diagnostic x-rays is 3 keV/µm. Energy transferred to tissue

Radiation Type/Energy	W_r
X- or gamma	1
Protons	2
Neutrons: 10–100 keV	10
Neutrons: 100 keV–2 MeV	20
Alpha particles	20

Organ/Tissue	W_t
Skin	0.01
Thyroid	0.05
Breast	0.05
Lung	0.12
Gonads	0.20

can cause molecular damage. Any manifestation of that damage will depend on the extent of molecular disruption and the type of tissue affected.

D. MOLECULAR EFFECTS OF IONIZING RADIATION

The principal interactions that occur between x-ray photons and body tissues in the diagnostic x-ray range, the *photoelectric effect* and *Compton scatter*, are ionization processes producing photoelectrons and recoil electrons that traverse tissue and subsequently ionize molecules. These interactions occur randomly but can lead to molecular damage in the form of *impaired function* or *cell death*. The *target theory* specifies that DNA molecules are the targets of greatest importance and sensitivity; that is, DNA is the key sensitive molecule. However, since 65% to 80% of the body is composed of water, most interactions between ionizing radiation and body cells will involve radiolysis of water rather than direct interaction with DNA (see below).

1. Direct Effect. The two major types of effects that occur are the direct effect and the indirect effect. The direct effect usually occurs with high LET radiations (e.g., alpha particles and neutrons) and when ionization occurs at the deoxyribonucleic acid (DNA) molecule itself.

2. Indirect Effect. The indirect effect, which *occurs most frequently*, happens when ionization takes place away from the DNA molecule, in cellular water. However, the energy from the interaction can be transferred to the DNA molecule via a *free radical* (formed by *radiolysis of cellular water*). The indirect effect is predominant with low LET radiation (e.g., x- and gamma rays).

DNA is the primary target for cell damage from ionizing radiation. Possible types of damage to the DNA molecule are diverse. A single main chain/side rail scission (break) on the DNA molecule is *repairable*. A double main chain/side rail scission may repair with difficulty or may result in *cell death*. A double main chain/side rail scission on the same "rung" of the DNA ladder results in *irreparable* damage or *cell death*. Faulty repair of main chain breakage can result in "cross-linking."

Damage to the nitrogenous bases, that is, damage to the base itself or to the rungs connecting the main chains, can result in alteration of base sequences causing a *molecular lesion/point mutation*. Any subsequent divisions result in daughter cells with incorrect genetic information.

The majority (approximately 90%) of cell damage is repairable. However, subsequent or multiple "hits" to the same cell are more likely to leave permanent damage.

E. CELLULAR AND RELATIVE TISSUE RADIOSENSITIVITY

These types of molecular damage can occur to any of the somatic cells or to genetic cells. For example, high levels of radiation exposure to the bone marrow (where blood cells are produced) can cause a decrease in the number of circulating blood cells.

Tissue radiosensitivity is closely related to the cell (life and division) cycle. Cells divide for the purposes of reproduction, repair, and growth, and the cell cycle is an orderly arrangement of events. The cell

Types of DNA Damage

Main chain, double side rail break
Main chain, single side rail break
Main chain breakage, cross-linking
Base damage, point mutations
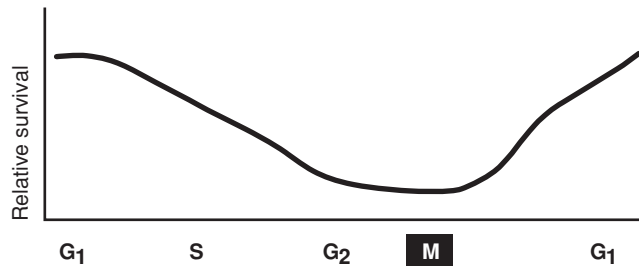
Figure 7–9. Cell radiosensitivity during cell cycle. Cells in late G2 and in mitosis are most radiosensitive.

cycle can be divided into two parts: interphase and *mitosis*. Interphase is further divided into three steps: gap 1 (*G1*), synthesis (*S*), and gap 2 (*G2*). Important, radiologically, is the fact that cells are *particularly radiosensitive* during late G2 and mitosis (*M*). DNA replication occurs during the S phase, which is the *least radiosensitive* stage of the cell cycle (Fig. 7–9).

Lymphocytes, a type of white blood cell that plays an important role in the immune system, are particularly radiosensitive. If lymphocytes suffer radiation damage, the body loses its ability to fight infection and becomes more susceptible to disease.

Epithelial tissue, which lines the respiratory system and intestines, is also a highly radiosensitive tissue. In contrast, *muscle* and *nervous* tissues are comparatively insensitive to radiation. Because nerve cells in the adult do not undergo mitosis, they comprise the most *radioresistant* somatic tissue. However, nervous tissue *in the fetus* (particularly the second to eighth week) is highly mitotic and, hence, highly *radiosensitive.*

The *genetic cells* of the gonads are considered especially radiosensitive tissues. Exposure to ionizing radiation can cause temporary infertility, permanent sterility or mutations in succeeding generations. In particular, the reproductive cells of the fetus and young children are exceptionally radiosensitive. Other factors that determine tissue response, and can modify radiation injury, include the following:

1. *Fractionation and protraction*: Small doses delivered over a long period of time produce a lesser effect. (The greatest effect of irradiation will be observed if a *large quantity* of radiation is delivered in a *short time* to the *whole body*.)
2. *Oxygen*: The greater the oxygen content of tissues, the greater their radiosensitivity. Dissolved oxygen in tissues increases stability and toxicity of free radicals. The oxygen enhancement ratio (OER) can be determined by dividing the dose required to cause an effect *without* oxygen *by* the dose required to cause that effect *with* oxygen.
3. *Temperature*: Tissues are more radiosensitive at higher temperatures; chromosome aberrations are more likely to occur at lower temperatures because repair processes are inhibited.
4. *Age*: Fetal tissue is most radiosensitive. As the individual ages, tissue sensitivity decreases. Radiosensitivity increases again in old age, but only slightly.

Remember, as the LET of the ionizing radiation increases, the radiation's ability to produce biological damage also increases. This is described quantitatively as RBE; LET and RBE are directly related.

It is well established that sufficient quantities of ionizing radiation can cause a number of serious *somatic* and/or *genetic* effects. What is not clear, however, are the long-term effects of low-level (diagnostic and occupational) x-radiation.

Health care professionals involved in prescribing and delivering radiologic examinations have an obligation to keep nonproductive radiation exposure to all individuals as low as possible. Possible abusive overuse of radiologic (and other diagnostic) examinations is currently being scrutinized by many health care facilities as part of a continuous quality improvement program. Some formerly routine examinations are now considered excessive and unnecessary, for example, routine chest x-ray on admission to the hospital, are no longer performed unless the patient is admitted to the pulmonary medicine or surgical service; preemployment chest and/or lumbar spine examinations are frequently considered to have little benefit.

In states having no *licensure* requirements for radiographers, physicians and hospitals often assume the responsibility of hiring only credentialed radiographers. Participation in *quality assurance* ensures that imaging equipment is functioning optimally and that image quality is up to expected standards.

Radiographers must consider patient dose when selecting exposure factors. One component of a radiographer's professionalism, as stated in the principles of the *ARRT Code of Ethics*, is to consistently employ every means possible to decrease radiation exposure to the population.

Radiographers must follow the *ALARA* principle (keeping exposure As Low As Reasonably Achievable) as they carry out their tasks. The radiologic facility must undergo appropriate radiation surveys. Staff must be properly oriented and regular inservice reviews of radiation safety must take place. Proper radiation monitoring and review of monthly radiation reports is essential.

■ *SUMMARY*

- **The Law of Bergonié and Tribondeau states that the most radiosensitive cells are young, undifferentiated, and highly mitotic cells.**
- **LET is another means of expressing radiation quality and determining the radiation weighting factor.**
- **Identical doses of different kinds of radiation will cause different biologic effects, hence the need for the radiation weighting factor.**
- **Diagnostic x-radiation is low-energy, low-LET radiation.**
- **Radiation effect on cells is named according to the interaction site, namely, direct effect, indirect effect, radiolysis of water.**
- **The most radiosensitive cell is the lymphocyte.**
- **As radiation professionals, we are obligated to keep radiation exposure to our patients and ourselves ALARA.**

IV. GENETIC EFFECTS

A. PREGNANCY

There are a number of situations that require the radiographer's special attention. Irradiation during *pregnancy*, especially in early pregnancy, must be avoided. The fetus is particularly radiosensitive during the first trimester, during much of which time pregnancy may not even be suspected. *Especially high-risk examinations* include pelvis, hip, femur, lumbar spine, cystograms and urograms, upper gastrointestinal (GI) series, and barium enema examinations.

During the first trimester, specifically the 2nd to 10th week of pregnancy (i.e., during major organogenesis), if the radiation dose is sufficient, fetal anomalies can be produced. *Skeletal and/or organ anomalies* can appear if irradiation occurs in the early part of this time period, and *neurologic anomalies* can be formed in the latter part; *mental retardation,* childhood *malignant diseases*, such as cancers or leukemia, and retarded growth/development can also result from irradiation during the first trimester.

Fetal irradiation during the second and third trimesters is not likely to produce anomalies, but rather, with sufficient dose, some type of childhood malignant disease. Fetal irradiation during the first 2 weeks of gestation can result in *embryonic resorption or spontaneous abortion*.

It must be emphasized, however, that the likelihood of producing fetal anomalies at doses below 20 rad is exceedingly small and that most general diagnostic examinations are likely to deliver fetal doses of less than 1 to 2 rad.

Ways To Reduce Risk to Recently Fertilized Ovum

- Elective scheduling/10-Day Rule
- Patient questionnaire
- Posting

B. FEMALES

1. Elective Scheduling/10-Day Rule. In consideration of the potential risk, female patients of childbearing age should be questioned regarding their last menstrual period (LMP) and the possibility of their being pregnant. Figure 7–10 is an example algorithm for questioning female patients having reproductive potential. Facilities offering radiologic services should make inquiries of their female patients regarding LMP and advise them of the risk associated with radiation exposure during pregnancy. The *10-day rule* identifies the first 10 days following onset of the menses as the safest time to schedule elective procedures of the abdomen/pelvis.

2. Patient Questionnaire. In addition to supporting the ALARA concept, many institutions also use a patient questionnaire as a guide for scheduling elective abdominal x-ray examinations on women of reproductive age. The patient completes a form that requests information concerning her LMP and the possibility of her being pregnant.

3. Posting. In place of either or both of the above—or in addition to them—posters can be obtained, or signs can be made, that caution the patient to tell the radiologic technologist if she suspects that she might be pregnant. Most facilities will post these signs in waiting rooms, dressing rooms, and radiographic rooms.
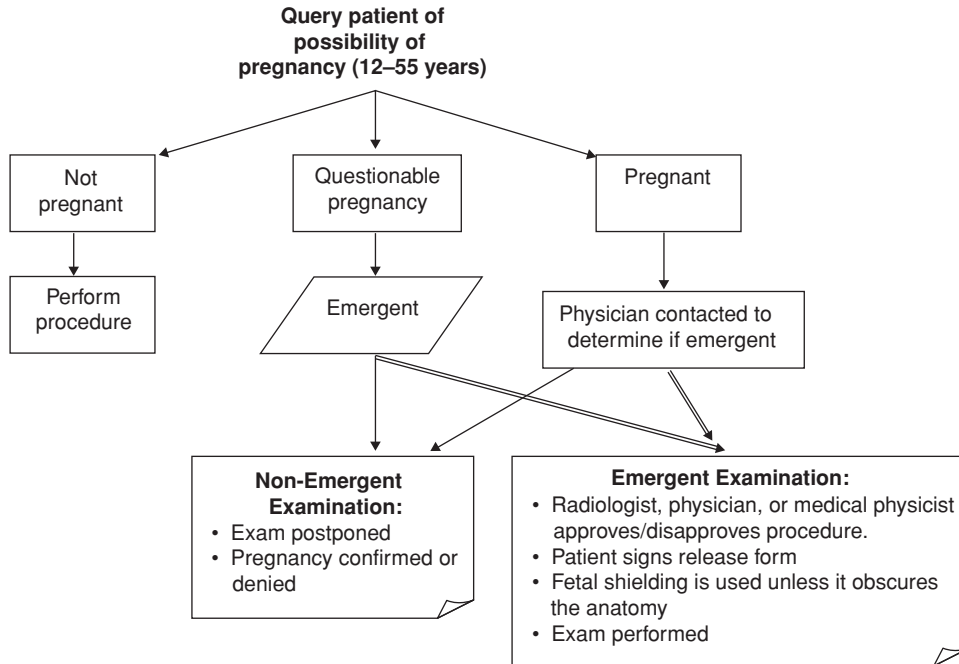
Figure 7–10. Algorithm for questioning female patients having reproductive potential. (Courtesy of Tom Piccoli, DABR.)

Concern is occasionally expressed regarding dose received during diagnostic *mammography*. Yet the risk associated with the x-ray dose received is minimal compared to the benefits of early detection of breast cancer. The use of dedicated mammography equipment with digital or screen–film technique performed by credentialed radiographers delivers a very low skin and glandular dose.

C. MALES

Because of the location of the gonads and *shielding* restrictions thus imposed in the female patient, the female gonads (ovaries) receive more radiation exposure than the male gonads (testes) undergoing similar examinations. The ovaries lie within the abdominal cavity and frequently cannot be effectively shielded during abdominal, pelvic, and lumbar spine radiography. Therefore, they can receive far more organ dose than the shielded testes (which are located outside the abdominal cavity) during diagnostic examinations of the abdominal region (e.g., lumbar spine, upper and lower GI, intravenous or retrograde pyelography).

It is important to note that the ovarian stem cells, the oogonia, reproduce only during fetal life. During childbearing years, there are only 400 to 500 mature ova accessible for fertilization, that is, one ovum per menstrual cycle for each of the fertile years. The male germ cells, spermatogonia, are being produced continuously and longevity of fertility is quite different than in the female.

D. CHILDREN

The female oogonia of fetal life and early childhood and male spermatogonia are especially radiosensitive because of their immature

stage of development. Consequently, particular care should be taken to adequately shield the reproductive organs of pediatric patients. All too often a radiographer will conscientiously shield adult patients of reproductive age, but fail to consider children whose reproductive lives are ahead of them and whose reproductive cells are particularly radiosensitive.

Very sizable doses of radiation to children are also thought to be associated with increased incidence of leukemia and other radiation-induced malignancies. Examples of high-risk examinations might include pelvic and abdominal radiography and examinations requiring periodic follow-ups, such as scoliosis series. It is advisable to shield the hematopoietic bones of children to reduce radiation dose to blood-forming cells.

E. GENETICALLY SIGNIFICANT DOSE

Each member of the world's population bears a particular genetic dose of radiation. Its sources include environmental exposure, radiation received for medical and dental purposes, and occupational exposure. The quantity of exposure to each individual depends on that individual's geographic location (environmental radiation and elevation of terrain), overall general health, the accessibility of health care, and the occupational worker's adherence to radiation protection guidelines. Generally speaking, the genetic dose to an *individual* is very small. Some individuals may receive no genetic dose in a given year, some individuals are past their reproductive years, and some individuals will not or cannot bear children. Even if some individuals receive larger quantities of radiation exposure, its impact is "diluted" by the total number of population. This concept is referred to as *genetically significant dose*, defined as the average annual gonadal dose to the population of childbearing age, and estimated to be 20 mrem.

It is appropriate to mention *repeat radiographs* at this time. Poor images resulting from technical error (e.g., incorrect positioning, improper selection of technical factors) or equipment malfunction must be repeated, thereby subjecting the patient to twice the necessary exposure dose. An exceedingly important feature with significant impact on patient dose is appropriate *collimation*. An important part of radiation protection, then, is care and attention to detail to avoid technical errors requiring repeat images. Another component is a quality assurance program (through an ongoing preventive maintenance program and appropriate inservice education) that assures proper equipment function and compliance with established standards.

V. SOMATIC EFFECTS

Somatic effects of radiation are those that affect the irradiated body itself. Somatic effects are described as being *early* or *late*, depending on the length of time between irradiation and manifestation of effects.

Early somatic effects are manifested within minutes, hours, days, or weeks of irradiation, and occur only following a very large dose of ionizing radiation. It must be emphasized that doses received from diagnostic radiologic procedures are not sufficient to produce these early effects. An exceedingly *high dose of radiation delivered to the*

whole body in a short period of time is required to produce early somatic effects.

A. CARCINOGENESIS

Late somatic effects are those that can occur years after initial exposure and are caused by low, chronic exposures. Occupationally exposed personnel are concerned with the late effects of radiation exposure. Some somatic effects like *carcinogenesis* have been mentioned earlier: the *bone malignancies* developed by the radium watch-dial painters as a result of radiation exposure to bone marrow, the *thyroid* cancers of the individuals irradiated as children for thymus enlargement, the leukemia eventually developed by patients whose pain from anky-losing spondylitis was relieved by irradiation, and the *skin cancers* developed by early radiology pioneers working so closely with the "unknown ray." These malignancies are examples of somatic effects of radiation.

B. CATARACTOGENESIS

Another example of somatic effects of radiation is *cataract* formation to the lenses of eyes of those individuals accidentally exposed to suf-ficient quantities of radiation (e.g., early cyclotron experimenters).

C. LIFE SPAN SHORTENING

The lives of many of the early radiation workers were several years shorter than the lives of the general population. Statistics revealed that radiologists, for example, had a shorter life span than physicians of other specialties. *Life span shortening*, then, *was* another somatic effect of radiation. Certainly, these effects should *never be experienced today*. So much has been learned about the biologic effects of radiation since its discovery and a part of what we have learned has, sadly, been as a result of the experiences of the radiology pioneers.

D. REPRODUCTIVE RISKS

The human reproductive organs are particularly radiosensitive. *Fertility* and *heredity* are greatly affected by the *germ cells* produced within the testes (*spermatogonia*) and ovaries (*oogonia*). Excessive radiation exposure to the gonads can cause *temporary or permanent sterility*, and/or *genetic mutations*.

E. EMBRYOLOGIC/FETAL EFFECTS

Embryologic/fetal effects are those experienced by the body of the developing embryo or fetus. Spontaneous abortion, skeletal or neuro-logic anomalies (mental retardation and microcephaly), and leukemia are examples of embryologic or fetal somatic effects.

F. SYSTEMIC EFFECTS

After a large dose (at least 2 Gy or 200 rad) of radiation to the *skin*, a mild *erythema* will result in 1 or 2 days. With a large enough dose, in approximately 2 weeks, a moist *desquamation* can occur followed by a dry desquamation. It takes approximately 5 Gy or 500 rad to produce skin erythema (*skin erythema dose [SED]*) in 50% of a population so

exposed. This is termed the SED$_{50}$. Another skin response is *epilation*, that is, hair loss as a result of damage to hair follicles and associated structures.

Most blood cells in circulation are manufactured by the bone marrow. The most radiosensitive of these cells are the *lymphocytes*—cells involved in immune response. They are the first to demonstrate depletion after a large enough exposure (0.25 Gy or 25 rad threshold), although all cells will decrease in number following a large dose of ionizing radiation.

Sufficient exposure of the *hematologic* system to ionizing radiation can result in nausea, vomiting, diarrhea, decreased blood count, and infection. Very large exposure of the *GI system* (10–50 Gy or 1000–5000 rad) causes severe damage to the (stem) cells lining the GI tract. This can result in nausea, vomiting, diarrhea, blood changes, and hemorrhage.

Exposure greater than 50 Gy or 5000 rad will affect the normally resilient *central nervous system*. Effects occur very quickly and include those mentioned above as well as ataxia and shock.

■ *SUMMARY*

- Delivery of ionizing radiation during early pregnancy is particularly hazardous.
- Possible responses to irradiation in utero include spontaneous abortion, congenital anomalies, mental retardation, microcephaly, and leukemia or other childhood malignancies.
- Elective booking, patient questionnaire, and posting are suggested ways to avoid irradiation of a new embryo/fetus.
- Gonadal shielding is easier in the male patient because the reproductive organs are located externally.
- All children should be shielded whenever possible.
- Genetic effects refer to damage to reproductive cells, affecting the reproductive capacity of the individual, or creating mutations that will be passed on to future generations.
- The genetic dose of radiation borne by each member of the reproductive population is called the genetically significant dose.
- Somatic effects include those manifesting themselves in the exposed individual and can be described as early or late effects.
- Early somatic effects can occur only after a very large single exposure of radiation to the whole body.
- Late somatic effects include carcinogenesis, cataractogenesis, embryologic effect, life span shortening, reproductive risks, and systemic effects.
- Occupationally exposed personnel are concerned with the late effects of radiation exposure.

Chapter Exercises

Congratulations! You have completed this chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to the multiple-choice questions without first completing the short-answer questions below.

1. List various kinds of electromagnetic radiation *(p. 231).*

2. Identify the way in which all electromagnetic radiations are similar and in what respects they differ *(p. 231).*

3. Define the terms *wavelength* and *frequency (p. 231).*

4. Explain how wavelength and energy, and how frequency and energy, are related *(pp. 231–233).*

5. Describe what is meant by the term *ionizing* radiation and how it differs from other electromagnetic radiations *(p. 232).*

6. Give examples of natural and artificial/man-made background radiations and identify the percentage each contributes to the population's annual radiation dose *(p. 232).*

7. What are the two ways in which x-ray photons are produced at the tungsten anode? Describe each. Which occurs more often *(pp. 232–233)?*

8. Describe the photoelectric effect and Compton scatter. The following should be included in your description *(pp. 233–235).*
    A. energy required for production of each
    B. electron shell involved
    C. any electron shell vacancy or occupancy changes
    D. type of absorber (atomic number) most likely involved
    E. retention or loss of energy of incoming photon
    F. interaction associated with a recoil electron
    G. effect on image contrast
    H. impact on patient dose

9. Describe the purpose of dose–response (dose–effect) curves *(p. 236).*

10. Describe the difference between linear and nonlinear dose–response curves *(p. 236).*

11. Describe the difference between threshold and nonthreshold dose–response curves *(p. 236).*

12. Differentiate between stochastic and nonstochastic effects *(p. 236).*

13. Name the type of dose–response curve that identifies *no* safe dose *(p. 236).*

14. Explain why occupationally exposed individuals are mainly concerned with the late, or long-term, effects of radiation exposure *(p. 237).*

15. List possible long-term effects of radiation exposure *(p. 237).*

16. List the three types of cells described by Bergonié and Tribondeau in 1906 as being the most radiosensitive *(p. 238).*

17. What is described as the rate at which radiation deposits energy in tissue *(p. 238)?*

18. Why is a W_r assigned to different types of radiation; a W_t assigned to different tissue types *(p. 238)?*

19. How can effective dose (*EfD*) be determined *(p. 238)?*

20. How are LET and RBE related *(p. 238)?*

21. With respect to the molecular effects of radiation, describe the difference between the direct and indirect effects; identify the one that occurs more frequently in the diagnostic range *(p. 239).*

22. What type(s) of DNA damage is/are repairable; which can result in cell death; mutation *(p. 239)?*

23. Identify each of the following as either radiosensitive or radioresistant: muscle, nerve (fetal and adult), and epithelial tissue; lymphocytes; and reproductive cells *(pp. 239–240).*

24. How does each of the following affect the response of tissue to irradiation: tissue age, oxygen content, fractionation/protraction of radiation delivery *(p. 240)?*

25. Identify the meaning of the acronym ALARA and how it relates to the radiographer *(p. 240).*

26. What is the most radiosensitive portion of the human gestational period? List four possible results of excessive radiation exposure during this period *(p. 242).*

27. What can result from excessive radiation exposure during the second and third trimesters of pregnancy *(p. 242)?*

28. How much radiation exposure is necessary to produce fetal anomalies? Approximately how much fetal radiation do most diagnostic examinations deliver *(p. 242)?*

29. List three methods the radiology department can use to avoid irradiating a newly fertilized ovum *(p. 242).*

30. Explain the value of determining the LMP for female patients of childbearing age *(p. 242).*

31. Describe the effectiveness of gonadal shielding in the male versus female patient; discuss the importance of shielding children *(p. 243)*.

32. Describe the concept of genetically significant dose *(p. 244)*.

33. Why are we concerned with genetic dose? When do genetic effects manifest themselves *(p. 244)?*

34. Distinguish between early and late somatic effects; when does each occur with respect to initial exposure? Can you give historic examples of each *(pp. 244–246)*.

35. What kind of radiation exposure would be required to cause early somatic effects? Give examples of early somatic effects *(pp. 244–245)*.

36. What kind of radiation exposure is characteristic of late somatic effects? Give examples of late somatic effects *(p. 245)*.

Chapter Review Questions

1. The type of dose–response curve used to predict stochastic effects is the:
   (A) nonlinear nonthreshold
   (B) nonlinear threshold
   (C) linear nonthreshold
   (D) linear threshold

2. A dose of 0.25 Gy or 25 rad to the fetus during the 3rd or 4th week of pregnancy is more likely to cause which of the following:
   (A) spontaneous abortion
   (B) skeletal anomalies
   (C) neurologic anomalies
   (D) organogenesis

3. Linear energy transfer (LET) is:
   1. a method of expressing radiation quality
   2. a measure of the rate at which radiation energy is transferred to soft tissue
   3. absorption of polyenergetic radiation
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

4. What is the effect on relative biologic effectiveness (RBE) as linear energy transfer (LET) decreases?
   (A) as LET decreases, RBE increases
   (B) as LET decreases, RBE decreases
   (C) as LET decreases, RBE stabilizes
   (D) LET has no effect on RBE

5. The effects of radiation to biologic material are dependent on several factors. If a quantity of radiation is delivered to a body over a long period of time, the effect:
    (A) will be greater than if it were delivered all at one time
    (B) will be less than if it were delivered all at one time
    (C) has no relation to how it is delivered in time
    (D) is solely dependent on the radiation quality

6. Which of the following account(s) for x-ray beam heterogeneity?
    1. incident electrons interacting with several layers of tungsten target atoms
    2. electrons moving to fill different shell vacancies
    3. its nuclear origin
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

7. What is used to account for the relative radiosensitivity of various tissues and organs:
    1. tissue weighting factors (W_t)
    2. radiation weighting factors (W_r)
    3. absorbed dose
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

8. How are wavelength and energy related?
    (A) directly
    (B) inversely
    (C) chemically
    (D) empirically

9. The beam of x-ray photons leaving the x-ray tube focus can be described as having what sort of nature?
    (A) homogeneous
    (B) heterogeneous
    (C) homologous
    (D) focused

10. Long-term effects of radiation exposure include:
    1. formation of cataracts
    2. cancer
    3. genetic effects
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

Answers and Explanations

1. (C) The linear nonthreshold curve is used to illustrate responses such as leukemia, cancer, and genetic effects. These are also referred to as stochastic effects. Stochastic effects occur randomly and are "all-or-nothing" type effects; that is, they do not occur with degrees of severity. Remember that *in a nonthreshold curve there is no safe dose*, that is, no dose below which there will definitely be no biologic response. Theoretically, even one x-ray photon can cause a biologic response. The linear nonthreshold curve is the curve of choice to predict effects of low level (e.g., medical and occupational) exposure to ionizing radiation.

2. (B) During the first trimester, specifically the 2nd to 8th week of pregnancy (during major organogenesis), if the radiation dose is at least 0.2 Gy or 20 rad, fetal anomalies can be produced. *Skeletal anomalies* usually appear if irradiation occurs in the early part of this time period, and *neurologic anomalies* are formed in the latter part; mental retardation and childhood malignant diseases, such as cancers or leukemia, can also result from irradiation during the first trimester. Fetal irradiation during the second and third trimesters is not likely to produce anomalies, but rather, with sufficient dose, some type of childhood malignant disease. Fetal irradiation during the first 2 weeks of gestation can result in *spontaneous abortion.*

   It must be emphasized that the likelihood of producing fetal anomalies at doses below 0.2 Gy or 20 rad is exceedingly small and that most general diagnostic examinations are likely to deliver fetal doses of less than 0.01–0.02 Gy or 1–2 rad.

3. (B) When biologic material is irradiated, there are a number of modifying factors that determine what kind and how much response will occur in the biologic material. One of these factors is LET, which expresses the rate at which particulate or photon energy is transferred to the absorber. Because different kinds of radiation have different degrees of penetration in different materials, it is also a useful way of expressing the quality of the radiation.

4. (B) LET expresses the rate at which photon or particulate energy is transferred to (absorbed by) biologic material (through ionization processes) and is dependent on radiation type and tissue absorption characteristics. RBE describes the degree of response or amount of biologic change we can expect of the irradiated material, and is *directly related to LET*. As the amount of transferred energy (LET) *increases* (from interactions occurring between radiation and biologic material), the amount of biologic effect or damage (RBE) will also *increase*; as the amount of LET *decreases,* the RBE will also *decrease.*

5. (B) The effects of a quantity of radiation delivered to a body is dependent on a few factors, including the amount of radiation received, the size of the irradiated area, and how the radiation is delivered in time. If the radiation is delivered in portions over a period of time, it is said to be fractionated and has a less harmful effect than if the radiation was delivered all at once. Cells have an opportunity to repair and some recovery occurs between doses.

6. (B) The x-ray photons produced at the tungsten target comprise a heterogeneous beam, that is, a spectrum of photon energies. This is accounted for by the fact that the incident electrons have different energies. Also, the incident electrons travel through several layers of tungsten target material, lose energy with each interaction, and therefore produce increasingly weaker x-ray photons. During characteristic x-ray production, vacancies may be filled in the K, L, or M

shells, differing with each other in binding energies, and therefore, a variety of energy photons are emitted.

7. (A) The *tissue weighting factor* (W_t) represents the relative tissue radiosensitivity of irradiated material (e.g., muscle vs. intestinal epithelium vs. bone, etc.). The radiation weighting factor (W_r) is a number assigned to different types of ionizing radiations to better determine their effect on tissue (e.g., x-ray vs. alpha particles). The W_r of different ionizing radiations is dependent on the LET of that particular radiation. The following formula is used to determine *effective dose* (*EfD*).

Effective dose (*EfD*) =
  Radiation weighting factor (W_r) × Tissue weighting factor (W_t) × Absorbed dose (D)

8. (B) Frequency and wavelength are closely associated with the relative energy of electromagnetic radiations. *More energetic radiations have shorter wavelengths and higher frequency*; thus, they are inversely related. The relationship between frequency, wavelength, and energy is illustrated in the electromagnetic spectrum (Fig. 7–1). Some radiations are energetic enough to rearrange atoms in materials through which they pass, and can therefore be hazardous to living tissue.

9. (B) Electrons may undergo any one of a few types of interactions as they encounter the target. The emitted photons can therefore have a variety of energies and thus are termed heterogeneous or polyenergetic. It is only at extremely high energies that photon energy becomes more homogeneous; only gamma radiation can be accurately termed homogeneous or monoenergetic.

10. (D) Occupationally exposed individuals are concerned principally with *late* (i.e., *long-term* or *delayed*) effects of radiation, such as *genetic effects*, *leukemia*, *cancers*, and *cataractogenesis*, which can occur many years following initial exposure to low levels of ionizing radiation. These long-term, or delayed, effects are represented by the linear, nonthreshold, dose–response curve, with the exception of cataractogenesis, which is represented by the linear, threshold, dose–response curve. An acute dose of approximately 200 rad would be required to cause radiogenic cataracts. A far greater occupational (i.e., fractionated) dose of approximately 1000 rad would be required to induce cataracts.

Patient Protection
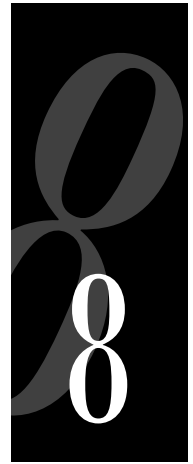
All radiologic imaging professionals have the ethical responsibility to keep radiation exposure to patients (and themselves) to an absolute minimum. This chapter reviews means of achieving this goal.

Statistics indicate that the number of radiologic imaging examinations performed annually is steadily increasing. Although the benefits of these examinations far outweigh the risks, the concern about the risk of possible long-term effects of x-ray exposure obliges us to practice the *ALARA* (as low as reasonably achievable) principle.

One exceedingly important consideration in reducing patient exposure is *good patient communication*. Explaining the examination and answering the patient's questions will better ensure understanding and cooperation and reduce the chance for retakes.

Quality assurance programs are in place to ensure that retakes will not be required as a result of equipment malfunction. Employees receive orientation on new equipment to ensure that it is used to best advantage and to reduce retakes as a result of unfamiliarity with equipment operation.

The following topics discuss important factors having impact on patient protection.

Beam Restriction

- reduces patient dose
- improves image quality

I. BEAM RESTRICTION

A. PURPOSE

Beam restriction, or limitation of irradiated field size, is probably the single most important factor in keeping patient dose to a minimum. The primary beam must be confined to the area of interest; thus, only tissues of diagnostic interest should be irradiated.

Another benefit of beam restriction is that, because a smaller quantity of tissue is irradiated, less scattered radiation will be produced. Remember, scattered radiation does not carry useful information; it degrades the radiographic image by adding a layer of fog that impairs image visibility.

There are three basic types of *beam restrictors*: aperture diaphragms, cones, and collimators.

B. Types

1. Aperture Diaphragms.

The *aperture diaphragm* is the most elementary of the three types and is frequently used in dedicated head units and many dedicated chest units. It is simply a flat piece of lead (Pb) having a central opening with a size and shape that determines the size and shape of the x-ray beam. Head units have a variety of aperture diaphragm sizes available for various types of skull examinations and required cassette sizes. Today's dedicated chest units frequently have a fixed aperture diaphragm. Regardless of the type, the aperture diaphragm should demonstrate adequate beam restriction by providing an unexposed border around the edge of the x-ray image.

2. Cones.

Cones are circular, lead-lined devices that slide into place in the tube head or onto the collimator housing. They may be the straight *cylinder* type, with proximal and distal diameters that are identical, or the infrequently used *flare type*, with a distal diameter that is greater than its proximal diameter. Cylinder cones are frequently able to extend, like a telescope, by means of a simple thumbscrew adjustment (Fig. 8–1).

A disadvantage of both the aperture and cone is that they have a fixed opening size, which will provide only one field size at a given distance. To change the size of the irradiated field, the radiographer must change to a different size aperture or cone. Additionally, the cylinder cone can be used only for relatively small field sizes, such as the paranasal sinuses, L5–S1, or other small areas of interest.

Beam Restrictor Types

- Aperture Diaphragm
- Cone
- Collimator

Figure 8–1. Cylinder cones (especially the extendible type) are generally considered more efficient than aperture diaphragms because they restrict the size and shape of the x-ray beam for a greater distance. The closer the distal end of the beam restrictor is to the area of interest, the greater its efficiency. (Courtesy of Burkhart Roentgen, Inc.)

3. Collimators. The *collimator* is, overall, the most efficient beam-restricting device. It is attached to the tube head, and its upper aperture, the first set of shutters, is placed as close as possible to the x-ray tube port window (Fig. 8–2). This is done to control the amount of image degrading "off-focus" radiation leaving the x-ray tube (i.e., radiation produced when electrons strike surfaces other than the focal track). The next set of *lead shutters* ("blades" or "leaves") actually consists of two pairs of adjustable shutters—one pair for field length and another pair for field width. It is these shutters that are used to change the field size and shape.

C. LIGHT-LOCALIZATION APPARATUS

Another important part of the collimator assembly is the *light-localization apparatus*. It consists of a small light bulb (to illuminate the field) and a mirror. For the light field and x-ray field to correspond accurately, *the x-ray tube focal spot and the light bulb must be exactly at the same distance from the center of the mirror* (Fig. 8–2). If the light and x-ray fields do not correspond, image receptor alignment can be "off" enough to require a repeat examination.

Collimator accuracy should be regularly checked as part of the quality assurance program. National Council on Radiation Protection and Measurements (NCRP) guidelines state that collimators must be accurate to within 2% of the source-to-image-receptor distance (SID).

D. ACCURACY

Cylinder cones are sometimes attached to the tube housing and used in conjunction with collimators. It is important to collimate to the approximate cone diameter size; wide-open collimator shutters can lead to excessive scattered radiation production and can degrade the resulting radiographic image.

As a backup to the illuminated light field, should the light bulb burn out, there is a calibrated scale on the front of the collimator that indicates the x-ray field size at various SIDs.

An important feature of nearly all collimators today (radiographic and fluoroscopic) is *positive beam limitation (PBL)*. Sensors located in the Bucky tray or other cassette holder signal the collimator to open or close according to the cassette size being used in the Bucky tray. A properly calibrated PBL system will provide a small unexposed border on all sides of the finished radiograph and is required by NCRP guidelines to be accurate to within 3% of the SID for a single side, and within 4% of the SID total for all sides (e.g., if PBL inaccurate by 2.75% in one direction, it is acceptable as long as inaccurate less than 1.25% in other directions). The NCRP guideline for *manual* collimation is to be within 2% of the SID.
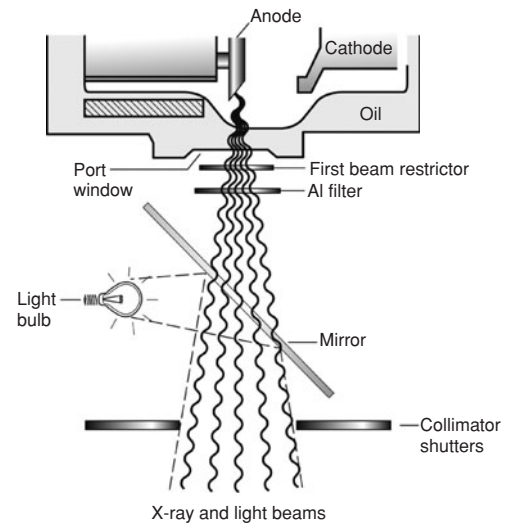
Figure 8–2. X-ray tube, filters, and collimator. The position of the collimator shutters can be seen. Note the position of the first beam restrictor, located at the x-ray tube port window. The oil coolant surrounding the x-ray tube contributes to inherent filtration. Added filtration includes the aluminum filter, the mirror, and collimator.

■ SUMMARY

- **Beam restriction is the most important way to reduce patient dose.**
- **Beam restrictors reduce the production of scattered radiation.**

- **Types of beam restrictors include aperture diaphragms, cones and cylinders, and collimators.**
- **Most x-ray equipment today uses PBL.**
- **A properly calibrated PBL device will provide an unexposed border on all sides of the finished radiograph.**
- **For the light and x-ray field to correspond accurately, the focal spot and light bulb must be exactly the same distance from the mirror.**

II. EXPOSURE FACTORS

A. mAs AND kV

Selection of exposure factors has a significant impact on patient dose. Remember that milliampere-seconds (mAs) is used to regulate the *quantity* of radiation delivered to the patient, and *kV* (kilovoltage) determines the *penetrability* of the x-ray beam. As kilovoltage is increased, more high-energy photons are produced and the overall average energy of the beam is increased. An increase in mAs increases the number of photons produced at the target, but mAs is unrelated to photon energy.

Generally speaking then, in an effort to keep radiation dose to a minimum, it makes sense to use the lowest mAs and the highest kV that will produce the desired radiographic results. An added benefit is that at high kV and low mAs values, the heat delivered to the x-ray tube is lower and tube life is extended.

B. GENERATOR TYPE

Three-phase or high-frequency generators predominate in stationary radiologic equipment today. They produce a nearly constant potential waveform, thereby offering the advantage of *reducing patient dose* somewhat. If voltage never drops to zero, more high-energy photons are produced—that have less likelihood of being absorbed by the patient. High-frequency generators are often smaller, more efficient, and less costly than the older high-voltage generators.

III. FILTRATION

X-ray photons emanating from the target/focal spot comprise a *polyenergetic* primary beam. There are many low-energy (or "soft") x-rays that, if not removed, would contribute significantly to patient *skin dose*. These low-energy photons are too weak to penetrate the patient and expose the image receptor; they simply penetrate a small thickness of tissue before being absorbed. Filters, usually made of aluminum, are used in radiography to reduce patient dose by removing this low-energy radiation (i.e., *decreased* beam *intensity*), and resulting in an x-ray beam of *higher average energy. Total filtration* is composed of *inherent filtration* plus *added filtration.*

A. INHERENT FILTRATION

Inherent filtration is that which is "built-in" and is composed of materials that are a permanent part of the tube housing, that is, the *window*

of the *glass envelope* (∼0.5 mm Al equivalent) of the x-ray tube, its *oil coolant*, and the *collimator* and its mirror (∼1.0 mm Al equivalent). The glass envelope window in *mammographic* x-ray tubes is often made of *beryllium*, that is, a substance having a low atomic number ($Z\# = 4$) and that has an inherent filtration of approximately 0.1 mm Al equivalent.

B. ADDED FILTRATION

Added filtration refers to the *thin sheets of aluminum* that are added (Fig. 8–2) to make the necessary total thickness of aluminum equivalent filtration. For equipment operated above 70 kV, the total filtration requirement is 2.5 mm Al equivalent.

The effect of total aluminum filtration is to remove the low-energy photons, thereby *decreasing patient skin dose*, and resulting in an x-ray beam having *higher average energy* and greater penetrability.

C. NCRP GUIDELINES

NCRP guidelines state that equipment operating above 70 kV must have a minimum *total* (inherent plus added) filtration of 2.5 *mm Al equivalent*. Equipment operating between 50 and 70 kV must have at least 1.5 mm Al equivalent filtration. X-ray tubes operating below 50 kV must have at least 0.5 mm Al equivalent filtration. Mammography equipment with a molybdenum target will have 0.025- to 0.03-mm molybdenum filtration. For magnification studies, a fractional tungsten target tube, having at least 0.5 mm Al equivalent total filtration, may be used.

Inherent filtration tends to increase as the x-ray tube ages. With use, tungsten evaporates and is deposited on the inner surface of the glass envelope, effectively acting as additional filtration and decreasing tube output.

Filtration Summary

<50 kV = 0.5 mm Al equivalent
50–70 kV = 1.5 mm Al equivalent
>70 kV = 2.5 mm Al equivalent

■ SUMMARY

- **Low mAs and high kV factors keep patient dose to a minimum.**
- **Proper calibration of equipment is essential for predictable results.**
- **Proper selection of technical factors and an effective QA system help reduce radiation exposure.**
- **Filtration removes low-energy x-rays from primary beam, thereby**
  - **reducing patient skin dose and**
  - **increasing the average energy of the beam.**
- **Filtration is usually expressed in mm of Al equivalent.**
- **Inherent + added filtration = total filtration.**
- **Inherent filtration includes the glass envelope, oil coolant, and collimator and its mirror.**
- **Equipment operated above 70 kV must have at least 2.5 mm Al equivalent.**
- **Inherent filtration increases with tube age, thereby decreasing tube output.**
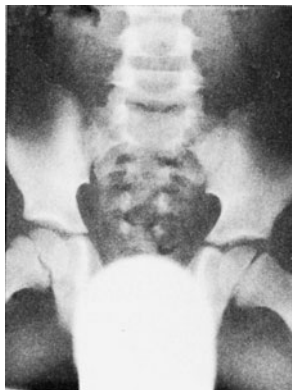
Figure 8–3. Correct placement of shadow shield. (Courtesy of C.B. Radiology Design, Jamestown, NY.)

Gonadal Shielding Should Be Used If

- the gonads lie in, or within 5 cm of, the collimated field;
- the patient has reasonable reproductive potential;
- diagnostic objectives permit.

IV. SHIELDING

A. RATIONALE FOR USE

Protective shielding to reduce unnecessary radiation exposure for especially radiosensitive organs (i.e., gonads, lens, blood-forming organs) should be provided whenever possible during radiographic and fluoroscopic examinations (Fig. 8–3).

There are three indications for the effective use of gonadal shields. If the gonads lie in or within 5 cm of a well-collimated field, shielding should be used. A patient with reasonable reproductive potential should be shielded; a generally accepted procedure is to include all women younger than 55 years and men younger than 65 years. Gonadal shielding should be used if diagnostic objectives permit, that is, as long as the shield does not obscure important diagnostic information. Protective shields must be carefully placed; superimposition on diagnostically important anatomic structures can cause retakes and exposure to unnecessary radiation. Accurate positioning and beam restriction must always accompany gonadal shielding. When positioning body parts such as the extremities or the breast, the radiographer must be certain that the unshielded gonads do not intercept any of the primary/useful x-ray beam.

The use of protective shielding during mobile radiography should not be neglected. *Gonadal shielding* is far more effective in the male patient because the reproductive organs lie outside the body. Male patients are therefore more easily shielded, and shielding is much less likely to interfere with the diagnostic objectives of the examination. Female reproductive organs are located within the abdominal cavity, where shielding becomes a much less feasible option.

B. TYPES AND PLACEMENT OF SHIELDS

There are three types of gonadal shields available: flat, contact shields; shadow shields; and contour (shaped) contact shields.

1. Flat, Contact. The simplest types are flat, *contact shields*, such as pieces of lead-impregnated vinyl that are placed over the patient's gonads. Because they are difficult to secure in place, flat contact shields are useful only for anteroposterior (AP) or posteroanterior (PA) recumbent positions. They cannot be secured adequately for oblique, lateral decubitus, erect, or fluoroscopic procedures.

2. Shadow. *Shadow shields* attach to the x-ray tube head. They consist of a piece of leaded material attached to an arm extending from the tube head (Fig. 8–4). The leaded material casts a shadow within the illuminated field that corresponds to the shielded area. Although shadow shields are initially more expensive, they are likely to be a one-time expense. Shadow shields can be used for more positions than flat contact shields and may also be used without contaminating a sterile field. They cannot be used for fluoroscopic procedures.

3. Contour (Shaped) Contact Shields. *Contour* (shaped) *contact shields* are very effective gonadal shields. They are shaped to enclose
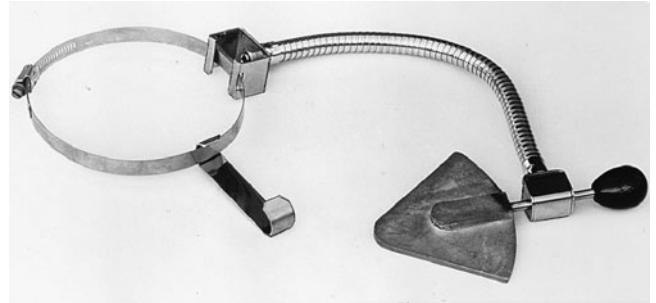
Figure 8–4. **(A)** and **(B)** A shadow shield is attached to the collimator housing. It has a moveable arm that allows a shield of the desired size and shape to be placed in the radiation field over the gonadal area. It is manually operated and swings away when not in use. (Courtesy of Nuclear Associates.)

the male reproductive organs and held in place by disposable briefs (Fig. 8–5). They are effective for a variety of positions, including oblique, erect, and fluoroscopic procedures.

4. Breast Shields. *Breast shields* should be used for female patients during scoliosis series. Scoliosis series are typically performed at ages when developing breast tissue is particularly radiosensitive. Breast shields are available incorporated in vertebral column compensating filters (Fig. 8–6), and as leaded vinyl vests ("spinal stoles," – Fig. 8–7) that can be used in upright or recumbent positions. Additionally, when performed *PA*, radiation dose to the breast can be reduced to *0.1%* of that received in the AP projection; magnification considerations are minimal.

Some companies have environmentally friendly recycle/renew programs. They will recycle frontal or full protection aprons into smaller/half aprons, thyroid shields, gonad shields, etc. for up to half the price of a new shield. Some companies will safely dispose of old lead aprons for a small fee.

Additionally, there are some new types of "lead" shields that are completely lead-free, very light-weight, provide 0.5 mm lead equivalency, and are environmentally friendly.

C. PATIENT POSITION

Because the primary x-ray beam has a *polyenergetic* (heterogeneous) nature, the entrance or skin dose is significantly greater than the

Figure 8–5. Male gonad shield inserts into a disposable brief. Male gonadal shielding can reduce gonadal dose by more than 90%. (Courtesy of Shielding International.)

Figure 8–6. Spinal column studies are often required for evaluation of adolescent scoliosis, thus presenting a twofold problem: radiation exposure to youthful gonadal and breast tissues, and significantly differing tissue densities and thicknesses. Both problems can be resolved with the use of a compensating filter (for uniform density) that incorporates lead shielding for the breasts and gonads. **(A)** Performed without the filter/shield. **(B)** Performed with the filter/shield. Note the improved visualization of the entire vertebral column and appropriate protection of the breasts and gonads. (Courtesy of Nuclear Associates.)
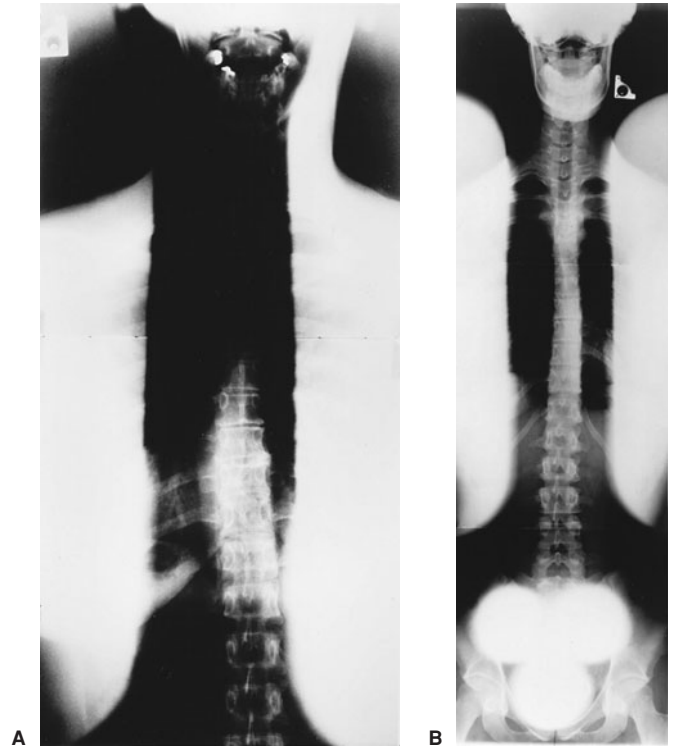
Figure 8–7. Breast shields are available as leaded vinyl vests, "spinal stoles," that can be used in upright or recumbent positions. (Courtesy of Shielding International.)

exit dose. This principle may be employed in radiation protection by placing particularly radiosensitive organs away from the primary beam.

To place the gonads further from the primary beam and reduce gonadal dose, abdominal radiography should be performed in the PA position whenever possible. Dose to the lens is significantly decreased when skull radiographs are performed in the PA position.

The same principle applies when performing scoliosis series on young children in an effort to reduce gonadal dose, and to decrease dose to breast tissue in young girls. Dose to breast tissue during scoliosis survey can also be reduced with the use of breast shields. The PA projection does not generally cause a significant adverse effect on recorded detail and is advocated to decrease dose to the reproductive organs and other radiosensitive areas.

Lead aprons can also be placed over chest/abdomen during radiography of various body parts to protect radiosensitive organs from unnecessary exposure to scattered radiation. Half aprons can be used to protect the gonads from scattered radiation in chest radiography.

■ SUMMARY

- **Especially radiosensitive organs include the gonads, lenses, and blood-forming organs.**
- **Gonadal shielding should be used**
  - **if the gonads lie in or within 5 cm of collimated beam,**
  - **if the patient has reproductive potential, and**
  - **if diagnostic objectives permit.**

- **Three types of gonadal shields are**
  - **flat contact,**
  - **shadow, and**
  - **contour contact.**
- **Male gonads are more easily and effectively shielded.**
- **Breast shields should be used as needed.**
- **To reduce exposure to reproductive organs and/or breasts, it is helpful to perform abdominal radiography and scoliosis series in the PA position whenever possible.**

V. REDUCING PATIENT EXPOSURE

A. PATIENT COMMUNICATION

Gaining the patient's confidence and trust through effective communication is an essential part of the radiographic examination. Some patients will require a greater use of the radiographer's communication skills—patients who are seriously ill or injured; traumatized patients; patients who have impaired vision, hearing, or speech; pediatric patients; non–English-speaking patients; the elderly and infirm; the physically or mentally impaired; alcohol and drug abusers—the radiographer must adapt his or her communication skills to meet the needs of many types of individuals. It is imperative that the radiographer take adequate time to thoroughly explain the procedure or examination to the patient.

The radiographer requires the cooperation of the patient throughout the course of the examination. A thorough explanation will alleviate the patient's anxieties and permit fuller cooperation. Better understanding and cooperation will yield a good radiographic image and reduce the likelihood of repeat exposures. *Repeat exposures contribute to a significant increase in unnecessary patient exposure*, as well as increased facility expense.

B. POSITIONING OF PATIENT

Another means of reducing patient exposure is by careful and accurate positioning. As mentioned above, repeat exposures contribute to a significant increase in unnecessary patient exposure, as well as increased facility expense.

Exact positioning and centering is particularly critical when using automatic exposure control (AEC). The anatomic part of interest must be positioned (centered) accurately with respect to the AEC's sensors; otherwise, the resulting image can be over- or underexposed.

C. AUTOMATIC EXPOSURE CONTROL

An *AEC* is used to automatically regulate the amount of ionizing radiation delivered to the patient and image recorder, thereby serving to produce consistent and comparable radiographic results time after time. When AEC is installed in the x-ray circuit, it is calibrated to produce radiographic densities as required by the radiologist. AECs have sensors that signal to terminate the exposure once a predetermined, known-correct exposure has been reached. When using film/screen
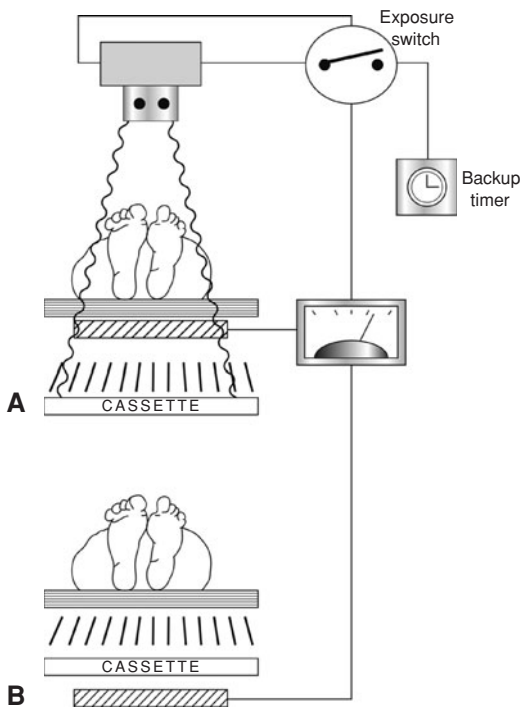
Figure 8–8. Two types of AECs. **(A)** The ionization chamber is positioned between the tabletop and cassette. **(B)** The photomultiplier/phototimer is located below the cassette. Note that a backup timer, which serves to terminate the exposure in the event of AEC failure, is used in conjunction with both AECs.

systems, it is essential to use the correct speed screen and film combination with the AEC—the screen and film combination that it has been programmed for. The AEC cannot compensate for a speed system that it does not "know" about. For example, if the system has been programmed for a 400 system and a 200 speed cassette is used, the image will exhibit half the expected density.

Whether using traditional or computerized imaging equipment, *exact positioning and centering* is particularly critical when using equipment with AECs. The anatomic part of interest must be positioned (centered) accurately with respect to the AEC's sensors; otherwise, the result can be over- or underexposure.

There are two types of AECs: *ionization chambers* and *phototimers/photomultipliers*.

1. Ionization Chamber. A parallel plate *ionization chamber* consists of a radiolucent chamber just beneath the tabletop above the cassette and grid (Fig. 8–8). As x-ray photons emerge from the patient, they enter the chamber and ionize the air within. When a predetermined quantity of ionization has occurred (as determined by the selected exposure factors), the exposure automatically terminates.

2. Phototimer. In the *phototimer*, a small fluorescent screen is positioned beneath the cassette (Fig. 8–8). When remnant radiation emerging from the patient exits the cassette, the fluorescent screen emits light. The fluorescent light charges a photomultiplier tube and, once a predetermined charge has been reached, the exposure is terminated.

3. Backup Timer. In either case, the manual timer should be used as *backup timer*. This ensures that, in case of AEC malfunction, the exposure will terminate and *avoid patient overexposure and tube overload*.

4. Minimum Response Time. Another important feature of the AEC to be familiar with is its *minimum response/reaction time*. This is the length of the *shortest exposure possible* with a particular AEC. If less than the minimum response time is required for a particular exposure, the radiograph will exhibit excessive density.

■ *SUMMARY*

- **Effective communication can increase patient cooperation and decrease repeats.**
- **Repeat exposures result in an increase in patient dose.**
- **When used properly, AECs ensure consistency of radiographic density.**
- **There are two types of AECs: ionization chamber type and phototimer/photomultiplier type.**
- **The ionization chamber type is located between the patient and cassette.**
- **The phototimer/photomultiplier type is located beneath the cassette.**
- **Every AEC has a minimum response time.**

- **AECs require accurate positioning and centering to produce predictable results.**
- **The manual timer must be used as backup timer to avoid patient overexposure and tube overload.**

VI. IMAGE RECEPTORS

The higher the speed of the film and screen system, the smaller the dose of radiation required to produce a diagnostic radiograph. As one component of the effort to reduce population dose, rare earth phosphors are used almost exclusively in general screen/film radiography. Rare earth phosphors are at least four times faster than the earlier calcium tungstate phosphors, and the recorded detail they provide is entirely satisfactory. In general, the fastest film and screen combination consistent with diagnostic requirements should be used.

An advantage of *digital fluoroscopy* (DF) and digital static imaging is reduced patient dose. The lower DF dose is because DF x-ray beams are *pulsed*, rather than continuous. The static DF images are also lower dose because the TV camera tube or the CCD (charge-coupled device) has greater sensitivity than the spot film emulsion.

VII. GRIDS AND AIR-GAP TECHNIQUE

Grids, both stationary and moving, function to *remove a large percentage of scattered* (primarily Compton) radiation from the remnant beam before it reaches the image receptor, thereby *improving radiographic contrast*.

Because scattered radiation often makes a significant contribution to the overall radiographic density, the addition of a grid (or increase in the grid ratio) must be accompanied by an appropriate *increase in exposure factors* (usually mAs) to maintain adequate density. The improvement in image quality is usually more significant than the *increased exposure to the patient* (Fig. 8–9). However, the radiographer should avoid using a high-ratio grid with low kilovoltage; the relatively small amount of scattered radiation produced does not warrant the large increase in mAs required by the high-ratio grid.

It is interesting to note that, to produce a given density, a moving grid generally requires more exposure than a stationary grid of the same ratio. This is because, as the lead strips continually change position moving back and forth, some of the perpendicular rays will unavoidably be "caught" by the lead strips moving into their path. An *air-gap* technique can function similar to, or in place of, a grid. A distance is introduced between the patient/part and the image recorder. Scattered photons emerging from the patient will continue to diverge and never reach the image recorder.

A "natural" air gap exists in the lateral projection of the cervical spine and a 72-inch SID is used *without* a grid (Fig. 8–10). Because no air gap is introduced in the AP projection of the cervical spine, it is usually radiographed at 40 inches SID *with* the use of a grid.

The SID required in *magnification radiography* is an air gap and therefore grids are rarely needed when this special imaging technique is performed.
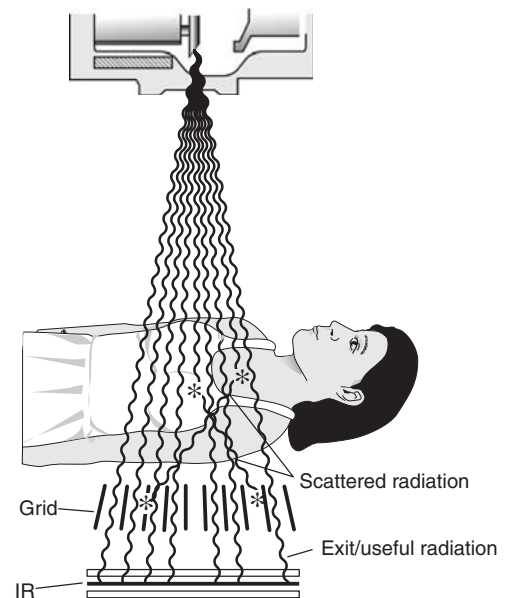
Figure 8–9. Scattered radiation generated within the patient can cause serious degradation of image quality. The improvement in image quality afforded by the use of grids more than makes up for the required increase in patient exposure.
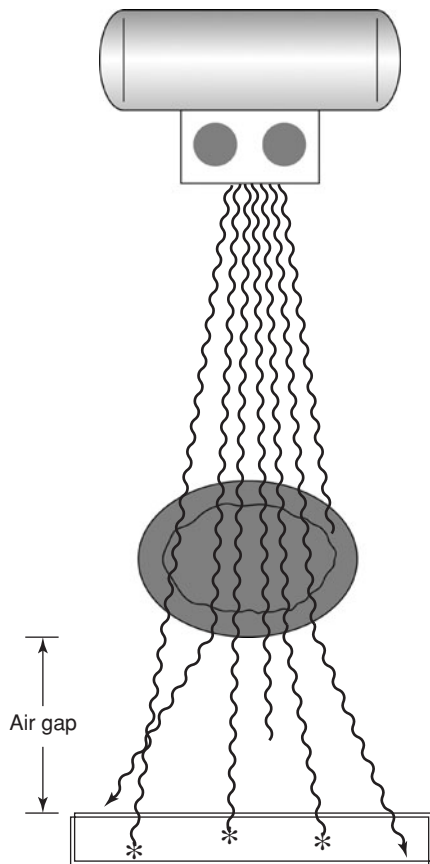
Figure 8–10. When an air gap is used, much of the scattered radiation generated within the patient never reaches the image receptor. An air gap may occasionally be used in place of a grid.

Air-gap technique may also be used in place of a grid in chest radiography. However, to maintain optimum recorded detail and avoid excessive magnification, the SID must be increased considerably, followed by a significant increase in mAs. Air-gap technique is limited in use to radiography of fairly thin parts, as dense tissues would require excessive and impractical radiation exposures.

Additionally, equipment must be properly calibrated to produce consistently predictable results; specifically, the equipment must have *linearity* and *reproducibility*. *Linearity* refers to consistency in exposure with adjacent mA stations and exposure times adjusted to produce the same mAs. *Reproducibility* refers to consistency in exposure output during repeated exposures at a particular setting.

VIII. FLUOROSCOPY

Fluoroscopy is potentially a high patient dose procedure. The principal reason for this is that the source of x-ray photons is so much closer to the patient than in overhead radiography. There are NCRP recommendations that provide guidelines for minimum source-to-skin distance (SSD), maximum tube output, collimation, timer and exposure switch specifications, etc. Many of these guidelines are listed in the following section.

An advantage of *digital* fluoroscopy is reduced patient dose. The principal reason for lower patient dose in DF is that DF x-ray beams are *pulsed*, rather than continuous. Additionally, the TV camera tube/charge-coupled device has greater sensitivity than does film emulsion.

Remember that the entrance or skin dose is significantly greater than the exit dose; this holds true in fluoroscopy as well as radiography. This principle may be employed in radiation protection by placing particularly radiosensitive organs away from the primary beam. Moreover, lead aprons or half aprons can be placed *under* particularly radiosensitive areas (when using under table fluoroscopy), as long as those areas are not of clinical significance.

High-kilovoltage exposure factors are preferred to reduce patient dose in fluoroscopy as well as radiography. The length of the fluoroscopic examination must be monitored by a 5-minute cumulative timer.

IX. NCRP RECOMMENDATIONS FOR PATIENT PROTECTION

Note: Many of the means of patient protection serve to protect the operator as well.

- Equipment operating above 70 kV must have a minimum total (inherent plus added) *filtration* of 2.5 mm Al equivalent.
- *Reproducibility*: for a given group of exposure factors, output intensity must be consistent from one exposure to the next; any variation in output intensity must not exceed 5%.
- *Linearity*: output intensity must be constant when adjacent mA stations are used, with exposure times adjusted to maintain the same mAs; any variation in output intensity must not exceed 10%.
- X-ray tube *housing* must keep leakage radiation to less than 100 mR/h when measured 1 m from the tube.

- A device (*centering light*) must be provided to align the center of the x-ray beam with the center of the image receptor.
- *Beam limiting devices* must be provided; the *collimated* x-ray field must correspond with the visible light field to within 2% of the SID in manual collimation and to within 4% in PBL.
- The x-ray timer must be accurate. Single-phase equipment can be tested with a simple *spinning-top* test tool. Three-phase equipment is tested with a *synchronous spinning top* or an oscilloscope.
- *SSD* must not be fewer than 12 inches for all radiographic procedures other than dental radiography.
- The SSD must be at least 15 inches in stationary (fixed) fluoroscopic equipment, and at least 12 inches for mobile fluoroscopic equipment.
- The tabletop intensity of the *fluoroscopic* beam must be fewer than 10 R/min.
- A *cumulative timing device* must be available to signal the fluoroscopist (audibly, visibly, or both) when a maximum of 5 minute of fluoroscopy time has elapsed.
- The *SID indicator* must be accurate to within 2% of the indicated SID.
- When more than one x-ray tube can be energized from a single control panel, there must be an obvious indicator on the control panel and on or near each tube housing that indicates which tube is being operated.
- The location of the *focal spot* must be indicated on the outside of the tube housing.
- Film–screen combinations should be the *fastest possible*, consistent with the diagnostic objectives of the examination.
- Radiographic *intensifying screens* should be cleaned and checked regularly, at least every 6 months.
- X-ray *film* must be stored in an adequately protected place.
- Radiographic equipment should undergo regular *quality assurance* (QA) testing.
- The radiographer must be able to see and communicate with the patient at all times.
- The exposure switches must be the "*dead-man*" type.

■ SUMMARY

- **The fastest screen–film combination consistent with diagnostic requirements should be used.**
- **Digital imaging can reduce patient dose significantly.**
- **Grids improve the radiographic image by reducing the amount of scattered radiation fog, but necessitate an increase in exposure.**
- **An air gap can have the same effect as a low-ratio grid in decreasing the amount of scattered radiation reaching the image receptor; however, SID, and therefore exposure, must be increased to preserve recorded detail.**
- **Fluoroscopy generally delivers a higher patient dose because of decreased SSD.**
- **There are several important NCRP recommendations governing patient protection with which the radiographer should be familiar.**

Chapter Exercises

⭐ ***Congratulations!*** *You have completed your review of this chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to the multiple-choice questions without first completing the short-answer questions below.*

1. What are some methods of achieving the ALARA goal *(p. 253)*?

2. What is the most important factor in minimizing patient exposure? Give an example of how it affects patient dose *(p. 253).*

3. List the three types of beam restrictors; describe the particular use(s) and efficiency of each *(p. 254).*

4. What effect does beam restriction have on the production of scattered radiation *(p. 253)*?

5. What degree of accuracy must beam restrictors maintain (both manual and PBL) *(p. 255)*?

6. How is "off focus" radiation minimized *(p. 255)*?

7. Describe the relationship between the focal spot and collimator light bulb with respect to cassette alignment *(p. 255).*

8. Explain the importance of a backup timer *(p. 262).*

9. What is meant by the minimum response time of an AEC *(p. 262)*?

10. Why is positioning and centering so critical when using AECs *(p. 261)*?

11. What combination of exposure factors can be used, in general, to keep patient dose to a minimum *(p. 256)*?

12. How does filtration affect patient dose *(p. 256)*?

13. Describe the two types of filtration that comprise total filtration *(p. 256)*

14. What are the NCRP filtration requirements *(p. 257)*?

15. How and why does inherent filtration change as the x-ray tube ages; how does it affect tube output *(p. 257)*?

16. List the three criteria for determining when gonadal shielding should be used *(p. 258).*

17. Describe the three types of gonadal shielding and indicate the effectiveness of each *(pp. 258–259).*

18. When might a breast or lens shield be used *(p. 259).*

19. Explain the value of performing scoliosis series, abdominal, and skull radiography in the PA position *(pp. 259–260).*

20. How do screen and film combinations impact patient dose *(p. 263)*?

21. The NCRP makes several recommendations that can impact patient dose. Briefly describe the recommendations for each of the following *(p. 257,264,265).*
    A. patient visibility during examination
    B. QA testing
    C. speed and care of intensifying screens
    D. external indication of focal spot
    E. energizing multiple x-ray tubes from one control panel
    F. minimum SSD in fluoroscopy units
    G. x-ray timer testing and accuracy
    H. beam limitation accuracy (manual and PBL) required
    I. beam alignment
    J. leakage radiation
    K. quantity of filtration
    L. linearity and reproducibility

Chapter Review Questions

1. Which of the following is (are) a feature(s) of x-ray equipment, designed especially to eliminate unnecessary radiation to the patient?
    1. filtration
    2. minimum SSD of 12 inches
    3. collimator accuracy
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

2. The quality assurance term used to describe consistency in output intensity from one exposure to the next is:
   (A) automatic exposure control
   (B) positive beam limitation
   (C) linearity
   (D) reproducibility

3. How does filtration affect the primary beam?
    (A) filtration increases the average energy of the primary beam
    (B) filtration decreases the average energy of the primary beam
    (C) filtration results in an increased patient dose
    (D) filtration increases the intensity of the primary beam

4. All of the following affect patient dose, *except*:
    (A) inherent filtration
    (B) added filtration
    (C) focal spot size
    (D) source–image distance

5. Which of the following groups of exposure factors will deliver the *greatest* amount of exposure to the patient?
    (A) 50 mAs, 100 kV
    (B) 100 mAs, 90 kV
    (C) 200 mAs, 80 kV
    (D) 400 mAs, 70 kV

6. The principal function of x-ray beam filtration is to:
    (A) reduce operator dose
    (B) reduce patient skin dose
    (C) reduce image noise
    (D) reduce scattered radiation

7. Patient dose can be *decreased* by using:
    1. high speed film and screen combination
    2. high ratio grids
    3. air-gap technique
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

8. Which of the following are included in the types of gonadal shielding?
    1. flat contact
    2. shaped (contour) contact
    3. shadow
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

9. The advantages of beam restriction include:
    1. production of less scattered radiation
    2. irradiation of less biologic material
    3. less total filtration is required
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

10. A backup timer for the automatic exposure control serves to:
     1. protect the patient from overexposure
     2. protect the x-ray tube from excessive heat
     3. eventually increase inherent filtration
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

Answers and Explanations

1. (D) According to NCRP regulations, radiographic and fluoroscopic equipment must have a total Al *filtration* of at least 2.5 mm Al equivalent whenever the equipment is operated at 70 kV or greater, to reduce excessive exposure to low-energy radiation. *Collimator* and beam alignment must be accurate to within 2% for manual, 4% for PBL. The *SSD* must not be less than 12 *inches* for all procedures other than dental radiography. Distance is the single best protection from radiation. Excessively short SIDs/SSDs cause a significant increase in patient skin dose.

2. (D) Equipment must be properly calibrated to produce consistently predictable results; specifically, the equipment must have *linearity* and *reproducibility*. Linearity refers to consistency in exposure with adjacent mA stations (very similar to reciprocity law) and exposure times adjusted to produce the same mAs. *Reproducibility* refers to consistency in exposure output during repeated exposures at a particular setting. Positive beam limitation (PBL) is automatic collimation. The two types of automatic exposure control (AEC) are the photomultiplier and ionization chamber.

3. (A) X-rays produced at the target comprise a heterogeneous primary beam. Filtration serves to eliminate the softer, less-penetrating photons leaving an x-ray beam of higher average energy. Filtration is important in patient protection because unfiltered, low-energy photons not energetic enough to reach the image receptor are absorbed by the body and contribute to total patient dose.

4. (C) *Inherent* filtration is composed of materials that are a permanent part of the tube housing; that is, the glass envelope of the x-ray tube and the oil coolant. *Added* filtration, usually thin sheets of aluminum, is present to make a total of 2.5 mm Al equivalent for equipment operated above 70 kV. Filtration is used to decrease patient dose by removing the weak x-rays having no value but contributing to skin dose. According to the inverse square law of radiation, exposure dose increases as *distance* from the source decreases, and vice versa. The effect of the *focal spot size* is principally on radiographic detail, having no effect on patient dose.

5. (D) mAs regulates the quantity of radiation delivered to the patient. kV regulates the quality (penetration) of the radiation delivered to the patient. The higher the mAs, the greater the patient dose. Higher energy (more penetrating) radiation—which is more likely to *exit* the patient—accompanied by a lower mAs is the safest combination for the patient.

6. (B) It is our ethical responsibility to minimize radiation dose to our patients. X-rays produced at the target comprise a heterogeneous primary beam. There are many "soft" (low-energy)

photons that, if not removed, would contribute to only greater patient dose. They are too weak to penetrate the patient and expose the image receptor; they just penetrate a small thickness of tissue and are absorbed. Filters, usually made of aluminum, are used in *radiography to reduce patient dose by removing this low-energy radiation*, resulting in an x-ray beam of higher average energy. Total filtration is composed of inherent filtration plus added filtration.

7. (A) The *higher the speed* of the film and screen system, the *smaller the dose* of radiation required to produce a diagnostic radiograph. As one component of the effort to reduce population dose, rare earth phosphors are used almost exclusively today in general radiography, as they are at least four times faster than calcium tungstate phosphors.

Grids, both stationary and moving, function to remove a large percentage of scattered (primarily Compton) radiation from the remnant beam before it reaches the image receptor, thereby improving radiographic contrast. Because scattered radiation often makes a significant contribution to the overall radiographic density, the addition of a *grid* (or an increase in the grid ratio) must be accompanied by an appropriate *increase in exposure factors* (usually mAs) to maintain adequate density. The improvement in image quality is usually more significant than the increased exposure to the patient (Figs. 8–9 and 8–10).

Air-gap technique functions similar to, or in place of, a grid. A distance is introduced between the patient and the image receptor. However, to maintain optimum recorded detail and avoid excessive magnification, the SID must be increased considerably, followed by a *significant increase in mAs.*

8. (D) Gonadal shielding should be used whenever appropriate and possible during radiographic and fluoroscopic examinations. *Flat contact* shields (flat sheets of flexible leaded vinyl) are useful for recumbent studies, but when the examination necessitates that oblique, lateral, or erect projections be obtained, they become less efficient. *Shaped contact (contour)* shields are best because they enclose the male reproductive organs, remaining in oblique, lateral, and erect positions—but they can be used only for male patients. *Shadow* shields that attach to the tube head are particularly useful for surgical sterile fields.

9. (B) With greater beam restriction (i.e., smaller field size), less biologic material is irradiated, thereby reducing the possibility of harmful effects. If less tissue is irradiated, less scattered radiation is produced, resulting in improved image contrast. The total filtration is not a function of beam restriction, but rather, is a radiation protection guideline aimed at reducing patient skin dose.

10. (B) A parallel plate *ionization chamber* consists of a radiolucent chamber just beneath the tabletop (Fig. 8–8). As x-ray photons emerge from the patient, they enter the chamber and ionize the air within. When a predetermined quantity of ionization has occurred (as determined by the selected exposure factors), the exposure automatically terminates. In the *phototimer*, a small fluorescent screen is positioned beneath the cassette (Fig. 8–8). When remnant radiation emerging from the patient exits the cassette, the exposure is terminated. The *manual* timer should be used as *backup timer*, in case the AEC fails to terminate the exposure, *thus protecting the patient from overexposure and the x-ray tube from excessive heat load.* The backup timer is unrelated to filtration.

<div style="text-align: right">

Personnel Protection

9

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I. GENERAL CONSIDERATIONS

A. OCCUPATIONAL EXPOSURE

Radiographers must avoid unnecessary radiation exposure to themselves and strive to keep patient dose to an absolute minimum. The sources of radiation exposure to the radiographer are the primary beam and secondary radiation (scatter and leakage). *Radiographers must never be exposed to the primary, or useful, x-ray beam.*

The patient is the principal source of scattered radiation; protection guidelines address secondary radiation exposure. The National Council on Radiation Protection and Measurements (NCRP) recommends *personal monitoring* for individuals who might receive 10% of the occupational dose equivalent limit of 5 rem/y (50 mSv/y).

B. ALARA

The use of radiation monitoring devices helps us evaluate the *effectiveness* of our radiation protection practices. Monthly reports received from dosimeter laboratories are official legal documents. They are reviewed and attempts should be made to reduce *any* exposure, no matter how small. Radiographers must follow the *ALARA* (as low as reasonably achievable) principle as they carry out their tasks. Radiologic facilities undergo regular radiation surveys. New radiologic staff participates in radiation safety orientation, and regular inservice education on radiation safety is conducted. Proper radiation monitoring and review of monthly radiation reports is essential.

II. OCCUPATIONAL RADIATION SOURCES

A. SCATTERED RADIATION

When primary x-ray photons intercept an object and undergo a change in direction, *scattered radiation* results.

The most significant occupational radiation hazard in diagnostic radiology is scattered radiation from the *patient*, particularly in *fluoroscopy*, where use of high kilovoltage results in energetic Compton scatter emerging from the patient. This poses a real occupational hazard to the radiologist and radiographer.

The intensity of scattered radiation 1 m from the patient is approximately 0.1% of the intensity of the primary beam. That is why, in terms of radiation protection, the patient is considered the most important source of scatter. Other scattering objects include the *x-ray table*, the *Bucky-slot cover/closer*, and the *control booth* wall.

B. LEAKAGE RADIATION

Leakage radiation is that which is emitted from the x-ray tube housing in directions other than that of the primary beam. NCRP regulations state that any leakage radiation from lead-lined x-ray tubes must not exceed 100 mR/h at a distance of 1 m from the x-ray tube.

C. NCRP GUIDELINES

NCRP guidelines regulate equipment design, among other things, in an effort to reduce exposure to personnel and patients. Among the guidelines that serve to reduce exposure to personnel are

- The control panel must somehow indicate when the x-ray tube is energized (i.e., "exposure-on" time) by means of an audible or visible signal/sign.
- The x-ray exposure switch must be a *"dead-man" switch* and situated so that it cannot be operated outside the shielded area of the control booth.

Some patients are unable to maintain the required radiographic position, for example, infants and children. Mechanical immobilizing and restraining devices, carefully and intelligently used, will serve to prevent motion on the resulting image. Additional help, though infrequently required, could be a nonpregnant relative or friend (older than age 18 years) or, as last recourse, another hospital employee. The services of radiology personnel must *never* be used to hold patients.

NCRP recommendations regarding protection of the *patient and/or personnel* during *fluoroscopic* procedures include the following:

- During fluoroscopic procedures, the *image intensifier* serves as a protective barrier from the primary beam and must be the equivalent of 2.0 mm Pb.
- The exposure switch must be the "dead-man" type.
- With undertable fluoroscopic tubes, a Bucky-slot closer/cover having at least the equivalent of 0.25 mm Pb must be available to attenuate scattered radiation (which is about at gonad level).
- A cumulative timing device must be available to signal the fluoroscopist (audibly, visibly, or both) when a maximum of 5 minutes of fluoroscopy time has elapsed.
- A leaded screen drape and tableside shield to reduce scattered radiation to the operator must be available having at least 0.25 mm Pb equivalency.

Rules for Selecting Someone to Assist the Patient in the Radiographic Room

- A male (older than 18 years) is preferred; however, a female who is older than 18 years and not pregnant may also assist.
- The individual must be provided with protective apparel.
- The individual must be as far as possible from the useful beam.
- The individual must not stand in the path of the useful beam.

- The tabletop intensity of the fluoroscopic beam must be fewer than 10 R/min.
- Protective *lead aprons* must be *at least 0.50 mm Pb* equivalent and must be worn by the workers in the fluoroscopy room.
- Protective *lead gloves* must be at least 0.25 mm Pb equivalent. The unshielded hand must not be placed in the unattenuated or useful beam.
- When fluoroscopy is performed with an undertable image intensifier (as in "remote" x-ray units), palpation must be performed mechanically.

■ *SUMMARY*

- ■ **Time, distance, and shielding are the principal guidelines for reducing radiographic exposure; monitoring evaluates their effectiveness.**
- ■ **The principal scattering object is the patient; others include the x-ray table, Bucky-slot cover, and control booth walls.**
- ■ **It is important to be familiar with pertinent guidelines established by NCRP reports: Medical X-Ray, Electron Beam and Gamma-Ray Protection for Energies Up to 50 MeV [Equipment Design, Performance and Use (1989) (NCRP Report No. 102); Radiation Protection for Medical and Allied Health Personnel (1989) (NCRP Report No. 105); and Limitation of Exposure to Ionizing Radiation (1993) (NCRP No. 116)].**
- ■ **Mechanical restraining devices should be used to immobilize the patient/part when necessary during radiographic examinations.**
- ■ **Persons occupationally exposed to radiation must never assist (hold) patients during radiographic examinations.**
- ■ **If someone is required to assist a patient during an examination, it is essential that radiation safety guidelines be adhered to.**
- ■ **There are several NCRP recommendations regarding protection during fluoroscopic procedures with which the radiographer should be familiar.**

III. FUNDAMENTAL METHODS OF PROTECTION

A. CARDINAL RULES

The practice of effective radiation safety depends chiefly on common sense. That is, to safeguard yourself from something harmful, you generally remove yourself from it as soon as possible, stay as far away from it as possible, and keep a barrier between it and yourself. Hence, the cardinal principles of *time, distance*, and *shielding*.

The greatest amount of occupational exposure is received in fluoroscopic procedures and mobile radiography. It is here that the radiographer must place special emphasis on the cardinal rules of radiation protection: time, distance, and shielding. Federal government controls also regulate manufacturing standards for the protection of both personnel and patients.

Radiation Protection Rules:

- time
- distance
- shielding

B. INVERSE SQUARE LAW

Reducing the length of time exposed to ionizing radiation, as in reducing fluoroscopy time, results in a reduction of occupational exposure. Increasing the distance from the source of radiation, as illustrated by the *inverse square law*, results in a reduction of occupational exposure. Placing a barrier, like a lead wall or lead apron, between you and the source of radiation results in a reduction of occupational exposure. Review the following examples:

Time:
- If 10 mrem is received in 1 hour of fluoroscopic procedures, how much will be received if the fluoroscopic time is reduced to 30 minutes? (If the fluoroscopic exposure time is cut in half, from 60 to 30 minutes, the exposure dose received would be correspondingly one-half of the original, or 5 mrem.)

Distance:
- If 40 mrem (0.4 mSv) is received at a distance of 40 inches from the x-ray source, what dose will be received at a distance of 80 inches from the source? (According to the inverse square law, if the distance from the radiation source is doubled, exposure dose will be one-fourth of the original quantity, or 10 mrem/0.1 mSv.)

To reduce exposure dose to health care professionals, patients, and the general population, we must minimize the *time* of exposure to the source of radiation, provide effective *shielding* from the radiation source, and, most importantly, maximize the *distance* from the source of radiation.

IV. PRIMARY AND SECONDARY BARRIERS

A. NCRP GUIDELINES

Primary radiation barriers protect against direct exposure from the primary (useful) x-ray beam and have much greater attenuation capability than *secondary barriers*, which protect only from leakage and scattered radiation.

Examples of primary barriers are the lead walls and doors of a radiographic room, that is, any surface that could be struck by the useful beam. Primary protective barriers of typical installations generally consist of walls with 1/16 inch (1.5 mm) lead thickness and 7 feet high.

Secondary radiation is defined as leakage and/or scattered radiation. The x-ray tube housing protects from leakage radiation as stated previously. The patient is the source of most scattered radiation.

Secondary radiation barriers include that portion of the walls above 7 feet in height; this area requires only 1/32 inch lead. The control booth is also a secondary barrier, toward which the primary beam must never be directed (Fig. 9–1). The radiographer must be protected by the control booth shielding during exposures, and the exposure switch or cord must be positioned and attached so that the exposure can be made only *within* the control booth. Leaded glass,

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Primary Barriers

- protect from the useful beam

Secondary Barriers

- protect from scattered and leakage radiation

Attenuation Characteristics of Lead Aprons

X-ray attenuation at:

Pb equivalent thickness	75 kV	100 kV
0.25 mm	66%	51%
0.50 mm	88%	75%
1.0 mm	99%	94%
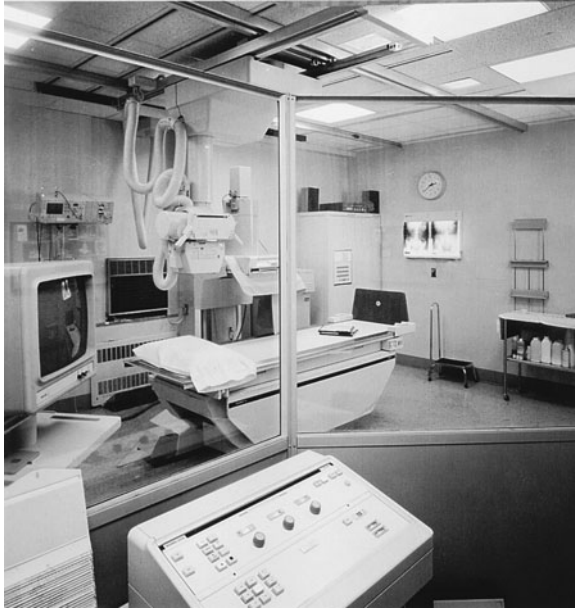
Figure 9–1. The control booth permits the operator to view the patient. The leaded booth and glass protect the operator from exposure to scattered radiation. The control booth is a secondary barrier toward which the primary beam must never be directed. (Courtesy of Nuclear Associates.)

usually 1.5 mm Pb equivalent, should be available for patient observation.

B. PROTECTIVE APPAREL AND ITS CARE

During fluoroscopic procedures requiring the radiographer's presence in the radiographic room, the radiographer must wear protective apparel, to include a lead apron (Fig. 9–2). According to NCRP Report No. 102, lead aprons must provide the equivalent of at least 0.50 mm Pb, and lead gloves at least 0.25 mm Pb equivalent. Other useful protective apparel includes thyroid shields (Fig. 9–3) and leaded eyewear (Fig. 9–4). *Lead aprons, lead gloves, and other apparel are secondary barriers; they will not provide protection from the useful beam!*

Proper care of protective apparel is essential to ensure effectiveness. Lead aprons and gloves should be hung on appropriate racks, not dropped on the floor or folded. Careless handling can result in formation of cracks. Lead aprons and gloves should be imaged annually (either fluoroscopically or radiographically) to check for cracks.

Some companies have environmentally friendly recycle/renew programs. They will recycle frontal or full protection aprons into smaller/half aprons, thyroid shields, gonad shields, etc. for up to half the price of a new shield. Some companies will safely dispose of old lead aprons for a small fee.

Additionally, there are some new types of "lead" shields that are completely lead-free, very light-weight, provide 0.5 mm lead equivalency, and are environmentally friendly.

Figure 9–2. A protective lead apron must be worn during fluoroscopic procedures. Various types/styles of lead aprons are available. The figure shows a wraparound type protective apron. (Courtesy of Shielding International.)

Figure 9–3. A protective thyroid shield is shown. Thyroid shields usually have lead equivalent of 0.5 mm. (Courtesy of Shielding International.)
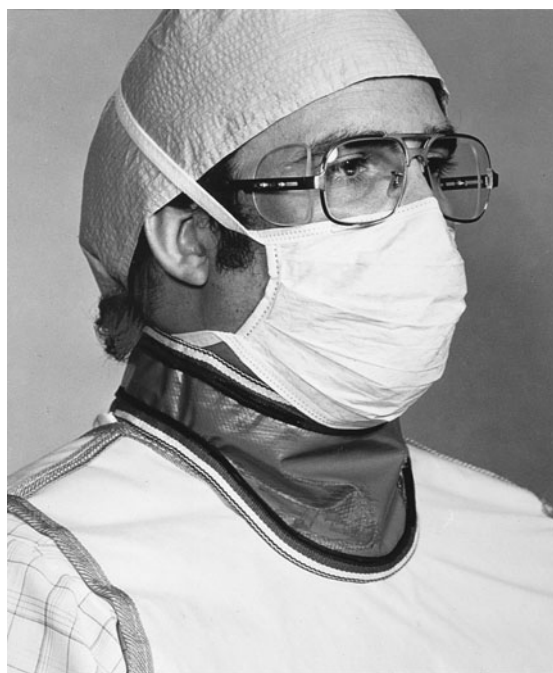
Figure 9–4. Other protective apparel available for fluoroscopic procedures include leaded eyewear. (Courtesy of Nuclear Associates.)

C. PROTECTIVE ACCESSORIES

Another device available for individuals required to remain in the fluoroscopy room is a mobile leaded barrier (Fig. 9–5). Mobile barriers provide full body protection from scattered radiation and are available in a variety of lead equivalents.

Lead aprons can be placed under the patient's pillow during GI and BE examinations when the radiographer's assistance is required at the head end of the table during fluoroscopy.

V. SPECIAL CONSIDERATIONS

A. PREGNANCY

Deserving special consideration in protection from occupational exposure is the *pregnant radiographer*. As soon as the radiographer knows she is pregnant, it is advisable that she declare her pregnancy in writing. At that time, her occupational radiation history will be reviewed. She must be provided with a second (fetal) monitor. Modifications can be made to the pregnant radiographer's work assignments (e.g., no fluoroscopic assignments), but this is unnecessary if routine radiation safety guidelines are followed.

A radiographer who wears his or her radiation monitor on the collar outside the lead apron usually receives fewer than 100 mrem (1 mSv)/y. If a *fetal monitor* were worn under the lead apron at waist level, it would receive 10% of that dose, or fewer than 10 mrem (0.1 mSv). Because the *gestational dose limit* to the fetus during the gestation period must not exceed *500 mrem* (5 mSv), under typical conditions, when sufficient protection measures are taken, modification of work assignments is not usually necessary. If a fetal, or "baby," monitor is worn, it must be clearly identified and not confused with the radiographer's regular monitor.

However, radiation protection standards should be reviewed during pregnancy and monthly dosimeter reports closely monitored. Many facilities document the counseling received by the pregnant radiographer from the time she advises her supervisor of her pregnancy and makes the signed documents part of the employee's records.

B. MOBILE UNITS

Each *mobile x-ray unit* should have a *lead apron* assigned to it. The radiographer should wear the apron while making the exposure at the furthest distance possible from the x-ray tube. The mobile unit's exposure cord must permit the radiographer to stand at least *6 feet* from the x-ray tube and patient. In *mobile fluoroscopic* units, there must be a source to patient skin distance of at least 12 inches.

C. FLUOROSCOPIC UNITS AND PROCEDURES

All *fluoroscopic* equipment must provide at least 12 inches (30 cm), and preferably 15 inches (38 cm), between the x-ray source (focal spot) and the x-ray tabletop (patient), according to NCRP Report No. 102. The *tabletop intensity* of the fluoroscopic beam must not exceed *10 R/min* or 2.1 R/min/mA. With undertable fluoroscopic tubes, a

Figure 9–5. Movable leaded barriers provide full body protection for individuals required to remain in the radiographic or fluoroscopic room. Mobile barriers provide protection from secondary radiation and are available in a variety of sizes and lead equivalents. (Courtesy of Nuclear Associates.)

Bucky-slot closer/cover having at least the equivalent of 0.25 mm Pb must be available to attenuate scattered radiation. Fluoroscopic mA (milliamperes) must not exceed 5, although image-intensified fluoroscopy usually operates between 1 and 3 mA.

Because the image intensifier functions as a primary barrier, it must have a lead equivalent of at least 2.0 mm. A cumulative timing device must be available to signal the fluoroscopist (audibly, visibly, or both) when a maximum of 5 minutes of fluoroscopy time has elapsed. Beam collimation must be apparent through visualization of unexposed borders on the TV monitor, and *total filtration* must be at least *2.5 mm Al* equivalent. Because occupational exposure to scattered radiation is of considerable importance in fluoroscopy, a *protective curtain/drape* of at least *0.25 mm Pb* equivalent must be placed between the patient and fluoroscopist.

The effect of kV and mA adjustment on fluoroscopic images is similar to that on radiographic images. The automatic exposure control automatically varies the exposure required when viewing body tissues of widely differing tissue densities (e.g., between the abdomen and chest). *As in radiography, high kV and low mAs (milliampere-seconds) values are preferred in an effort to reduce dose.*

■ *SUMMARY*

- **The cardinal principles of radiation protection are time, distance, and shielding.**
- **Primary barriers protect from the useful (primary) beam; for example, the walls and doors of the radiographic room.**
- **Secondary barriers protect from sources of leakage and scattered radiation; for example, x-ray tube housing, the patient.**
- **Secondary barriers (e.g., control panel wall, lead apron) will not afford protection from the primary beam.**
- **There are several NCRP recommendations with which the radiographer should be familiar regarding required thickness and uses of protective shielding (see p. 274.).**
- **A pregnant radiographer should advise her supervisor of her condition as soon as possible.**
- **A pregnant radiographer wears a second radiation monitor at waist level under her lead apron.**
- **Most occupational exposure is received in fluoroscopy and mobile radiography (especially C arm).**

Chapter Exercises

★ ***Congratulations!*** *You have completed your review of this chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to the multiple-choice questions without first completing the short-answer questions below.*

1. What are the three cardinal rules, or principal guidelines, for radiation protection *(p. 273)?*

2. When is personal radiation monitoring required *(p. 271)?*

3. What is the most significant scattering object in fluoroscopy? Why? List other scattering objects *(p. 272)*.

4. What are the NCRP recommendations on leakage radiation; exposure switches; exposure indicators *(p. 272)?*

5. What resources should be employed to assist and immobilize patients during radioscopic examinations *(p. 272)?*

6. What rules apply if an individual is required in the radiographic room for assistance during a procedure *(p. 272)?*

7. Describe the NCRP recommendations that are in place for patient and personnel protection during fluoroscopic procedures with respect to *(pp. 272–273)*.
    A. image intensifier lead equivalent
    B. exposure switch
    C. Bucky-slot cover
    D. cumulative timer
    E. lead drape or curtain
    F. tabletop intensity maximum
    G. apron and glove lead equivalency
    H. palpation with remote fluoroscopy units

8. Distinguish between, and give examples of, primary and secondary barriers *(p. 274)*.

9. What is the usual recommended thickness of x-ray room walls; the recommended height *(p. 274)?*

10. What protects from leakage radiation *(p. 274)?*

11. Identify each of the following as primary or secondary barriers: x-ray room walls, control panel, lead aprons, and gloves *(pp. 274–275)*.

12. How should lead aprons and gloves be cared for *(p. 275, 277)?*

13. Describe how a pregnant radiographer might use a second personal monitor *(p. 277).*

14. What is the gestational fetal dose limit *(p. 277)?*

15. What kinds of counseling and documentation are recommended for the pregnant radiographer *(p. 277)?*

16. What areas of an x-ray facility generally have the highest occupational exposure *(p. 277)?*

17. What NCRP recommendations govern mobile radiography with respect to availability of lead aprons, the exposure cord, the fluoroscope source-to-skin distance (SSD) *(p. 277)?*

18. What NCRP recommendations govern fluoroscopy equipment with respect to SSD, table-top intensity, maximum mA, image intensifier lead equivalent, fluoroscopy exposure switch *(pp. 277–278)?*

19. What NCRP recommendations govern fluoroscopy equipment with respect to collimation, total filtration, protective curtain, Bucky-slot cover, cumulative timer *(p. 278)?*

Chapter Review Questions

1. Each time an x-ray photon scatters, its intensity at 1 meter from the scattering object is what fraction of its original intensity?
   - (A) 1/10
   - (B) 1/100
   - (C) 1/500
   - (D) 1/1000

2. If an individual received 45 mR while standing at 4 feet from a source of radiation for 2 minutes, which of the options listed below will *most* effectively reduce his or her radiation exposure?
   - (A) standing 6 feet from the source for 2 minutes
   - (B) standing 5 feet from the source for 1 minute
   - (C) standing 4 feet from the source for 3 minutes
   - (D) standing 3 feet from the source for 2 minutes

3. How much protection is provided from a 100 kV x-ray beam when using a 0.50-mm lead equivalent apron?
   - (A) 65%
   - (B) 75%
   - (C) 88%
   - (D) 99%

4. Radiation dose to personnel is reduced by the following exposure cord guidelines:
    1. exposure cords on mobile equipment must allow the operator to be at least 6 feet from the x-ray tube
    2. exposure cords on fixed equipment must allow the operator to be at least 6 feet from the x-ray tube
    3. exposure cords on fixed and mobile equipment should be the coiled expandable type
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

5. Which of the following groups of exposure factors will deliver the *least* exposure to the patient?
    (A) 10 mAs, 100 kV
    (B) 20 mAs, 90 kV
    (C) 40 mAs, 80 kV
    (D) 80 mAs, 70 kV

6. Some patients, such as infants and children, are unable to stay in the necessary radiographic position and require assistance. If mechanical restraining devices cannot be used, who of the following is BEST suited to hold these patients?
    (A) floor nurse
    (B) transporter
    (C) friend or relative
    (D) student radiographer

7. Which of the following is (are) a guideline(s) used to reduce personnel and/or patient dose in fluoroscopy?
    1. maximum tabletop intensity of 10 R/min
    2. maximum SSD of 12 inches
    3. minimum filtration of 2.5 mm Al equivalent
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

8. Which of the following is (are) a feature(s) of fluoroscopy equipment, designed especially to eliminate unnecessary radiation to patient and personnel?
    1. protective curtain
    2. filtration
    3. collimation
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

9. How high primary radiation barriers must at least be?
   (A) 5 feet
   (B) 6 feet
   (C) 7 feet
   (D) 8 feet

10. The protective control booth from which the radiographer makes the x-ray exposure
    is a:
    (A) primary barrier
    (B) secondary barrier
    (C) useful beam barrier
    (D) remnant radiation barrier

Answers and Explanations

1. (D) One of the radiation protection guidelines for the occupationally exposed is that the
x-ray beam must scatter twice before reaching the operator. Each time the x-ray beam scatters,
its intensity at 1 m from the scattering object is approximately 0.1% of the intensity of the
primary beam, that is, *one-thousandth* of its original intensity. That is why, in terms of radiation
protection, the patient is considered the most important source of scatter. Of course, the op-
erator should be behind a shielded booth while making the exposure, but multiple scatterings
further reduce danger of exposure from scattered radiation. Other scattering objects include
the x-ray table, the Bucky-slot cover, and the control booth wall.

2. (B) A quick survey of the distractors reveals that options C and D will *increase* exposure
dose; thus, they are eliminated as possible correct answers. Both A and B will serve to reduce
radiation exposure, as distance is increased and exposure time is decreased in each case. It
remains to be seen then, which is the more effective. Using the inverse square law of radiation,
it is found that the individual would receive *20 mR at 6 feet in 2 minutes* and would receive
14.4 mR at 5 feet in 1 minute:

$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2}$$

Substituting known values from distractor (A):

$$\frac{45 \text{ mR}}{x} = \frac{6 \text{ feet}^2}{4 \text{ feet}^2}$$

$$\frac{45}{x} = \frac{36}{16}$$

$$36x = 720$$

$$x = 20 \text{ mR at 6 feet for 2 minutes}$$

$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2}$$

Substituting known values from distractor (B):

$$\frac{45 \text{ mR}}{x} = \frac{5 \text{ feet}^2}{4 \text{ feet}^2}$$

$$\frac{45}{x} = \frac{25}{16}$$

$$25x = 720$$

$$x = 28.8 \text{ mR at 5 feet for 2 minutes, } \textit{therefore 14.4 mR in 1 minute}$$

Note the inverse relationship between distance and dose. As distance from the source of radiation increases, dose rate significantly decreases.

3. (B) Lead aprons are worn by occupationally exposed individuals using fluoroscopic procedures. Lead aprons are available with various lead equivalents; 0.25, 0.5, and 1.0 mm are the most common. The *1.0 mm* lead equivalent apron will provide close to 100% protection at most kV levels, but it is rarely used because it weighs anywhere from 12 to 24 lb! A *0.5 mm* apron will attenuate approximately 99% of a 50 kV beam, 88% of a 75 kV beam, and 75% of a 100 kV beam. A *0.25 mm* lead equivalent apron will attenuate approximately 97% of a 50 kV x-ray beam, 66% of a 75 kV beam, and 51% of a 100 kV beam.

4. (A) Radiographic and fluoroscopic equipment is designed to help decrease the exposure dose to patient and operator. One of the design features is the exposure cord. Exposure cords on *fixed* equipment must be short enough to prevent the exposure from being made outside the control booth. Exposure cords on *mobile* equipment must be long enough to permit the operator to stand at least 6 feet from the x-ray tube.

5. (A) mAs regulates the *quantity* of radiation delivered to the patient. kV regulates the *quality* (penetration) of the radiation delivered to the patient. Therefore, higher energy (more penetrating) radiation—which is more likely to exit the patient—accompanied by lower mAs is the safest combination for the patient, delivering the *lowest* dose. Higher mAs at lower kV values *increases* patient dose.

6. (C) If mechanical restraint is impossible, a friend or relative accompanying the patient should be requested to hold the patient. If a friend or relative is not available, a nurse or transporter may be asked for help. Protective apparel, such as lead apron and gloves, should be provided to the person(s) holding the patient. *Radiology personnel must NEVER assist in holding patients, and the individual assisting should NEVER be in the path of the primary beam.*

7. (C) All *fluoroscopic* equipment (both stationary and mobile) must provide *at least* 12 inches (30 cm), and preferably 15 inches (38 cm), between the x-ray source (focal spot) and the x-ray tabletop, according to NCRP Report No. 102. The tabletop *intensity* of the fluoroscopic beam must not exceed 10 *R/min* or 2.1 R/min/mA. Required filtration must be at least the equivalent of 2.5-mm aluminum. Fluoroscopic mA must not exceed 5, although image-intensified fluoroscopy usually operates between 1 and 3 mA. The image intensifier functions as a primary barrier and has a lead equivalent of 2.0 mm.

8. (D) The *protective* curtain is usually made of leaded vinyl with at least 0.25 mm Pb equivalent. It must be positioned between the patient and fluoroscopist and greatly reduces exposure

of the fluoroscopist to energetic scatter from the patient. Just as overhead radiation barrier equipment, fluoroscopic total *filtration* must be at least 2.5 mm Al equivalent to reduce excessive exposure to low-energy radiation. *Collimator* or beam alignment must be accurate to within 2%.

9. (C) Radiation protection guidelines have established that *primary radiation barriers* must be at least 7 feet high. Primary radiation barriers are walls that the primary beam might be directed toward. They usually contain 1.5 mm lead, but this can vary depending on *use factor* and other factors.

10. (B) *Primary barriers* are those that protect us from the primary or useful beam. They have much greater attenuation capability than secondary barriers, which protect only from leakage and scattered radiation. The radiographic room walls are therefore considered primary barriers because the primary beam is often directed toward them, as in chest radiography. Most control booth barriers, however, are *secondary barriers* and the primary beam is never directed toward them. They are usually constructed of four thicknesses of gypsum board and/or 0.5 to 1 inch of plate glass. Remnant radiation penetrates the patient and forms the latent image on the image receptor.

Radiation Exposure and Monitoring

I. UNITS OF MEASUREMENT

W.C. Röntgen's paper, "On a New Kind of Rays," described the ionizing effect of x-rays on air and their effect on photographic emulsions. We still use these principles today to detect and quantify radiation exposure.

The (traditional/conventional) radiation units of measurement, the roentgen, rad, and rem, are of importance to the radiographer—the SI (Standard International) units of measure are gaining in usage and should also be used by the radiographer. The ARRT Content Specifications for the Examination in Radiography, implemented January 2008, indicate that the certification examination generally uses the conventional units of measurement. However, it is stated that questions referenced to specific reports, such as the National Council on Radiation Protection and Measurements (NCRP) reports, will use SI units to be consistent with those reports.

A. THE ROENTGEN

The ARRT examination does not capitalize "roentgen" as a unit of measurement, and no "s" is used at the end; for example, 10 roentgen, *not* 10 Roentgens (the same is true for the terms rad and rem). When used to express *rate*, it is abbreviated R/min or R/h. The *roentgen* is a unit of measurement of *ionization in air*, and referred to as the *unit of exposure*. Because x-rays ionize air, all the ions of *either* sign (positive or negative) formed in a particular quantity of air are counted and equated to a quantity of radiation expressed in the unit *roentgen*. The roentgen is valid only for *x and gamma radiations* at energies up to 3 MeV (million electron volts).

The roentgen SI unit of measurement is C/kg (coulomb per kilogram).

B. THE RAD

The *rad* is an acronym for *radiation absorbed dose*. As radiation passes through matter, a certain amount of energy is deposited in that matter.

Traditional and SI Equivalents

$1R = 2.58 \times 10^{-4}$ C/kg
100 rad = 1 Gy (1000 mGy)
100 rem = 1 Sv (1000 mSv)

Absorbed dose refers to the amount of energy deposited per unit mass and is strongly related to chemical change and biologic damage. The amount of energy deposited and, thus, the amount of possible biologic damage is dependent on the following:

- Type of radiation
- Atomic number of the tissue
- Energy of the radiation

Particulate radiation (alpha, beta, etc.) is highly ionizing. As an *internal* source of radiation, it increases LET (linear energy transfer), and a significant biologic effect can result. As an *external* source of radiation, most is virtually innocuous. However, some beta particles (e.g., Mo99 and Co60 beta) are very energetic and can cause serious external damage. As the *atomic number* of the irradiated tissue increases, a greater number of x-ray photons is absorbed by the tissue (the photoelectric interaction increases), and LET increases. As the *energy* of radiation increases, it becomes more penetrating and LET decreases, thereby decreasing the likelihood of biologic effects.

Because the rad does not take into account the biologic effect of various types of radiation, it is not used to express occupational exposure.

The rad SI unit of measurement is the Gy (gray).

C. THE REM

The *rem* is an acronym for *radiation equivalent man*. The rem uses the information collected for the rad, but also uses a quality factor (QF) to predict biologic effects from different types of radiation (Table 10–1). Thus, the equation: rad × QF = rem. Radiations having a high QF have a higher LET and greater potential to produce biologic damage. The rem is described as the unit of *dose equivalency* (DE) and used to express occupational exposure.

The rem SI unit of measurement is the Sv (sievert).

Similar absorbed doses of *different kinds* of radiation can cause different biologic effects to *tissues of differing radiosensitivity*. A *radiation weighting factor* (W_r) is a number assigned to different types of ionizing radiations so that their effect(s) may be better determined (e.g., x-ray vs. alpha particles). The W_r of different ionizing radiations is dependent on the LET of that particular radiation. A *tissue weighting factor* (W_t) represents the relative tissue radiosensitivity of the irradiated material (e.g., muscle vs. intestinal epithelium vs. bone, etc.). The weighting factor is like the *SI* equivalent of the *traditional* QF, e.g., rad × QF = rem, whereas, Gy × W_r = Sv.

TABLE 10–1. QUALITY FACTOR FOR DIFFERENT TYPES OF RADIATION

IONIZING RADIATION TYPE	QUALITY FACTOR
Gamma rays	1
X-ray photons	1
Alpha particles	20
Beta particles	1
Fast neutrons	20

II. MONITORING DEVICES

A. NATIONAL COUNCIL ON RADIATION PROTECTION GUIDELINES FOR USE

Radiation monitoring is used to evaluate the effectiveness of the radiation safety policies and practices in place. The Code of Federal Regulations (CFR) states that monitoring be provided for occupationally exposed individuals in a controlled area who are likely to receive more than 1/10 *the dose equivalent limit.*

B. OPTICALLY STIMULATED LUMINESCENCE

Optically stimulated luminescence (*OSL*) dosimeters are gradually replacing the long-used film badges. The OSL contains a thin layer of *aluminum oxide* (Al_2O_3). Aluminum oxide absorbs and stores the energy associated with exposure to ionizing radiation. OSL dosimeters are available with various combination filter packs (Fig. 10–1). Some contain a filter pack of tin, copper, and an open window. Others are available with aluminum, copper/aluminum, plastic, and an open window. Still others contain lead, copper/aluminum, plastic, and an open window. In any case, these various *filters* serve to identify the *type and energy of radiation* that interacted with the dosimeter—e.g., photons that penetrate the copper to interact with the dosimeter are more

Personal Radiation Monitors:

- OSL
- TLD
- Film Badge
- Pocket Dosimeter

Figure 10–1. OSL dosimeters are available with various combinations of filters. Some contain a filter pack of tin, copper, and an open window. Others are available with aluminum, copper/aluminum, plastic, and an open window. Still others contain lead, copper/aluminum, plastic, and an open window. These various filters serve to identify the type and energy of radiation. (Courtesy of Landauer Inc, Glenwood, IL.)

energetic than those that might have only enough energy to pass through the plastic filter. When the OSL is returned to the laboratory for processing, the Al_2O_3 chips are stimulated with green light from either a laser or light emitting diode source. The resulting blue light emitted from the Al_2O_3 is proportional to the amount of radiation exposure. Both high- and low-energy photons and beta particles can be measured with this technique. The quantity of light emitted is equated to a radiation quantity expressed in mrem on the written report returned to the user. The OSL allows for multiple readouts and can be used to reconfirm reported radiation doses. This is because only a fraction of the radiation exposure signal contained in the Al_2O_3 material is used up upon stimulation with the green light. Other advantages of the OSL include the ability to measure radiation doses as low as 1 mrem (with a precision of ± 1 mrem) and to be reanalyzed if necessary. Their tamper-proof plastic package is unaffected by heat, moisture, and pressure.

C. FILM BADGE

The radiation monitor used for many years was the *film badge*. The film badge consists of special radiation dosimetry film packaged like dental film and enclosed in a special plastic holder. The plastic holder features an open window (through which the user's name appears) and various *filters*, which serve to identify the *type and energy of radiation* (Fig. 10–2).

Radiation that exposes film behind an aluminum filter is more energetic than radiation that passes through only the open window, and less energetic than radiation penetrating a copper filter. Film badges are used for 1 *month*, collected, and sent to a special laboratory for processing. The degree of exposure is carefully evaluated and equated to a dose, usually expressed in *mrem*; the film badge can measure doses as low as 10 mrem.

Film badges had been the most widely used personal radiation monitors, but are being replaced by the OSL.
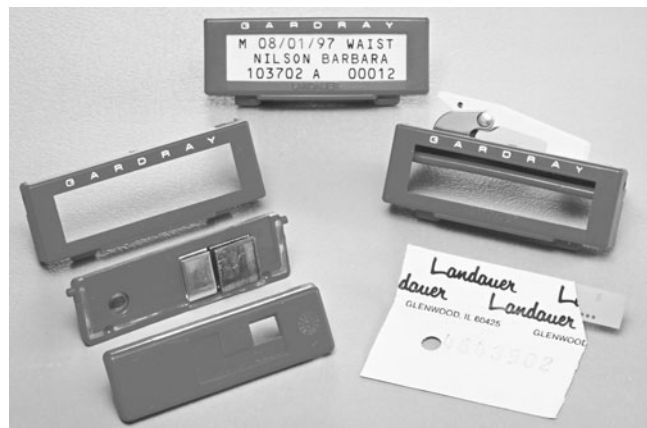
Figure 10–2. The radiation monitor used for many years was the *film badge*—consisting of special film packaged like dental film and enclosed in a special plastic holder. The plastic holder has an open window and various filters, which serve to identify the type and energy of radiation. (Courtesy of Landauer Inc, Glenwood, IL.)

Figure 10–3. The thermoluminescent dosimeter (TLD) contains crystalline chips of lithium fluoride (LiF), which absorb and store the energy associated with exposure to ionizing radiation. (Courtesy of Landauer Inc, Glenwood, IL.)

D. THERMOLUMINESCENT DOSIMETER

The thermoluminescent dosimeter (TLD) (Fig. 10–3) contains crystalline chips of lithium fluoride (LiF). LiF absorbs and stores the energy associated with exposure to ionizing radiation. When the TLD is returned to the laboratory for processing, the LiF chips are heated. This process causes a release of visible light from the chips in proportion to the amount of ionizing radiation absorbed. The quantity of light emitted is equated to a radiation quantity expressed in mrem on the written report returned to the user. The TLD is more sensitive and precise than the film badge because it can measure doses as low as 5 mrem. The TLD is unaffected by heat or humidity and can be worn up to 3 months before processing. However, in the unlikely event that the user had unknowingly received excessive radiation exposure, the user should be made aware of it as soon as possible, and the event should be recent enough to be able to recall. This is often considered the single disadvantage of the TLD. Both the film badge and TLD measure a variety of energies of *x*, beta, and gamma radiations.

E. POCKET DOSIMETER

The use of a *pocket dosimeter* (Fig. 10–4) is indicated when working with high exposures or large quantities of radiation for a short period of time, so that an immediate reading is available to the user. The pocket dosimeter is sensitive and accurate, but has limited application in diagnostic radiography.

The pocket dosimeter, or *pocket isolation chamber*, resembles a penlight. Within the dosimeter is a thimble ionization chamber. In the presence of ionizing radiation, a particular quantity of air will be ionized and cause the fiber indicator to register radiation quantity in milliroentgen (mR). The self-reading type may be "read" by holding the dosimeter up to the light and, looking through the eyepiece, observing

Figure 10–4. The pocket dosimeter contains a small ionization chamber that counts charges in proportion to the exposure received. (Courtesy of Nuclear Associates.)

the fiber indicator, which indicates a quantity of 0 to 200 mR. The disadvantage of the pocket dosimeter is that it does not provide a permanent legal record of exposure.

F. EVALUATION AND MAINTENANCE OF RECORDS

Personal monitors should be worn consistently in the same place and facing forward (i.e., with the open window and user's identification visible). The use of a second monitor is occasionally indicated. The *pregnant radiographer* may wear a second, waist level, dosimeter under her lead apron to approximate fetal dose (Fig. 10–5). If the first

Figure 10–5. The *pregnant radiographer* should wear a second, waist-level, dosimeter under her lead apron that will measure approximate fetal dose. (Courtesy of Landauer Inc, Glenwood, IL.)

Figure 10–6. The film badge (*left*) contains filters to determine the type and energy of radiation received by the wearer. The TLD (*right*) contains thermoluminescent crystals that emit quantities of light proportional to their degree of exposure. The ring badge (*center*) is particularly useful for individuals whose hands are in close proximity to radioactive nuclides or the fluoroscopic x-ray field. A report similar to the one shown is returned monthly, documenting the radiation dose received by each of the personal monitors. (Courtesy of Landauer Inc, Glenwood, IL.)

badge is worn at the collar outside the lead apron, it will approximate dose to the head and neck and will provide an overestimation of dose to the shielded organs. Some procedures require the hands to be near the useful beam (e.g., some fluoroscopic and vascular procedures). A finger, or ring, monitor will provide information on exposure to the hands (Fig. 10–6).

The radiographer is occupationally exposed to *low-energy, low-LET* radiation. Monitoring devices are worn *only for occupational purposes* and never if the individual is exposed for medical or dental reasons. The radiographer should review his or her record monthly or after each report is received by the institution. The radiation safety officer (RSO) is responsible for reviewing all dosimeter reports and being certain that staff is monitored, educated, and regularly updated.

An *official written report* is sent to the sponsoring institution (Fig. 10–7) to document doses received from the OSL, TLD, or film badge. A number of columns of specific data are reported. Exposure data that are *required* to appear are the current period exposure, the annual cumulative exposure, and separate readings for special dosimeters such as fetal or extremity dosimeters.

III. NCRP RECOMMENDATIONS

A part of the professional radiographer's responsibility lies in keeping occupational exposure to a minimum. The use of radiation monitoring

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RADIATION DOSIMETRY REPORT

ACCOUNT NO.	SERIES CODE	ANALYTICAL WORK ORDER	REPORT DATE	DOSIMETER RECEIVED	REPORT TIME IN WORK DAYS	PAGE NO.
103702	RAD	992150087	6/13/07	06/09/07	4	1

PARTICIPANT NUMBER	NAME (ID NUMBER / BIRTH DATE / SEX)	DOSIMETER	USE	RADIATION QUALITY	DEEP DDE	EYE LDE	SHALLOW SDE	DEEP DDE	EYE LDE	SHALLOW SDE	DEEP DDE	EYE LDE	SHALLOW SDE	RECORDS FOR YEAR	INCEPTION DATE (MM/YY)
					DOSE EQUIVALENT (MREM) FOR PERIODS SHOWN BELOW			YEAR TO DATE DOSE EQUIVALENT (MREM)			LIFETIME DOSE EQUIVALENT (MREM)				
FOR MONITORING PERIOD:				05/01/07 - 05/31/07				2007							
0000H	CONTROL	J	CNTRL		M	M	M							5	07/97
	CONTROL	P	CNTRL		M	M	M								07/97
	CONTROL	U	CNTRL				M								07/97
00189	ADAMS, HEATHER 336235619 08/31/1968 F	P	WHBODY		M	M	M	9	10	12	29	31	42	5	07/01
00191	ADDISON, JOHN 471563287 10/04/1968 M	J	WHBODY	PN	90	90	90	100	100	100	200	200	200	5	07/01
				P	60	60	60	70	70	70	170	170	170		
				NF	30	30	30	30	30	30	30	30	30		
00202	HARRIS, KATHY 587582144 06/09/1960 F	P	WHBODY		M	M	M	M	M	M	M	M	M	5	02/02
		U	RFINGR				M			30			30		02/02
00005	MEYER, STEVE 982778955 07/15/1964 M	P	COLLAR	PL	119	119	113							5	08/97
		P	WAIST	P	10	11	11								08/97
			ASSIGN		19	119	113	33	185	174	1387	2308	2320		
			NOTE		ASSIGNED DOSE BASED ON EDE 1 CALCULATION										
		U	RFINGR				140			690			2180		08/97
00203	STEVENS, LEE 335478977 08/25/1951 M	P	WHBODY		ABSENT			M	M	M	M	M	M	4	07/02
		U	RFINGR		ABSENT					M			M		07/02
00204	WALKER, JANE 416995421 03/21/1947 F	P	WHBODY		3	3	3	12	11	11	22	21	21	5	11/02
00188	WEBSTER, ROBERT 355381469 05/15/1972 M	P	WHBODY		40	40	40	200	200	200	240	240	240	5	07/01
			NOTE		CALCULATED										

M: MINIMAL REPORTING SERVICE OF 1 MREM
ELECTRONIC MEDIA TO FOLLOW THIS REPORT

QUALITY CONTROL RELEASE: **LMR**

1 - PR   6774 - PT131 - N1   -21587

NVLAP®
NVLAP LAB CODE 100518-0 **

Figure 10–7. An *official written report* documents doses received from the OSL, TLD, or film badge. Columns of specific data are reported, including the current period exposure, the annual cumulative exposure, and separate readings for special dosimeters such as fetal or extremity dosimeters. (Courtesy of Landauer Inc, Glenwood, IL.)

devices helps evaluate the effectiveness of radiation protection practices. The periodic reports received from OSL, film badge, or TLD laboratories are official legal documents that must be reviewed, and an attempt should be made to reduce *any* exposure, no matter how small.

NCRP Report No. 116 and the Code of Federal Regulations (10 CFR § 20) require that occupationally exposed individuals 18 years of age and older not receive exposures in excess of 5 rem (50 mSv) annually. A radiography student beginning his or her training before the age of 18 years must not receive an annual dose of more than 0.1 rem (100 mrem). Since the general population is not in the vicinity of man-made ionizing radiation on a daily basis their annual dose limit is 1/10 that of ours, that is, 0.5 rem (5 mSv)/y.

The lifetime cumulative exposure for the occupationally exposed individual is determined using the formula: 1 rem × age in years. Thus, a 26-year-old radiographer's lifetime occupational exposure must not

exceed 26 rem (260 mSv). The pregnant radiographer's *gestational* exposure to the fetus must not exceed 0.5 rem (500 mrem, 5 mSv); the *monthly* fetal dose must not exceed 0.05 rem (0.5 mSv).

These are the recommended maximum dose equivalent limits. The *actual* mean annual exposure to occupationally exposed medical personnel is 100 to 140 mrem (1 to 1.4 mSv), well below the recommended limit! This seems to indicate that we are performing our tasks in a safe, conscientious, and ethical manner.

■ SUMMARY

- ■ The roentgen (R unit), or unit of exposure, is the unit used to describe quantity of ionization in air.
- ■ The rad describes absorbed dose.
- ■ The rem is the unit of dose equivalency (DE), used to quantify biological effectiveness.
- ■ The OSL is the newest, most accurate personal dosimeter. It uses a thin layer of Al_2O_3 to store information.
- ■ Film badges are convenient, low-cost radiation monitors that are processed monthly.
- ■ TLDs use LiF crystals to store exposure information. They are more precise and more expensive than film badges and may be processed quarterly.
- ■ Film badges and TLDs measure exposure to beta, *x*, and gamma radiation.
- ■ Pocket dosimeters are thimble ionization chambers used to monitor larger quantities of radiation exposure, up to 200 mR.
- ■ Radiographers must strive to keep their occupational dose ALARA.
- ■ NCRP Report No. 116 and the Code of Federal Regulations (10 CFR §20) establish limits for exposure to ionizing radiation with which radiographers should be familiar.

Chapter Exercises

⭐ ***Congratulations!*** *You have completed your review of this chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to the multiple-choice questions without first completing the short-answer questions below.*

1. Discuss the R as a unit of measurement, including what it measures, the radiation(s) it measures, and up to what energy. Discuss/convert the R to SI unit *(p. 285)*.

2. What does the acronym rad mean? Define rad. Discuss/convert the rad to SI unit *(pp. 285–286)*.

3. Name the three factors influencing the amount of energy deposited (rad) in tissue *(p. 286)*.

4. Relate particulate radiation to degree of ionization in tissue, to LET, and to possible biologic effects *(p. 286)*.

5. Discuss the function of quality factor; weighting factors. *(p. 286)*.

6. What does the acronym rem mean? Discuss/convert the rem to SI unit *(p. 286)*.

7. Why can the rem be accurately used to describe occupational DE, whereas the rad cannot *(p. 286)?*

8. Describe the film badge. Include the following in your description *(p. 288)*.
   A. construction
   B. purpose of filters
   C. length of time used
   D. type(s) of radiation detected
   E. how it is "read" and in what unit
   F. any advantages or disadvantages

9. Describe the TLD. Include the following in your description *(p. 289)*.
   A. construction
   B. type of crystals used; their unique characteristics
   C. length of time used
   D. type(s) of radiation detected
   E. how it is "read" and in what unit
   F. any advantages or disadvantages

10. Describe the pocket dosimeter. Include the following in your description *(pp. 289–290)*.
    A. construction

    B. indications for use
    C. how it is "read," in what unit, and up to what maximum
    D. any advantages or disadvantages

11. Describe the "OSL", to include *(pp. 287–288)*:
    A. component parts
    B. type of crystal used, and how it reacts to radiation exposure
    C. types and purpose of filters
    D. how the OSL is "read"
    E. degree of accuracy
    F. how affected by environmental condition

12. What is the NCRP-recommended dose limit for occupational exposure in individuals younger than 18 years; older than 18 years *(p. 292)?*

13. How is lifetime cumulative occupational exposure determined *(pp. 292–293)?*

14. What is the NCRP-recommended dose limit for gestational fetal exposure *(p. 293)?*

Chapter Review Questions

1. Which of the following is a measure of dose to biologic tissue?
    (A) roentgen (C/kg)
    (B) rad (Gy)
    (C) rem (Sv)
    (D) RBE

2. If a student radiographer who is younger than 18 years begins clinical assignments, what is his or her annual dose limit?
    (A) 0.1 rem (1 mSv)
    (B) 0.5 rem (5 mSv)
    (C) 5 rem (50 mSv)
    (D) 10 rem (100 mSv)

3. The purpose of filters in a film badge is:
    (A) to eliminate harmful rays
    (B) to measure radiation quality
    (C) to prevent exposure from alpha particles
    (D) to support the film contained within

4. The dose limits established for the OSL, TLD, filmbadge and pocket dosimeter are valid for:
    (A) alpha, beta, and *x* radiations
    (B) *x* and gamma radiations only
    (C) beta, *x*, and gamma radiations
    (D) all ionizing radiations

5. On which of the following the operation of personal radiation monitoring devices depends?
      1. ionization
      2. thermoluminescence
      3. resonance
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

6. What is the established fetal dose-limit guideline for pregnant radiographers during the entire gestation period?
   (A) 0.1 rem (1 mSv)
   (B) 0.5 rem (5 mSv)
   (C) 5.0 rem (50 mSv)
   (D) 10.0 rem (100 mSv)

7. Which of the following crystals are used in an optically luminescent dosimetry system?
   (A) silver bromide
   (B) aluminum oxide
   (C) lithium fluoride
   (D) ferrous sulfate

8. In which period of development is the fetus most radiosensitive?
   (A) first trimester
   (B) second trimester
   (C) third trimester
   (D) fourth trimester

9. The unit of measurement used to express occupational exposure is the:
   (A) roentgen (C/kg)
   (B) rad (Gray)
   (C) rem (Sievert)
   (D) RBE

10. The NCRP recommends an annual effective occupational dose equivalent limit of:
   (A) 25 mSv (2.5 rem)
   (B) 50 mSv (5 rem)
   (C) 100 mSv (10 rem)
   (D) 200 mSv (20 rem)

Answers and Explanations

1. (C) Roentgen is the unit of exposure; it measures the quantity of ionization in air. The rad is an acronym for radiation absorbed dose; it measures the energy deposited in any material. The rem is an acronym for radiation equivalent man; it includes the relative biologic effectiveness (RBE) specific to the tissue irradiated, thereby being a valid unit of measurement of dose to biologic material.

2. (A) Because the established dose limit formula guideline is used for occupationally exposed persons 18 years of age and older, guidelines had to be established in the event a student entered

training prior to age 18 years. The guideline states that the occupational dose limit for students younger than 18 years is 0.1 rem (100 mrem or 1 mSv) in any given year.

3. (B) Film badge filters (usually aluminum and copper) serve to help measure radiation quality (energy). Only the most energetic radiation will penetrate the copper; radiation of lower levels will penetrate the aluminum, and the lowest energy radiation will pass readily through the unfiltered area. Thus, radiation of different energy levels can be recorded, measured, and reported.

4. (C) The occupational dose limit is valid for beta, x, and gamma radiations. Because alpha radiation is so rapidly ionizing, traditional personal monitors will not record alpha radiation. Because alpha particles are capable of penetrating only a few centimeters of air, they are practically harmless as an external source of radiation.

5. (B) Ionization is the fundamental principle of operation of both the film badge and pocket dosimeter. In the film badge, the film's silver halide emulsion is ionized by x-ray photons. The pocket dosimeter contains an ionization chamber, and the number of ionizations taking place may be equated to exposure dose. Resonance refers to motion and has no application to personal radiation monitoring.

6. (B) The declared pregnant radiographer poses a special radiation protection consideration, for the safety of the unborn individual must be considered. It must be remembered that the developing fetus is particularly sensitive to radiation exposure. Therefore, established guidelines state that the occupational radiation exposure to the fetus must not exceed 0.5 rem (500 mrem or 5 mSv) during the entire gestation period.

7. (B) Optically stimulated luminescent dosimeters (OSLs) are personal radiation monitors that use aluminum oxide crystals. These crystals, once exposed to ionizing radiation and then stimulated with a laser, give off light proportional to the amount of radiation received. OSLs are very accurate personal monitors. Thermoluminescent dosimeters (TLDs) use lithium fluoride as the sensitive crystal.

8. (A) The first trimester of the developing fetus is the most radiosensitive. Because the fetus is undergoing major organogenesis, very high doses of radiation at this time can cause congenital anomalies. Radiosensitivity gradually decreases through the rest of the pregnancy.

9. (C) *Roentgen* is the unit of exposure; it measures the quantity of ionizations in air. The *rad* is an acronym for *r*adiation *a*bsorbed *d*ose; it measures the energy deposited in any material. The *rem* is an acronym for *r*adiation *e*quivalent *m*an; it includes the relative biologic effectiveness (RBE) specific to the tissue irradiated, thereby being a valid unit of measurement of dose to biologic material.

10. (B) A 1984 review of radiation exposure data revealed that the average annual dose equivalent for monitored radiation workers was approximately 2.3 mSv (0.23 rem). The fact that this is approximately 1/10 the recommended limit indicates that the limit is adequate for radiation protection purposes. Consequently, the NCRP reiterates its 1971 recommended annual limit of 50 mSv (5 rem). *(NCRP Report No. 105, pp. 14–15.)*

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<p style="text-align:center">p a r t</p>

IV

Image Production and Evaluation

Selection of Technical Factors

Radiography students occasionally find the area of technical factors, or "technique," to be their first stumbling block. Everything prior to this may have seemed so straightforward and understandable: radiation protection, anatomy, positioning, even physics. Why is it that "technique" can be so confusing? Perhaps it is because there are so many variables, so many choices to be made, so many factors to consider. Confusion can be even greater when using electronic (CR, DR) imaging—how can one comprehend all the variables when the machine seems to make all the decisions?

The most obvious variable, and the one in which the least modification is possible, is the *patient*. The importance of careful and accurate patient evaluation cannot be overemphasized. Body habitus, muscle tone, pathology, trauma, and age all require accurate assessment prior to the intelligent selection of technical factors.

Even when using automatic exposure control or computerized or digital imaging, the radiographer's accurate evaluation of the patient will result in more efficient use of the technology. Sometimes, automatic exposure control selection will require adjustment or modification; sometimes it will be necessary to use manual technique.

After the patient is evaluated, various imaging accessories must be considered: screen and film combinations, grid ratios, and filters, to name a few. Fortunately, these items are fairly standard from one radiographic room to the next within a given department. When it comes to mobile radiography or being able to move from one department to another, however, a good working knowledge of imaging accessories and their use is required.

What about circumstances that require deviation from the normal source-to-image-receptor distance (SID), or the introduction of an object-to-image-receptor distance (OID)? What if the patient's leg is casted? How does collimation affect the radiographic image? How does scattered radiation affect an image plate differently than it affects film emulsion? Why does kV (kilovoltage) affect image density as well as regulate radiographic contrast? What is meant by the terms *contrast resolution* and *spatial resolution*?

This chapter will structure and show the relationship among these variables and will provide a clear presentation and complete review of their impact on the x-ray image.

I. FACTORS AFFECTING RECORDED DETAIL AND DISTORTION

The term *recorded detail* refers to the *clarity*, or *resolution*, with which a radiographic image is rendered. If the tiny image details (e.g., bony trabeculae, minute calcifications) of a variety of images made under different circumstances were compared, especially with the use of a magnifying glass, it would be noted that the image details appear with varying degrees of clarity. On some of the images, details would be clearly defined, while on other images the borders of tiny details would have varying degrees of unsharpness, that is, they would not be defined as sharply or with the same degree of resolution. This is the basic concept of recorded detail. The term used to describe this concept in electronic/digital imaging is *spatial resolution*.

The term *distortion* refers to misrepresentation of the actual *size* (*magnification*) or *shape* (*foreshortening* or *elongation*) of the structures imaged, which may be partly or wholly caused by inherent object unsharpness.

The degree of *resolution* transferred to the image receptor is a function of the resolving power of each of the system components and is expressed in *line pairs per millimeter* (lp/mm) (Fig. 11–1). One line pair refers to one line and the one space adjacent to it. Resolution describes how closely fine details may be associated and still be recognized as separate details before seeming to blend into each other and appear "as one" (Fig. 11–2).
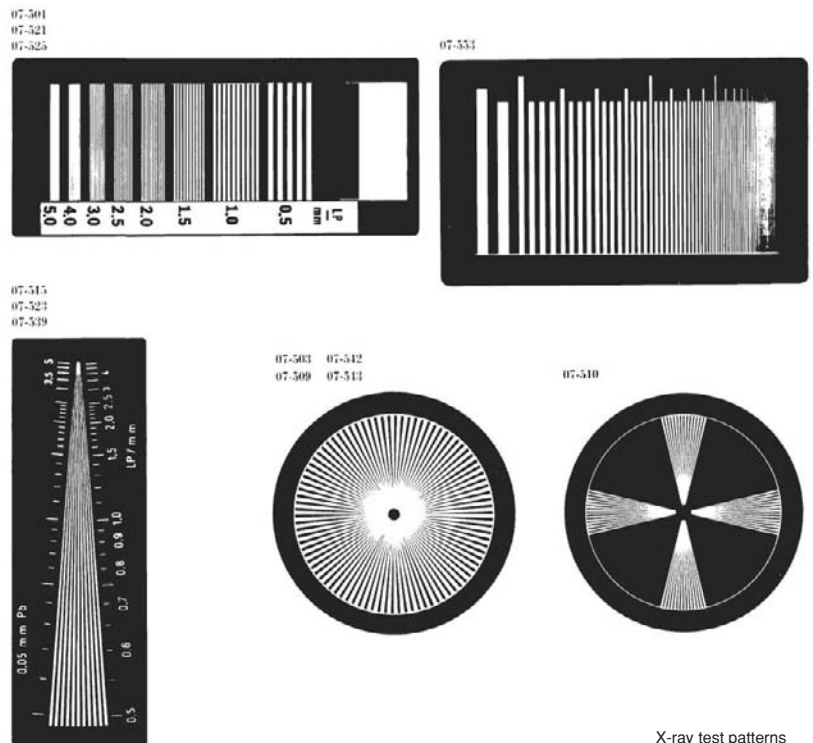
Figure 11–1. *Resolution test pattern.* Resolution is measured with a resolution test pattern and expressed in *line pairs per millimeter* (lp/mm). A variety of resolution test tools are pictured. The *star pattern* is generally used for focal spot size evaluation, while the *parallel line* type is used for evaluating intensifying screens. (Courtesy of Nuclear Associates.)
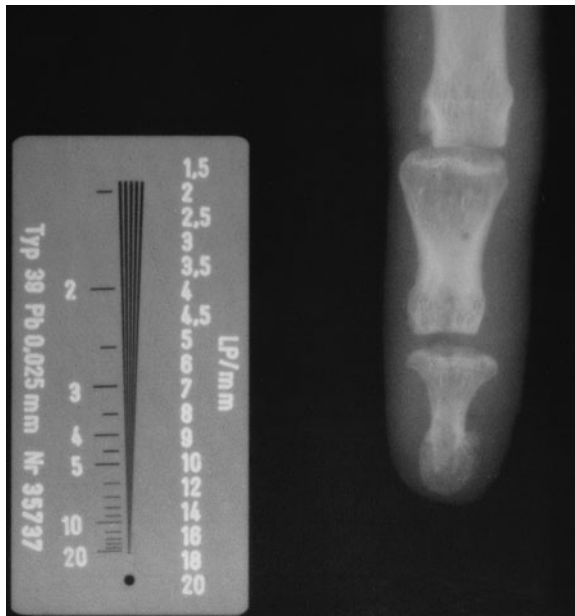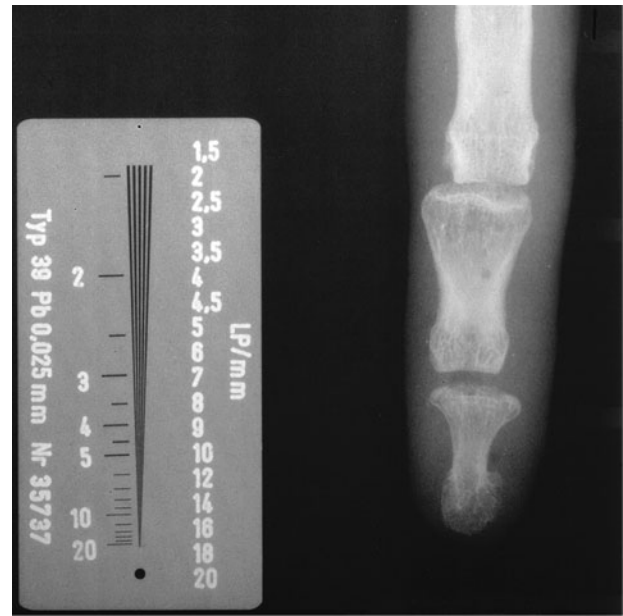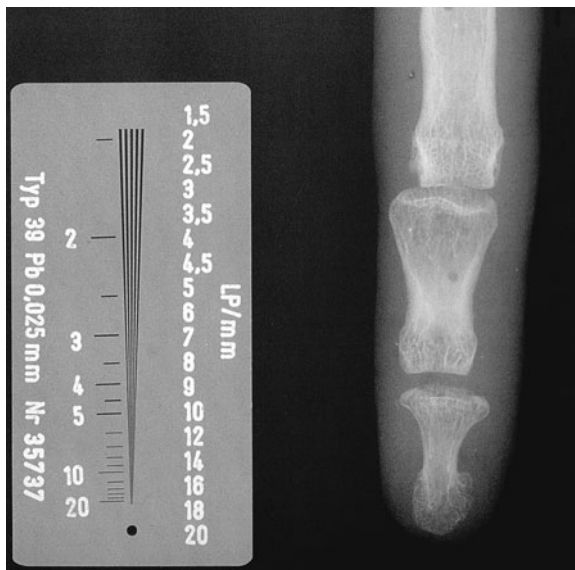
X-ray test patterns

Figure 11–2. *Magnified views of the first phalanx and resolution test pattern.* **(A)** Significant blur or unsharpness of image details; resolution is approximately 6 *lp/mm*. **(B)** Improved recorded detail; resolution of approximately 8 lp/mm. **(C)** Best recorded detail (least blur); resolution of approximately 12 *lp/mm*. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

The term *visibility of detail* refers to *how well the recorded detail can be seen*; for example, excessive density or scattered radiation fog impairs detail visibility because it obscures the details. Density and fog have no effect on how sharply an image detail is rendered; they do, however, determine how easily we are able to recognize those details (i.e., *visibility* of detail). In electronic/*digital imaging* the term used to describe this quality is *contrast resolution*.

There are a number of technical factors that impact recorded detail. Some of them influence the geometry (size and shape) of the image, and others affect its photographic qualities. Each of the factors having an effect on recorded detail will be discussed further.

■ *SUMMARY*

- ■ Recorded detail refers to the sharpness and abruptness of structural detail borders; in electronic/digital imaging, the term used to describe this quality is *spatial resolution.*
- ■ Other terms that refer to recorded detail are resolution, clarity, definition, and sharpness.
- ■ Recorded detail is measured with a resolution test pattern and expressed in lp/mm.
- ■ Recorded detail is affected by a number of factors; some influence the geometry of the image, while others affect its photographic qualities.
- ■ Anything that affects density or contrast affects visibility of detail; in electronic/digital imaging the term used to describe this quality is *contrast resolution.*
- ■ Distortion relates to the size and shape of the image compared to the actual size and shape of the object.
- ■ The terms *magnification, elongation,* and *foreshortening* are used when describing distortion.

A. DISTANCE

If you place your hand between a flashlight and the wall of a dimly lighted room, the shadow of your hand will vary in size and clarity as it changes position with respect to the flashlight and wall. As your
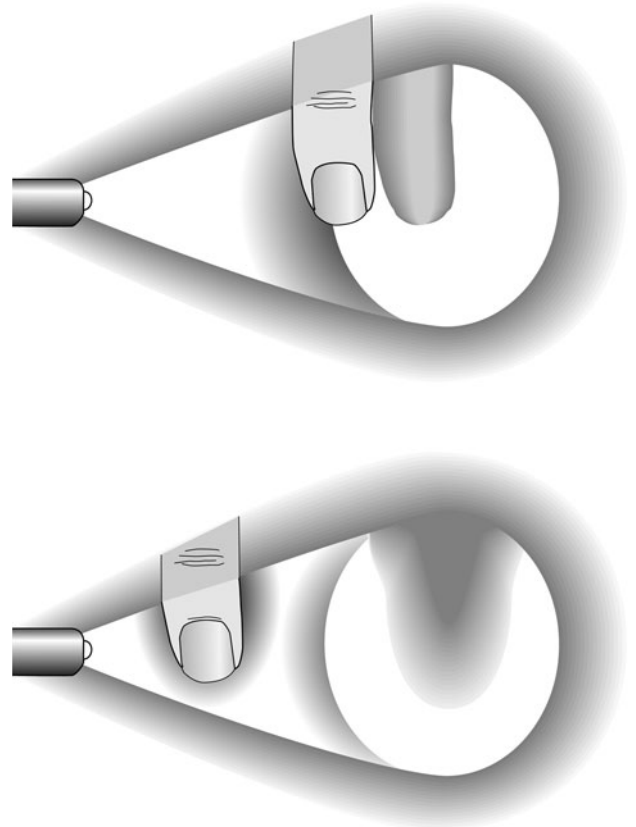
Figure 11–3. *Effect of OID on magnification and detail.* As the finger moves away from the surface (toward the light source), the shadow image becomes magnified and blurry.

hand moves farther from the wall, the shadow becomes larger and less distinct. As your hand is brought closer to the wall (and farther from the flashlight), the shadow becomes more like the actual size of your hand and appears with more clarity (Fig. 11–3).

1. OID. This is the effect *OID* has on recorded detail. Because (like visible light) the x-ray beam diverges as it leaves its source, an increase in OID will increase *magnification*. X-ray photons strike all parts of the object, continue traveling in a divergent fashion, and "deposit" the (now magnified and unsharp) image on the film or other image receptor (Fig. 11–4). *Geometrically recorded detail improves as OID decreases.*

2. SID. A similar example can be used to show the effect of *SID* on recorded detail. If your hand is placed at a given distance from the wall, any change in the distance between the light source and wall will affect the magnification and clarity of the shadow image. As the flashlight moves closer to your hand, the shadow will become larger and less distinct. As the flashlight is moved farther from the wall, the shadow approaches the actual size of your hand and becomes sharper and more distinct (Fig. 11–5). Similarly, as the distance between the x-ray source and image recorder increases, the x-ray image is less magnified and more distinct (Fig. 11–6). *Geometrically recorded detail improves as SID increases.*
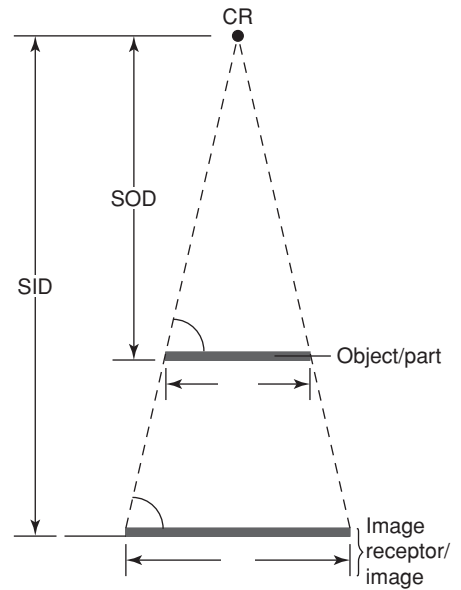
Figure 11–4. As distance from the object to the image receptor (OID) increases, the projected size of the image increases, that is, magnification increases.
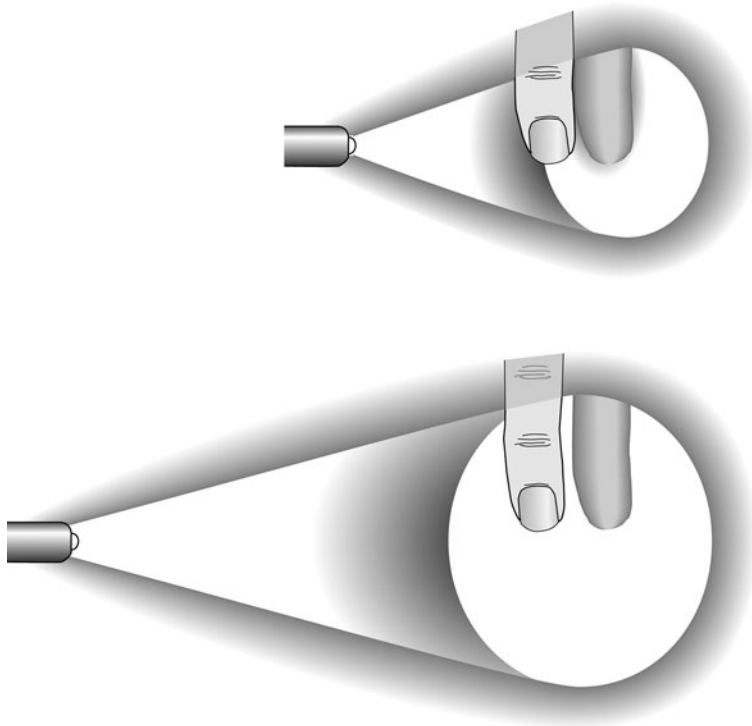
Figure 11–5. *Effect of SID on magnification and detail.* As the flashlight moves closer to the finger, the shadow image becomes magnified and blurry.

A

B
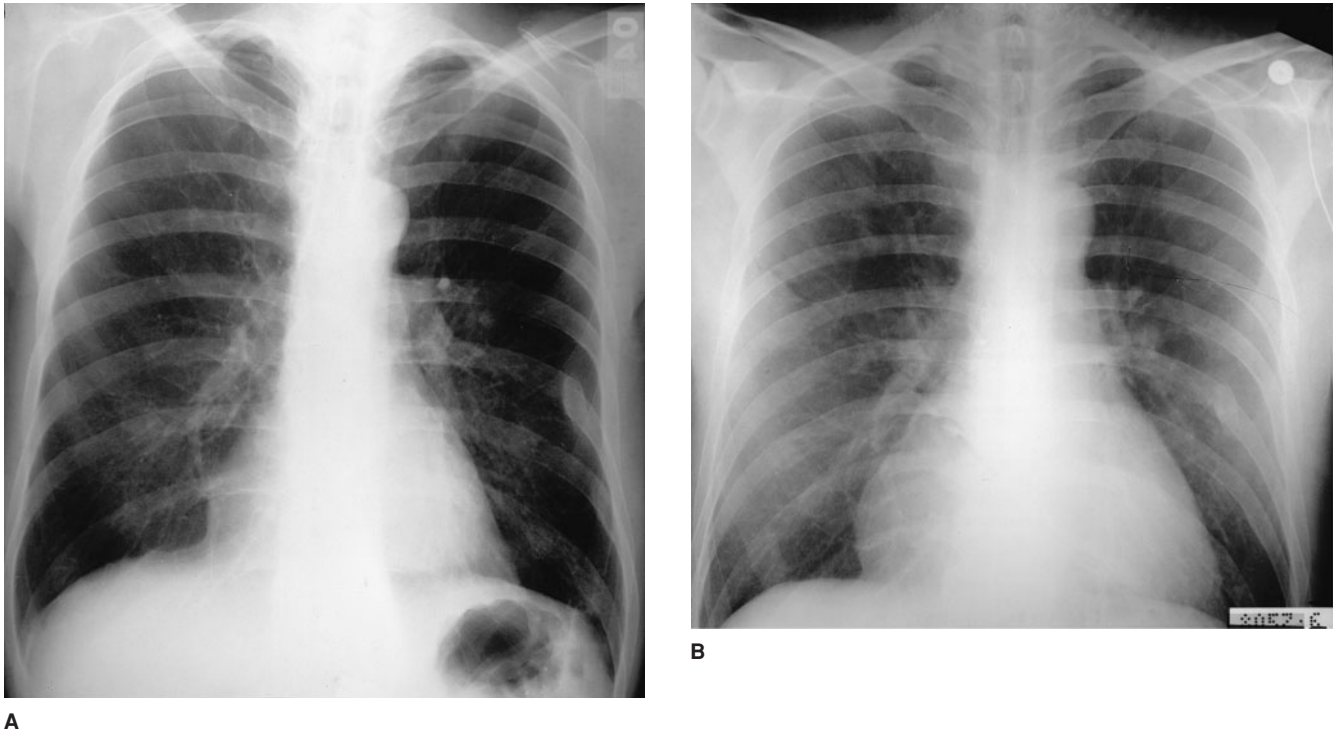
Figure 11–6. **(A)** *Posteroanterior* (PA) erect chest taken at a distance of 6 *feet* demonstrates an accurate representation of the heart shadow and various parenchymal and bony structures. **(B)** *Anteroposterior* (AP) erect at 50 *inches* of the same patient taken within 24 hours and with no change in patient condition. The heart appears markedly larger (15.5 cm on PA and 20 cm on AP) for *two reasons*: (1) the heart is farther from the image receptor in the AP projection, and (2) the SID is decreased; thus, the heart is magnified. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

■ *SUMMARY*

- **Recorded detail and magnification are *inversely* related; that is, recorded detail *increases* as magnification *decreases*.**
- **SID and OID regulate magnification and therefore influence the geometric properties, and hence recorded detail, of the radiographic image.**
- **SID is *inversely* related to magnification (increased SID = decreased magnification) and *directly* related to recorded detail (increased SID = increased recorded detail).**
- **OID is *directly* related to magnification (increased OID = increased magnification) and *inversely* related to recorded detail (increased OID = decreased recorded detail).**

B. PATIENT FACTORS

A certain amount of *object unsharpness* is an inherent part of every radiographic image *because of the position and shape of anatomic structures within the body.*

1. Structure Position. Structures within the three-dimensional human body lie in different planes. For example, the frontal sinuses are more anterior than the sphenoids, the ureters are more anterior than the kidneys, the upper renal poles lie in a plane posterior to the lower renal poles, the fundus of the stomach is more posterior than the body and pylorus, and the posterior portions of the sacroiliac joints are more medial than their anterior portions.

2. Structural Shape. Additionally, the three-dimensional shape of solid anatomic structures rarely coincides with the shape of the divergent beam. Consequently, some structures are imaged with more inherent distortion than others, and shapes of anatomic structures can be entirely misrepresented. Structures *farther* from the image receptor will be distorted (i.e., magnified) more than those *closer* to the image receptor.

For the shape of anatomic structures to be accurately recorded, the structures must be parallel to the x-ray tube and the image receptor and aligned with the central ray (CR). *The shape of anatomic structures lying at an angle within the body or placed away from the CR will be misrepresented on the image receptor* (Fig. 11–7). There are two types of shape distortion. If a linear structure is angled within the body, i.e., not parallel with the long axis of the part/body and not parallel to the image receptor, that anatomic structure will appear *smaller*—it will be *foreshortened*. A good example of foreshortening is demonstrated in the PA projection of the wrist. The curved carpal scaphoid appears smaller than its actual size because of foreshortening. On the other hand, *elongation* occurs when the x-ray tube is angled. This is often used to advantage in radiography. In the Towne method of the skull, the occipital bone is better visualized when the CR is angled 30 degree caudally because the facial bones are projected down away and removed from superimposition on the occipital bone. Similarly, the tortuous sigmoid colon can be "opened up" in the AP projection by employing a cephalad angle. Thus, distortion can be used to improve visualization of some structures.
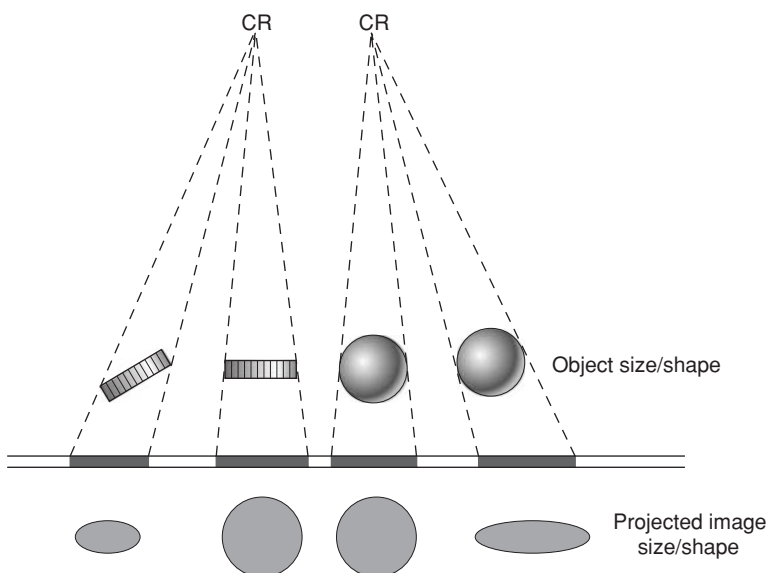
Figure 11–7. The shape of various structures can be radiographically misrepresented (i.e., *foreshortened or elongated*) as a result of their position in the body. That misrepresentation can be exaggerated when the part is away from the central axis of the x-ray beam.
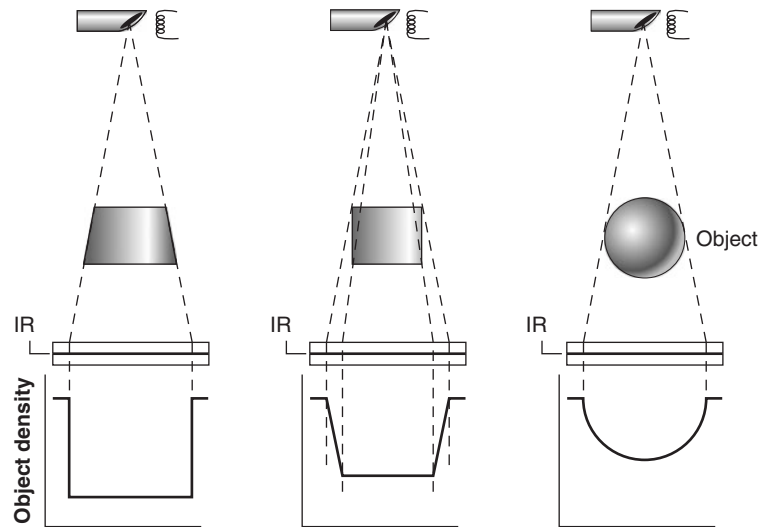
Figure 11–8. Blur or unsharpness results when the *shape* of a three-dimensional object does not coincide with that of the x-ray beam. Blur is accompanied by changes in image density as a result of differing thicknesses traversed by the x-ray beam.

Unless the edges of a three-dimensional *object* conform to the shape of the x-ray beam, blur or unsharpness will occur at the partially attenuating edge of the object. As Figure 11–8 illustrates, this will be accompanied by changes in radiographic/image density, according to the thickness of areas traversed by the x-ray beam.

■ *SUMMARY*

- ■ **Some geometric unsharpness is intrinsic because of the shape and position of the structure of interest within the body.**
- ■ **Structures that do not parallel the x-ray tube and image receptor and/or that lie outside the central axis of the x-ray beam will be foreshortened or elongated.**
- ■ **Structures within the body lie at varying distances from the x-ray image receptor, producing varying degrees of magnification.**

C. *FOCAL SPOT SIZE*

Another factor influencing the geometry of the image is focal spot size. If x-ray photons were emitted from a single point source, structures would be recorded and resolved with great clarity. However, because x-ray photons emerge from a measurable focus, image details are represented with unsharp edges. As shown in Figures 11–9 and 11–10, photons emerging from various points on a measurable focal spot are responsible for producing blurred, unsharp edges of anatomic details. The extent or size of the unsharp area is directly related to the focal spot size and OID, and inversely related to the SID; that is, unsharpness increases as focal spot size and OID increase and as the SID decreases.

This border of unsharpness around image details is often referred to as *focal spot blur, geometric unsharpness,* or *edge gradient*. The *smaller* the focal spot size, the *better the geometrically recorded detail*.

A distinction is made between the *actual focal spot* and the *effective* (projected or apparent) *focal spot*. The *actual* focal spot is the
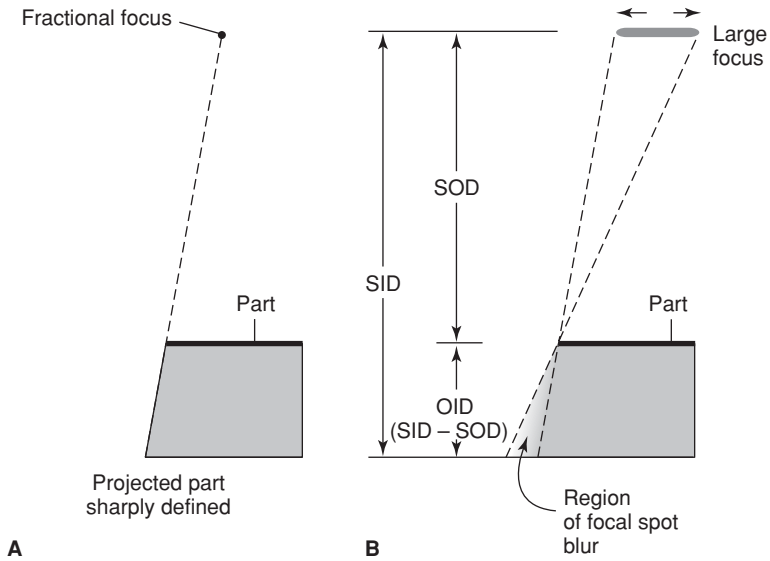
Figure 11–9. X-ray photons emitted from a point source **(A)** will provide an image having sharply defined borders. X-ray photons emitted from a measurable focal spot **(B)** will produce a zone of blur or unsharpness around each image detail. The degree of blur is directly related to the *size of the focal spot.*

Figure 11–10. *Effect of focal spot on recorded detail.* Both images were produced using direct exposure technique to better show the effect of focal spot size on detail, independent of the influence of intensifying screens. **(A)** Magnified image of the first metacarpal, made with a 0.6-mm focal spot. Note the blur or unsharpness associated with bony trabeculae, especially noticeable on the magnified image. **(B)** Image made under identical conditions but using a 1.2-mm focal spot; more severe degradation of recorded detail is demonstrated as a result of blur from the use of a larger focal spot. *Note:* Magnification views must be made with a 0.3-mm *(fractional)* focal spot, or smaller, to preserve recorded detail. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

finite area on the tungsten target that is actually bombarded by electrons from the filament. The *effective* focal spot is the foreshortened size of the focus as it is projected down toward the image receptor; that is, as it would be seen looking up into the emerging x-ray beam. This is called *line focusing* or the *line focus principle* (Fig. 11–11). We generally speak in terms of the effective, or projected, focal spot; manufacturers state effective focal spot size.

The angle of the anode can have a significant effect on recorded detail. Differences in anode angle, all other factors remaining constant, will affect the size of the effective focal spot, as illustrated in
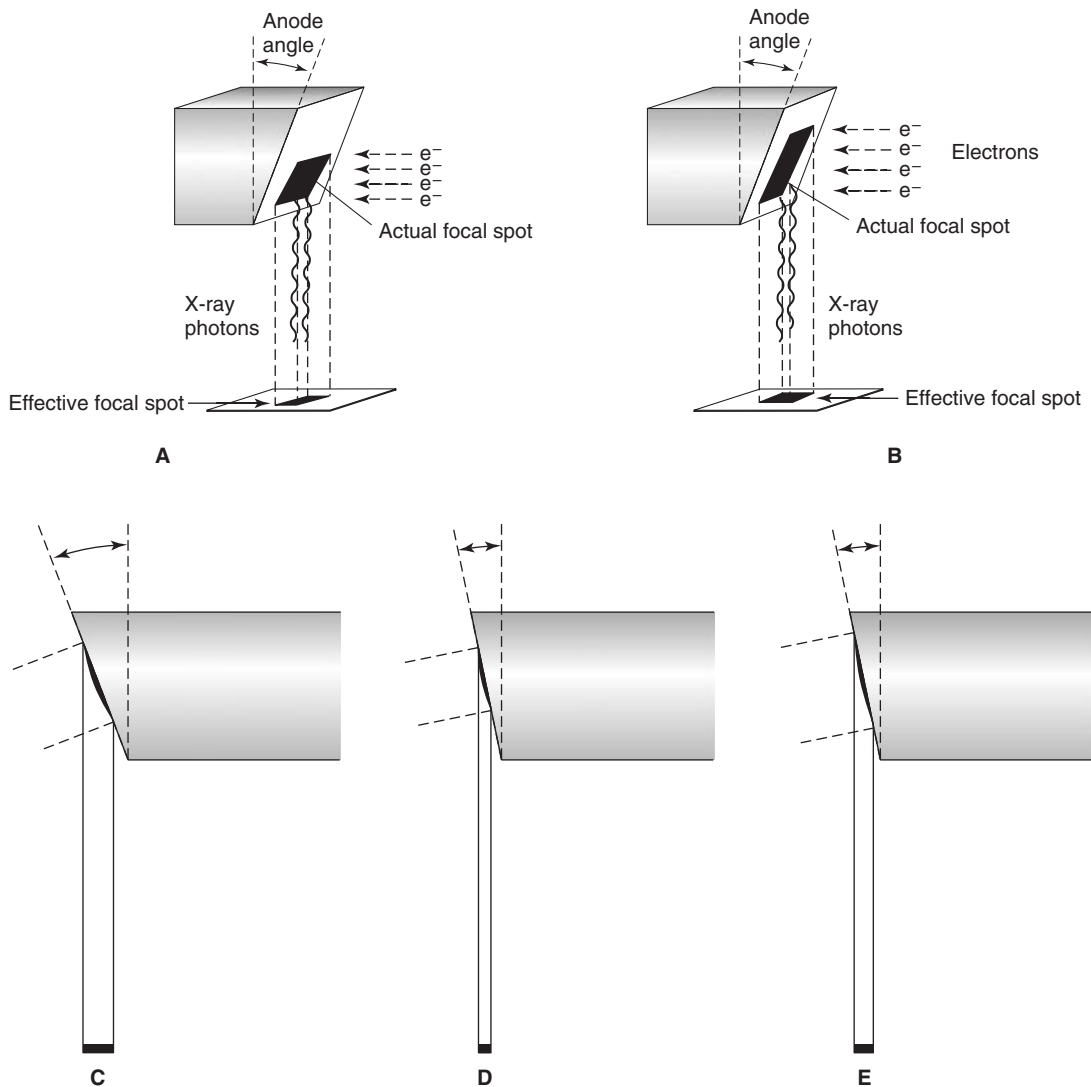
Figure 11–11. **(A)** and **(B)** How the apparent focal spot will differ from the actual focal spot as a result of the line focus principle. **(C)** and **(D)** How the angle/bevel of the actual focal spot will affect the projected focal spot. **(E)** How a small anode angle combined with a large actual focal spot can result in a small effective focal spot. *The size of the effective focal spot, with its associated blur, actually varies along the length of the image receptor,* being largest at the cathode end of the image receptor and smallest at the anode end (see Figs. 11–12 and 11–13).

Figure 11–11C, D, and E. The *actual* focal spots in Figure 11–11C and D are the same size, but the anode angle in D is half of that in C. Note how much smaller the *effective* or *projected* focal spot is in Figure 11–11D.

Hence, when using a very small anode angle, a larger actual anode area can be bombarded (Fig. 11–11E) while maintaining a small effective focal spot. Thus, a "fractional" (0.3 mm or smaller) effective focal spot can be maintained, recorded detail is improved, and anode heat load tolerance is not compromised. This type of x-ray tube is useful in magnification of small blood vessels.

The size of the effective focal spot, with its associated blur or unsharpness, actually *varies along the length of the image receptor*, being largest at the cathode end of the image receptor and smallest at the anode end (Figs. 11–12 and 11–13).
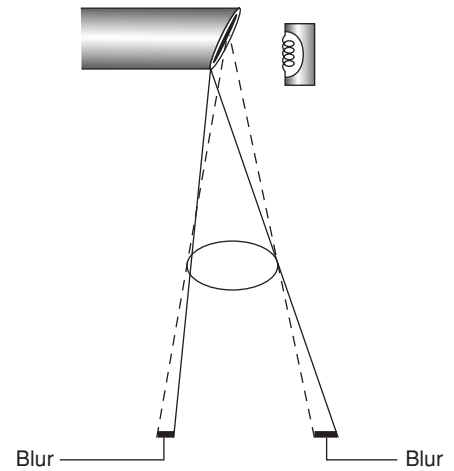
Figure 11–12. Because of the angle of the anode, unsharpness or blur is greatest at the cathode end of the image receptor.
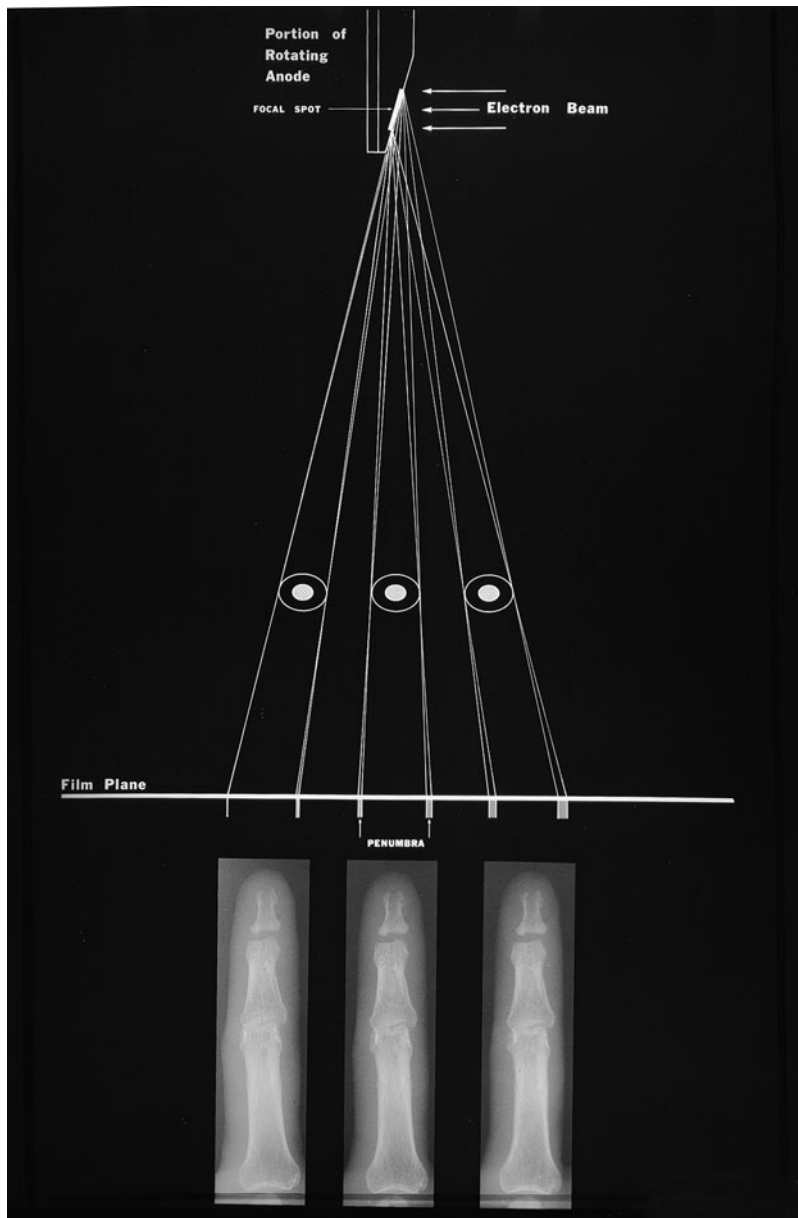
Figure 11–13. *Variation of effective focal spot size along the longitudinal tube axis.* Three images of the third phalanx are shown: one taken at the anode end of the x-ray beam, one at the central portion of the beam, and one at the cathode end. The images clearly illustrate gradual loss of recorded detail toward the cathode end of the x-ray beam. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
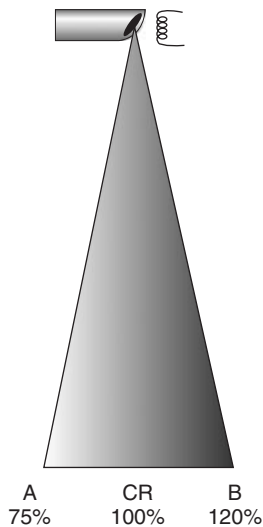
Figure 11–14. *The anode heel effect.* As x-ray photons are produced at the anode focus, a portion of the divergent beam nearest the anode end **(A)** is absorbed by the anode's "heel." This represents a decrease in x-ray beam intensity at the anode side of the x-ray beam. The smaller/steeper the anode angle/bevel, the more pronounced the heel effect.

If the use of a smaller focal spot size provides us with better recorded detail, why is the smallest focal spot available not always used? Simply because focal spot size is also associated with the buildup of heat within the x-ray tube. Large quantities of heat delivered to the x-ray tube, especially in a short period of time, can be very damaging to the tube and can shorten its life span.

If the focal spot is small, heat is confined to a tiny area; localized melting of the target material and anode pitting and/or cracking can occur more easily. The larger the focal spot, the greater the surface area available for heat dispersion. The perfect combination would, of course, be a large actual focus that could withstand heat and still provide a small effective focus for optimum-recorded detail. This can be achieved by using an x-ray tube with a small anode *angle* of approximately 7 to 10 degrees. As previously mentioned, the smaller angle enables a larger "face" to be presented to the electron stream, that is, a larger surface area over which to disperse heat (Fig. 11–11). The slight anode angle causes significant foreshortening of the actual focal spot, creating a very small *effective* focal spot.

A difficulty associated with the use of a small anode angle, however, is maintaining a large (14 × 17) field size. The small anode angle produces a pronounced *anode heel effect* (Fig. 11–14). Using a small anode angle, a typical radiographic distance of 40 inches SID, and a 14 × 17-inch image receptor, there will be approximately 2 inches of unexposed area at the anode end of the image. This can be remedied with an increase in SID, which must be accompanied by an appropriate increase in exposure factors.

■ *SUMMARY*

- **Focal spot size affects detail by influencing the degree of blur or unsharpness: increased focal spot size = increased blur = decreased detail.**
- **Unsharpness or blur is directly related to focal spot size and OID, and inversely related to SID.**
- **The use of a small focal spot improves recorded detail, but generates more heat at the anode.**
- **The effective or projected focal spot size is always smaller than the actual focal spot according to the line focus principle.**
- **Effective focal spot size varies along the longitudinal axis of the image receptor, being largest at the cathode end and smallest at the anode end of the x-ray beam.**
- **Smaller anode angles can permit larger actual focal spot sizes while maintaining small effective focal spot sizes—at the expense of accentuating the anode heel effect.**
- **Use of a small anode angle can limit image receptor coverage at traditional and short SIDs.**

D. MOTION

Image blur or unsharpness, as a result of motion, can cause severe degradation of recorded detail (Fig. 11–15). The best method of

Figure 11–15. Loss of recorded detail as a result of part motion. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

minimizing *voluntary motion* is through good *communication* and suspended respiration. A patient who understands what to expect and what is expected of him or her is better prepared and more likely to cooperate than a patient whose concerns have been inadequately addressed.

Involuntary motion, such as peristaltic activity, muscle spasms, and heart action, cannot be controlled by the patient. The best way to minimize involuntary motion is by using the shortest possible *exposure time*. Motion is often a problem in mobile radiography with machines of limited output (thereby prohibiting the use of short exposure times).

Special positioning devices (such as pediatric immobilizers), positioning sponges, and carefully placed sandbags are frequently used to assist the patient in maintaining the required position.

Equipment motion can cause an effect similar to that caused by patient motion. Bucky/grid motion can cause motion of the part during tabletop examinations; x-ray equipment often has a switch to turn off the Bucky/grid when doing tabletop work. Bumping an improperly balanced tube head just before making the exposure can result in motion blur or unsharpness if the exposure is made while the tube head is still vibrating. Motion blur is probably the greatest enemy of recorded detail and is most obvious when the motion is close to the

A

B

C

Figure 11–16. **(A)** Image made using 100 speed screens; 0.5 mm of motion was introduced. Motion blur is noticeable, particularly in the magnified view of the first metacarpal. Compare the recorded detail of image A with that of image B. **(B)** Also made using 100 speed screens, but having no motion. **(C)** Made with 400 speed screens and 0.5-mm motion. Notice how much more obvious detail loss becomes with a faster imaging system. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

image receptor (i.e., part motion is more damaging to recorded detail than tube motion; Fig. 11–16).

Deliberate motion is occasionally used to blur out unwanted structures so that the area of interest can be seen to better advantage. The "breathing techniques" of lateral thoracic spine and transthoracic shoulder are typical examples. Another is the infrequently performed procedure of (conventional) *tomography*, in which a preselected structure plane will be clearly delineated while structures above and below that plane are blurred (see Fig. 11–17).

A
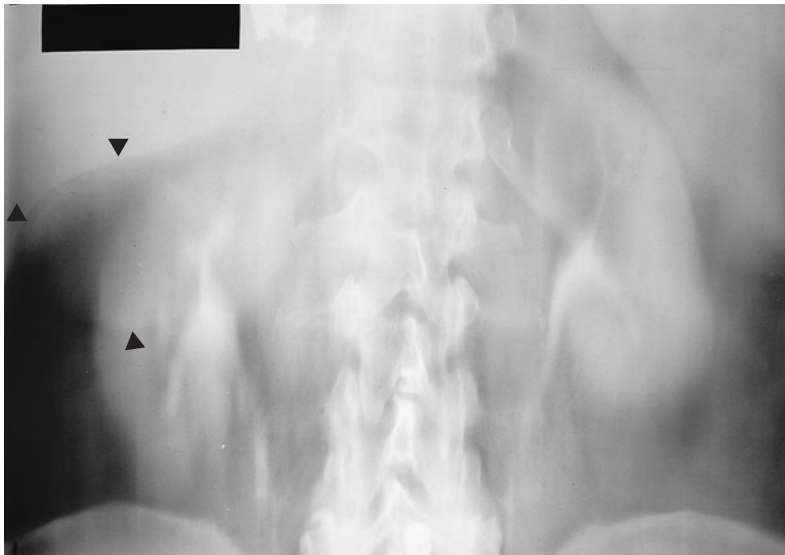
B

Figure 11–17. **(A)** Plain IVU image with no visible abnormalities. **(B)** An 8-cm tomographic section of the same patient clearly depicting a 7-cm renal cyst overlying the R midrenal cortex. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

■ *SUMMARY*

- ■ **Motion is the greatest adversary of recorded detail.**
- ■ **Voluntary patient motion can be minimized through good communication.**
- ■ **Involuntary patient motion is best minimized by using the shortest possible exposure time.**
- ■ **Various radiographic accessories are available to help minimize both voluntary and involuntary patient motion.**
- ■ **Equipment motion can also result in loss of recorded detail in the form of image blur.**
- ■ **Special techniques that introduce motion are sometimes employed to see some structures particularly well.**

E. INTENSIFYING SCREENS

In the very early days of radiography, before *intensifying screens* were available, images were produced by exposure of photographic emulsion to x-rays alone. Tremendously lengthy exposures were required for even the smallest parts. These exposures took their toll on the fragile, scarcely understood equipment and, of course, on the unsuspecting victims of excessive radiation exposure. Direct exposure technique was frequently used through the 1960s and 1970s for examinations of extremities and other small parts not requiring a grid. Because of the excessive patient dose, direct exposure technique is rarely used today.

In 1896, Thomas Edison developed the *calcium tungstate* intensifying screen that served to reduce the required exposure to a fraction of that needed without screens. Calcium tungstate screens gained wide acceptance during World War I and were used almost exclusively until the advent of *rare earth phosphors* in the early 1970s.

The active ingredient in intensifying screens is the fluorescent *phosphor*, which functions to change x-ray photon energy to fluorescent light energy. More than *98% of the exposure received by the film emulsion is from fluorescent light* emitted by intensifying screen phosphors. For every x-ray photon absorbed by the phosphor, many light photons are emitted. They truly *intensify* the action of x-rays and thus permit the use of much smaller exposures than those required with direct exposure methods.

In the production of intensifying screens, phosphors are ground to a fine powder and mixed with a transparent binding substance. A somewhat reflective plastic base material is used as a support. The phosphor mixture is spread in a smooth layer onto the plastic base; this is called the *phosphor layer* or *active layer* (Fig. 11–18).

Rare Earth Phosphors

Gadolinium
Lanthanum
Yttrium

Relationship Between Screen Speed and Tube Wear (Heat Units)

Screen Speed	mAs	Heat Units (HU)
100	60	5400
200	30	2700
400	15	1350
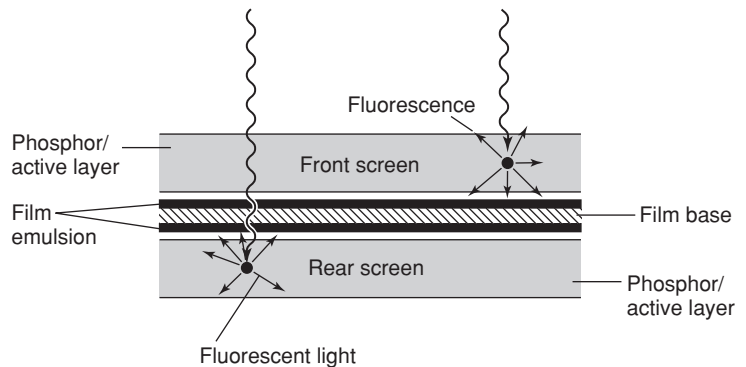
Figure 11–18. *A cross section of screens and film.* The illustration shows how duplitized x-ray film is sandwiched between two intensifying screens. Phosphors of the adjacent intensifying screens absorb x-ray energy and convert it to fluorescent light, which then exposes the neighboring film emulsion as shown in Figure 11–19. Notice that the rear intensifying screen is thicker. As x-ray photons travel through the cassette front and front screen, they are somewhat attenuated and, as a result, their interaction with the rear screen is somewhat diminished. If the rear screen is made thicker, its speed is increased to compensate for the attenuated x-ray beam.

All phosphors are not created equal. Different types of phosphors have different x-ray absorbing and fluorescent light–emitting properties. Some types of phosphors are more efficient than others. Some are able to absorb a greater percentage of the x-ray energy. A particular phosphor's ability to absorb x-ray energy and convert it to fluorescent light energy is referred to as its *conversion efficiency.* Phosphors having greater sensitivity (i.e., speed) have greater conversion efficiency.

Factors that contribute to the speed of intensifying screens include type of phosphor, phosphor size, active/phosphor layer thickness, and reflective backing.

1. Phosphors.
Phosphors with a *high atomic number* have a greater likelihood of interacting with an x-ray photon and therefore possess greater speed. How well a particular phosphor detects the presence of x-ray photons is referred to as quantum detection efficiency. The phosphor should have a high *conversion efficiency*; that is, it should emit a liberal measure of fluorescent light for each x-ray photon it absorbs. The greater the conversion efficiency, the greater the speed.

Fluorescence should terminate at the same time as the x-ray source; continued fluorescence after termination of exposure is termed *lag* and contributes to an overexposed image. The wavelength, or color, of light emitted must match the particular sensitivity of the film emulsion used. This is known as *spectral matching.* Calcium tungstate emits a blue violet fluorescence and *rare earth phosphors* may fluoresce either green or blue; each must be used with a corresponding green- or blue-sensitive film emulsion.

Phosphorescence refers to the luminescence from fluoroscopic screen phosphors. Their unique characteristic is the lingering luminescence *after* the termination of x-ray (*afterglow*). This permits the fluoroscopist to continue viewing the part for a short time as the image slowly fades from the monitor. Thus, the fluoroscopist can use intermittent fluoroscopy to reduce patient dose.

Rare earth phosphors possess a much higher conversion efficiency than calcium tungstate, making them the phosphors of choice today. The rare earth phosphors used in radiography are oxysulfides and oxybromides of *lanthanum, gadolinium*, and *yttrium.* The phosphors used in fluoroscopy are *cesium iodide* and *zinc cadmium sulfide.*

2. Phosphor Size.
Screen speed and phosphor size are directly related; that is, *as phosphor size increases*, more surface area is available for x-ray photon capture, resulting in an *increase in screen speed.*

3. Active or Phosphor Layer Thickness.
Screen speed and phosphor layer thickness are directly related; that is, as active layer thickness increases, more x-ray photons are converted to light and, therefore, screen speed increases.

4. Reflective Backing.
Screen speed and the degree of reflectance, given the base material, are directly related; that is, the greater the reflectance, the greater the number of light photons directed toward the film emulsion and, consequently, the greater the screen speed.

Some manufacturers incorporate a *dye* in the phosphor layer that functions to reduce light diffusion, thus improving resolution. It should

---

Intensifying Screen Speed Increases, Recorded Detail Decreases, As:

- Phosphor size increases
- Active/phosphor layer thickness increases
- Phosphor sensitivity increases
- Screen reflectance increases

Recorded Detail Increases As:

- Focal spot size decreases
- SID increases
- OID (magnification) decreases
- Motion decreases
- (Shape) distortion decreases
- Screen speed decreases
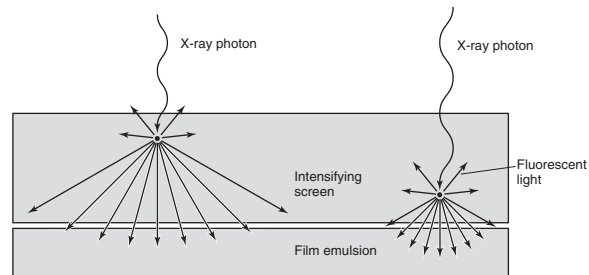
Figure 11–19. Screen thickness and diffusion of fluorescent light versus recorded detail. As intensifying screen thickness increases, the film is exposed by diffused light from distant phosphors. The phosphors of thinner intensifying screens fluoresce closer to the film; therefore, light is diffused to a lesser degree and recorded detail is maintained.

be noted, however, that the addition of dye does sacrifice a little speed.

Loss of recorded detail may be a result of intensifying screen blur or unsharpness. Fluorescent light emerging from the phosphors diffuses and spreads over a larger area (Fig. 11–19). It is this diffusion of fluorescent light that causes indistinct, blurry anatomic details. *The degree of diffusion, and hence, the degree of blurriness, is primarily dependent on the factors that regulate intensifying screen speed* (Fig. 11–20).

Screen speed and screen blurriness are directly related; that is, as intensifying screen speed increases, screen blurriness increases and image resolution/detail decreases.

Radiography departments frequently have more than one speed-intensifying screen available; slower (detail) screens are commonly used for extremity examinations and faster screens for general radiography.

The use of rare earth phosphors enables the radiographer to greatly reduce patient dose in comparison to exposures required for calcium tungstate screens. The use of rare earth phosphors involves only minimal loss of recorded detail and permits a significant reduction in patient dose; they are, therefore, generally considered the screens of choice.

Another way in which intensifying screens can have a significant impact on recorded detail is through *screen–film contact*. Areas of imperfect screen–film contact result in blurriness that severely degrades recorded detail (Fig. 11–21A). Causes of poor screen–film contact include warped screens, damaged cassette frames, and foreign bodies in the cassette. Elevation of the screen in areas of poor contact allows light to diffuse over a larger area, thus exaggerating screen blur. Larger cassettes are more susceptible to poor screen contact. Proper care of intensifying screens includes *periodic evaluation of screen contact by using a specially designed wire mesh* (Fig. 11–21B).

A related problem associated with screens and resolution is *quantum mottle*. As screen speed and kV are increased, mAs may be reduced to such a small amount that image *graininess*, or quantum mottle, becomes a problem (Figs. 11–22 and 11–23). This graininess becomes apparent and increases as the system speed increases. So
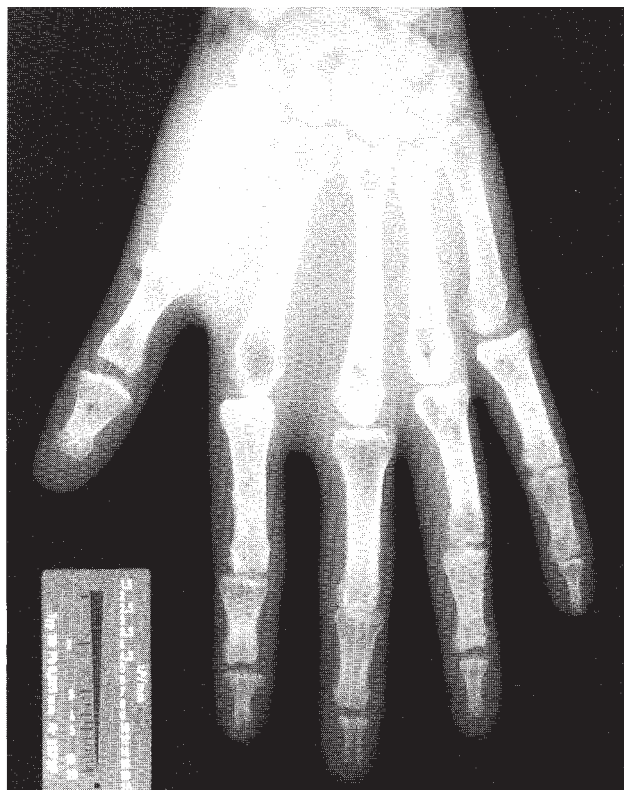
Figure 11–20. Imaging system speed versus required exposure and resolution. Image *A* was made without intensifying screens but required 128 mAs exposure. Image *B* was made using 100 speed screens and 10 mAs exposure. Image *C* was made with 400 speed screens and 1.33 mAs exposure. Note the progressive loss of recorded detail accompanying the increase in system speed. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
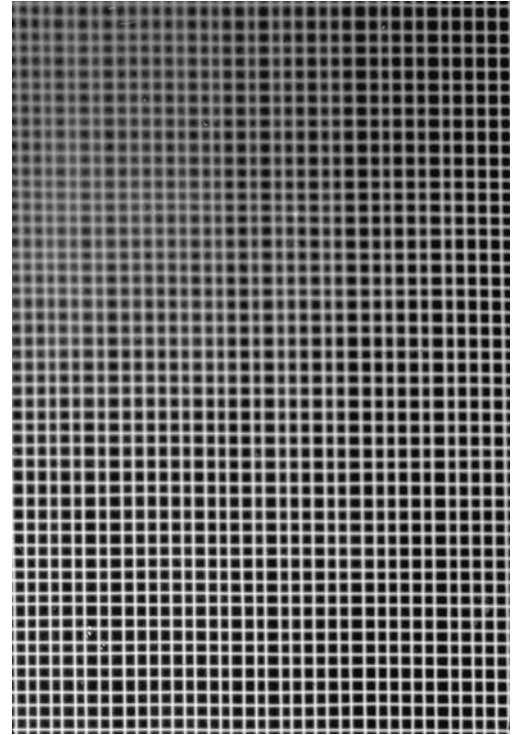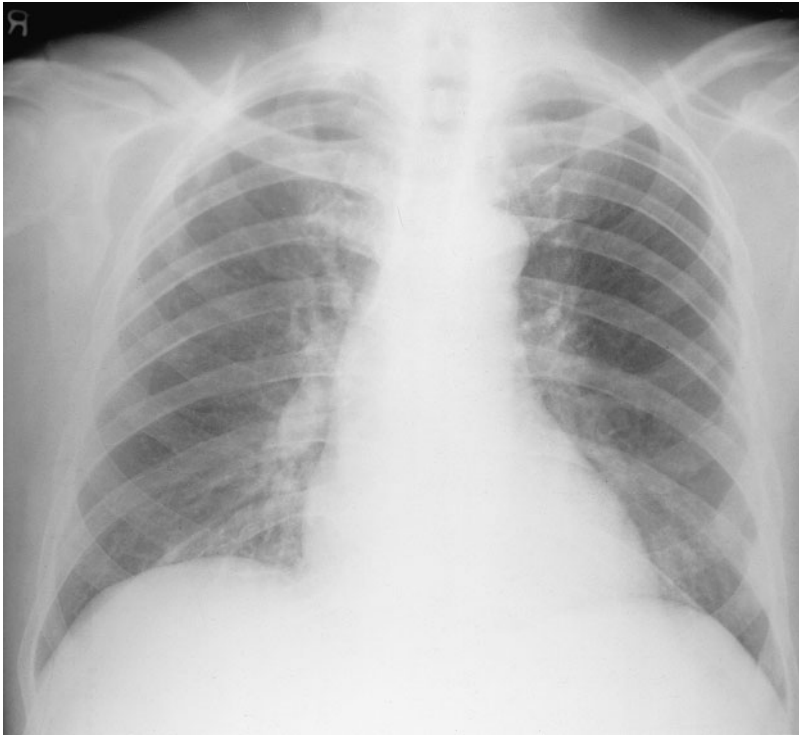
Figure 11–21. *Demonstration of poor screen–film contact.* **(A)** Blur as a consequence of poor film–screen contact in the apical region of the chest. **(B)** Wire mesh test of a different cassette illustrates blur caused by poor film-to-screen contact in the central region of the cassette. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
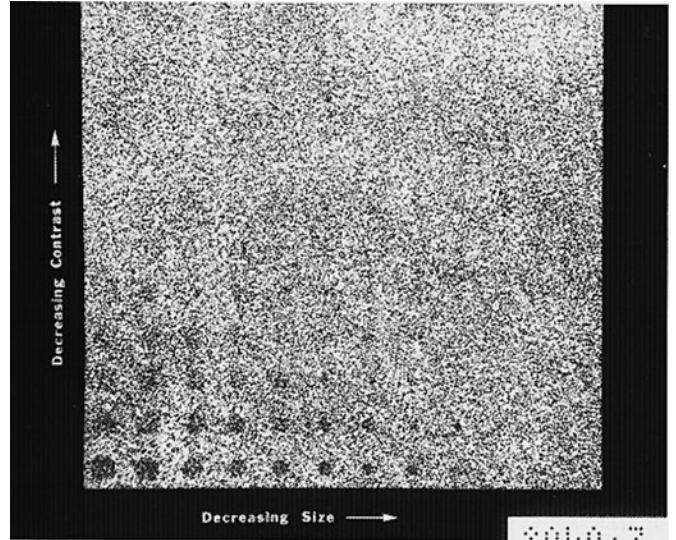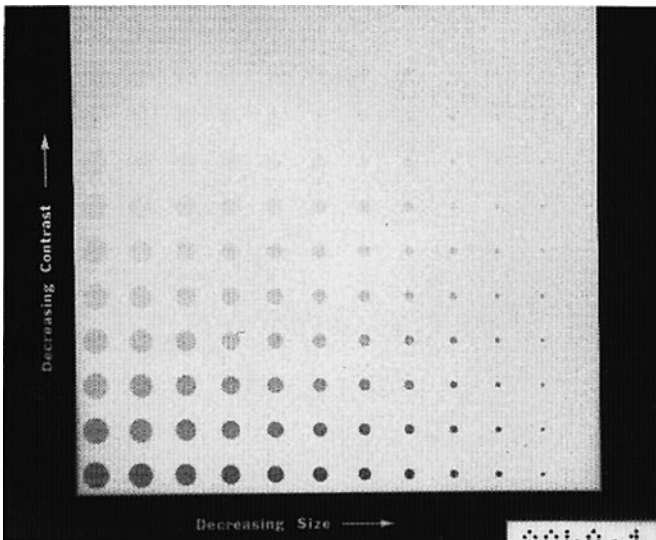
Figure 11–22. **(A)** and **(B)** The contrast–detail quality assurance device imaged illustrates the effect of x-ray exposure and resulting quantum mottle. Image *B* was made using a much lower mAs value (fewer x-ray photons) than image *A*; note the striking graininess in *B*. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 11–23. Quantum mottle/graininess can make visibility of small vessels difficult. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

few x-ray photons are used (mAs) to produce the image that one can almost count them as the representative black "grains" on the radiographic image!

■ SUMMARY

- **The use of intensifying screens helps to decrease patient dose and increase tube life; as intensifying screen speed increases, patient dose decreases and tube life increases.**
- **Intensifying screen phosphors absorb x-ray photons and emit a large quantity of fluorescent light.**
- **Fluorescent light is responsible for more than 98% of film emulsion exposure.**
- **The color light emitted by the phosphors must be correctly matched with the film emulsion sensitivity (spectral matching).**
- **Rare earth phosphors have a greater conversion efficiency than calcium tungstate phosphors.**
- **The greater the conversion efficiency and speed of screens, the poorer the recorded detail, as a result of greater fluorescent light diffusion at higher screen speeds.**

■ **Intensifying screen speed is influenced by the type and size of phosphor used, the thickness of the active/phosphor layer, and the degree of reflectance, given the screen base.**
■ **Quantum mottle is more likely to occur when using fast screens with low mAs and high kV factors.**
■ **Phosphors that continue to fluoresce after the x-ray source has terminated are said to possess "lag" or "afterglow."**
■ **Phosphorescence is associated with fluoroscopic screens.**
■ **Perfect screen–film contact is required to maintain recorded detail; screens can be tested for screen–film contact with the use of a specially designed wire mesh.**

Chapter Review Questions

☆ ***Congratulations!*** *You have completed a portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.*

1. Which of the following has (have) an effect on recorded detail?
    1. focal spot size
    2. screen–film contact
    3. object–image distance
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

2. A wire mesh is used to test:
    (A) focal spot size
    (B) for screen lag
    (C) film–screen contact
    (D) screen speed

3. Misalignment of the tube–part–image receptor relationship results in:
    (A) shape distortion
    (B) size distortion
    (C) magnification
    (D) blur

4. Which of the following is (are) considered a geometric factor(s) controlling recorded detail?
    1. OID
    2. SID
    3. screen speed
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

5. Although the stated focal spot size is measured directly under the actual focal spot, effective focal spot size actually varies along the width of the x-ray beam. At which portion of the x-ray beam is the effective focal spot the smallest?
    (A) at its outer edge
    (B) along the path of the central ray
    (C) at the cathode end
    (D) at the anode end

6. Which of the following will result in the best recorded detail?
    (A) 1.5-mm focal spot
    (B) 1.0-mm focal spot
    (C) 0.6-mm focal spot
    (D) 0.3-mm focal spot

7. All of the following are related to recorded detail, except:
    (A) motion
    (B) screen speed
    (C) object–image distance
    (D) grid ratio

8. Foreshortening may be caused by:
    1. the radiographic object being placed at an angle to the image receptor
    2. insufficient distance between the focus and the image receptor
    3. very little distance between the object and the image receptor
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 1, 2, and 3

9. When an intensifying screen continues to glow after the x-ray exposure has ended, the screen is said to possess:
    (A) fluorescence
    (B) incandescence
    (C) luminescence
    (D) lag

10. Which of the following has an effect on distortion?
    1. source–image distance
    2. angulation of the x-ray tube
    3. angulation of the part
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

Answers and Explanations

1. (D) Focal spot size affects recorded detail because of its effect on *blur*: the larger the focal spot size, the greater the blur produced. Recorded detail is significantly affected by distance

changes because of their effect on magnification. As SID increases, magnification decreases and recorded detail increases. As OID increases, magnification increases and recorded detail decreases. Screen–film contact has a significant effect on recorded detail—if intensifying screens are separated even slightly in one tiny area, there is a very significant loss of detail in that area (as well as a loss of contrast) owing to diffusion of fluorescent light (Fig. 11–21A and B).

2. (C) Intensifying screens can have a considerable impact on recorded detail through *screen–film contact.* Areas of imperfect screen–film contact result in blurriness that severely degrades recorded detail (Fig. 11–21A). Causes of poor screen–film contact include warped screens, damaged cassette frames, and foreign bodies in the cassette. Larger cassettes are more susceptible to poor screen contact. Proper care of intensifying screens includes *periodic evaluation of screen contact using a specially designed wire mesh* (Fig. 11–21B). Focal spot testing uses a slit camera or star pattern.

3. (A) Shape distortion (foreshortening, elongation) is caused by improper alignment of the tube, part, and image receptor. Size distortion, or magnification, is caused by too great an object–image distance or too short a source–image distance. Blur is caused principally by use of a large focal spot.

4. (B) The relationship among the focal spot, the anatomic part, and the image receptor determines geometric sharpness. That is, effective focal spot size determines the degree of geometric blur, and OID and SID determine the degree of magnification. The OID should be as short as possible and the SID should be as long as practical. The anatomic part should be accurately positioned as closely parallel to the image receptor as possible. Intensifying screens also lend a degree of unsharpness to the image, but do not affect the *geometry* of the image (i.e., size or shape).

5. (D) X-ray tube anodes are constructed according to the *line focus principle*; that is, the focal spot is angled (usually 12–17 degrees) to the vertical. As the actual focal spot is projected downward, it is foreshortened; thus, the effective focal spot is always smaller than the actual focal spot. As it is projected toward the cathode end of the x-ray beam, it becomes larger and approaches its actual size. As it is projected toward the anode end, it gets smaller because of the anode "heel" effect.

6. (D) One factor influencing geometric sharpness is penumbra, or blur. The production of blur is inversely proportional to recorded detail. As focal spot size increases, blur increases, and recorded detail decreases.

7. (D) Motion is said to be the greatest enemy of recorded detail because it completely obliterates image sharpness. Screen speed can reduce recorded detail according to the degree of light diffusion from the phosphors. Object–image distance causes magnification and blurriness of recorded detail. Grid ratio is related to scattered radiation cleanup; it is unrelated to detail.

8. (C) Size distortion (magnification) is inversely proportional to SID and directly proportional to OID. Decreasing the SID and/or increasing the OID will increase size distortion. Aligning the tube, anatomic part, and image receptor so as to be parallel *reduces* shape distortion.

Angulation of the long axis of the part with respect to the image receptor results in foreshortening of the object. *Tube* angulation causes elongation of the part.

9. (D) When intensifying screen phosphors absorb x-ray photons, the x-ray photon energy is converted to visible light energy. The light emitted by the phosphors is termed luminescence. There are two types of luminescence: fluorescence and phosphorescence. Fluorescence is luminescent light that ceases to be emitted *as soon* as the x-ray photon stimulation ceases. Phosphorescence, on the other hand, is when the phosphors continue to glow *after* x-ray photon stimulation ceases; another term for this is lag.

10. (D) Distortion can be described as being either size or shape. Size distortion is magnification, caused by either insufficient SID or excessive OID. Shape distortion results from misalignment of the x-ray tube, part, and image receptor. Tube angulation can cause elongation of the part. Angulation of the part with respect to the image receptor will foreshorten the image. Focal spot size is unrelated to distortion, but strongly related to production of penumbral unsharpness.

II. FACTORS AFFECTING RADIOGRAPHIC/IMAGE DENSITY

Radiographic, optical, or image density is defined as the overall amount of blackening on a radiographic image or a particular portion of the image. It provides the correct degree of background blackening for the anatomic image. In electronic/*digital imaging*, this quality is referred to as *brightness*. Excessive density can obscure image details; insufficient density can mask pathology. Radiographic density is a *quantitative* factor; that is, it describes an *amount* of image blackening determined by the *number* of x-ray photons used to create the image. Thus, radiographic density is regulated by the *exposure rate* or *number* of photons reaching the film emulsion or image receptor.

Radiographic/image density is generally thought of as being optimal, excessive, or insufficient, when in fact it can be precisely measured and quantified. Optical density can be described as the relationship between the amount of light incident upon the film image (i.e., from the illuminator) compared to the amount of light transmitted through the film image. This relationship is expressed in the following equation:

$$OD = \log_{10} \frac{I_o}{I_t}.$$

OD is *o*ptical *d*ensity expressed as a logarithm, demonstrating the relationship between the amount of light transmitted through the film (I_t) compared to the amount of light incident upon (I_o) the film. The diagnostically useful range of optical image density is 0.25 to 2.5 (Fig. 11–24).

A sensitometric curve, like the one shown in Figure 11–25, can be used to illustrate the relationship between the x-ray exposure given the film emulsion and the resulting density.

The study of film emulsion response to exposure is called *sensitometry*. The sensitometric curve is discussed further in Section IV, "Image Receptor and Grid Options."
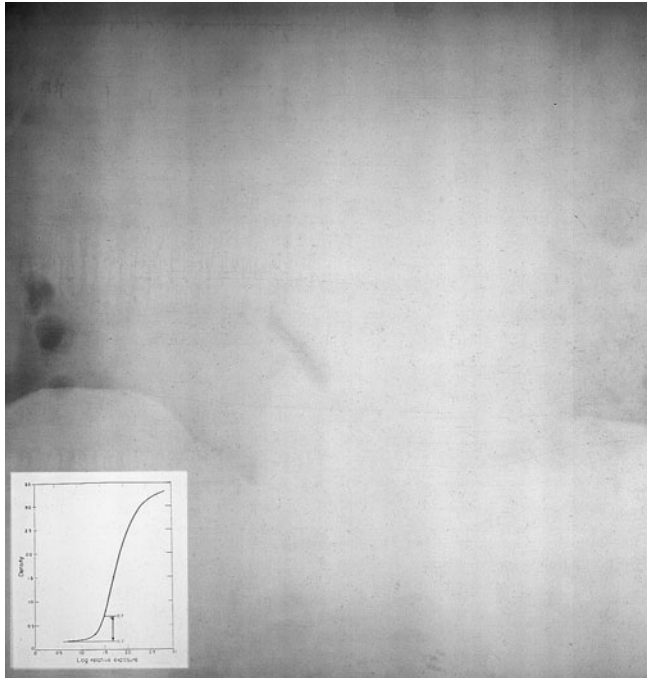
A

B

C

Figure 11–24. **(A)**, **(B)**, and **(C)** *The diagnostically use-ful range of optical densities is approximately 0.25 to 2.5.* Note the range of densities visualized on each of these radiographs as identified by the accompanying sensitometric curve on each. **(C)** The range of densities visualized lies between 1.2 and 2.9 (*too dark*), as indi-cated by the accompanying sensitometric curve. Notice the number and visibility of details imaged here as com-pared with those imaged in *A* density range 0.2–0.7 (*too light*) and *B* density range 0.5–2.3 (*appropriate*). (From the American College of Radiology Learning File. Cour-tesy of the American College of Radiology.)

A. MAS

Milliampere-seconds (*mAs*) is the *product* of milliamperes (mA) and exposure time (seconds). Technical factors are usually expressed in terms of mAs rather than mA and time. This is because there are a number of possible combinations of mA and time that will produce
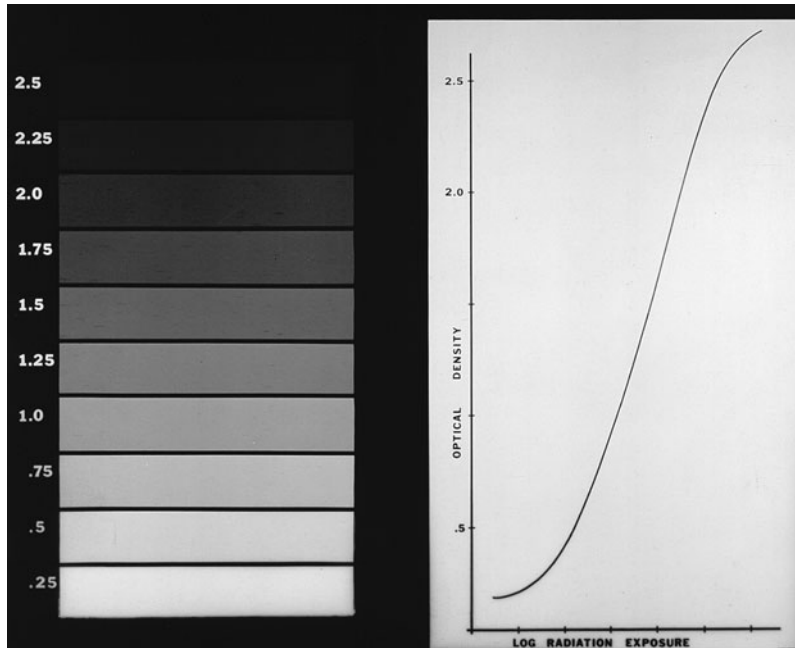
Figure 11–25. *Sensitometric curve.* Intervals of *exposure* appear in increments of 0.3 on the horizontal axis. This is because doubling the exposure (i.e., mAs) results in an increase in log relative exposure of 0.3. For example, 100% of the incident light is transmitted through a film having an optical density (OD) of zero (0), 50% of the light is transmitted through a film having an OD of 0.3, 25% of the light through a film with an OD of 0.6, and so on. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

the desired mAs. For example, it is known that 10 mAs is required to produce a given radiographic/image density. Therefore, each of the following combinations should produce the required (and identical) results: 100 mA and 100 msec, 200 mA and 50 msec, 300 mA and 33 msec, 400 mA and 25 msec, and so on.

Any combinations of mA and time that will produce a given mAs (i.e., a particular quantity of x-ray photons) will produce identical radiographic/image density. This is known as the *reciprocity law*.

Density is a quantitative factor because it describes the *amount* of image blackening. Milliampere-seconds is also a quantitative factor because it regulates x-ray beam *intensity, exposure rate, quantity*, or *number* of x-ray photons produced (mAs is the single most important technical factor associated with image density and is the factor of choice for regulating image density).

mAs is directly proportional to the intensity (exposure rate, number, quantity) of x-ray photons produced, and the resulting radiographic density. If the mAs is doubled, twice the exposure rate and twice the density occurs. If the mAs is reduced to half, the exposure rate and resulting density are reduced to half (Fig. 11–26).

It is not surprising then, that to produce just a *perceptible* change in radiographic density, an mAs change of at least 30% is required. For example, a particular image was produced using 25 mAs and 78 kV and exhibited somewhat insufficient background density. What factors would be required to produce an image having the desired image density?

Because the image density requires improvement, the mAs is the technical factor requiring manipulation. The above information implies that background density is only somewhat lacking; therefore, a 30% increase in mAs would most likely remedy the situation. Because 30% of 25 mAs is 7.5, a new mAs of 32.5 should provide adequate

A

B

C
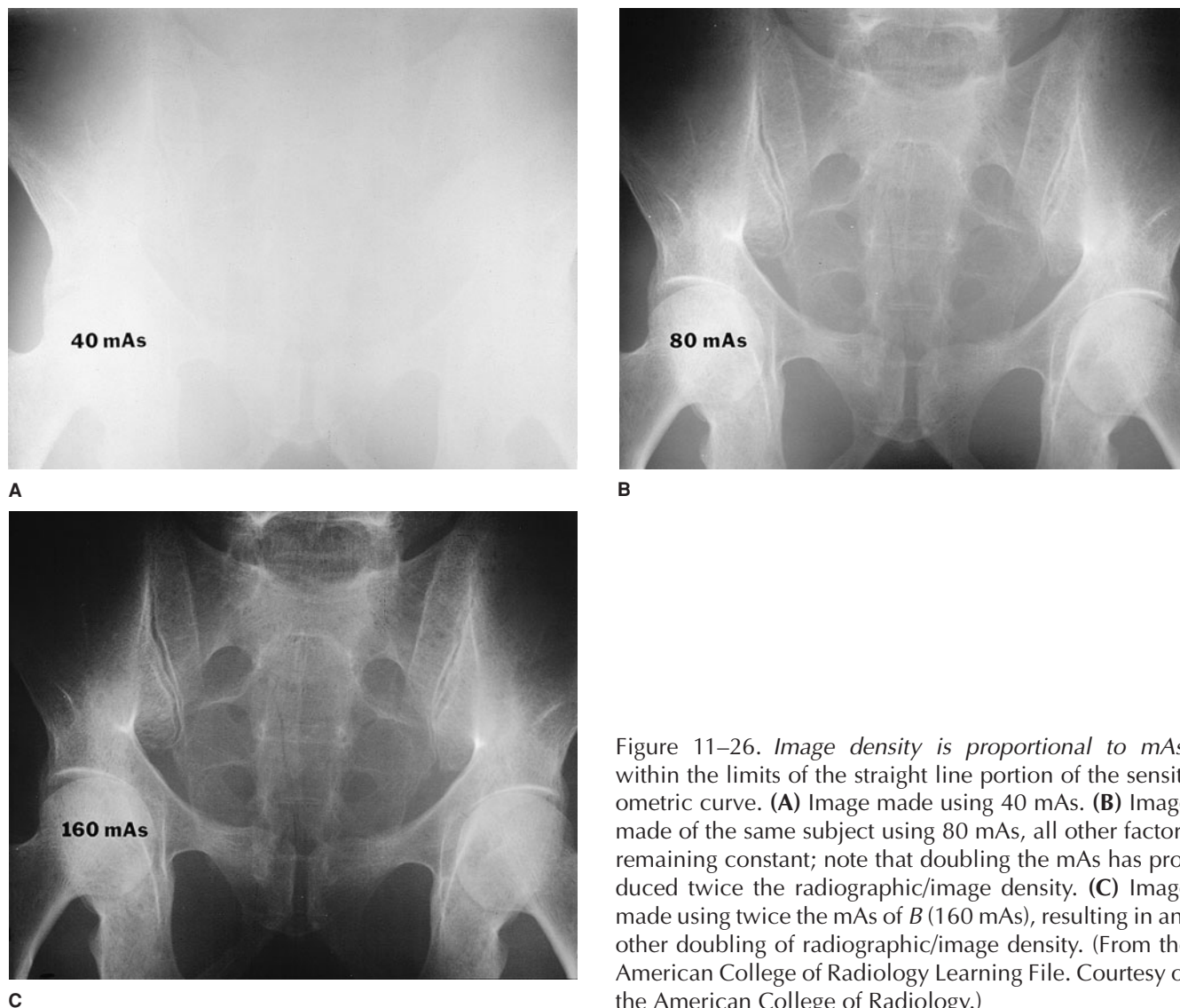
Figure 11–26. *Image density is proportional to mAs*, within the limits of the straight line portion of the sensit-ometric curve. **(A)** Image made using 40 mAs. **(B)** Image made of the same subject using 80 mAs, all other factors remaining constant; note that doubling the mAs has pro-duced twice the radiographic/image density. **(C)** Image made using twice the mAs of *B* (160 mAs), resulting in an-other doubling of radiographic/image density. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

image/optical density. If the image were significantly lacking in den-sity, it would have been appropriate to double the mAs.

■ *SUMMARY*

- mAs is the product of mA and exposure time in seconds.
- Any combination of mA and time that will produce a given mAs will produce identical radiographic density according to the *reciprocity law.*
- Radiographic density and mAs are quantitative factors and are directly related.
- Doubling the mAs will double the radiographic density; halv-ing the mAs will reduce the density to half.
- At least a 30% change must be made in mAs for there to be a perceptible change in radiographic density.

B. SID

As a child you may have been told to "read your book next to the lamp, where you'll have more light." Perhaps your youthful eyes could see just fine where you were, but in fact your advisor was correct in saying that more light was available closer to its source (the lamp).

As distance from a light source increases, the light diverges and covers a larger area; the quantity of light available per unit area becomes less and less as distance increases. The intensity (quantity) of light decreases according to the *inverse square law*; that is, the intensity of light at a particular distance from its source is inversely proportional to the square of the distance (Fig. 11–27). For example, if you decreased the distance between your book and the lamp from 6 feet to 3 feet, you would have four times as much light available.

Similarly, SID has a significant impact on x-ray beam intensity and, hence, radiographic density. *As the distance between the x-ray tube and image receptor increases, exposure rate (and therefore radiographic density) decreases according to the inverse square law.*

Notice that according to the *inverse square law*, the exposure rate is *inversely* proportional to the square of the distance, whereas using the *density maintenance formula* to determine new mAs because of diminished exposure rate, mAs is *directly* proportional to the distance squared.

The two equations that will be used are

$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2} \qquad \text{Inverse square law}$$

$$\frac{mAs_1}{mAs_2} = \frac{D_1^2}{D_2^2} \qquad \text{Density maintenance formula.}$$

In the inverse square law equation, *I* represents intensity (a quantitative term referring to exposure rate; expressed as R/time or mR/time) and *D* represents distance (SID). The original intensity is
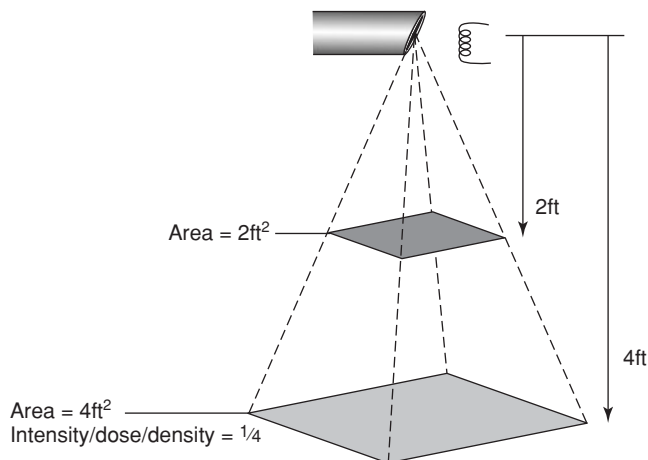
Figure 11–27. *The inverse square law.* Because x-ray beam coverage (area) increases with the square of the distance, the number of x-ray photons per unit area decreases by the same amount.

represented by I_1, the original distance squared is represented by D_1^2, and the new distance squared is represented by D_2^2. I_2 represents the new intensity (i.e., the new exposure rate). Note that the relationship is an *inversely proportional* one. That is, the formula is set up as "old over new = new over old." Also note that the *opposite* is true in the density maintenance formula; i.e., the relationship is *directly* proportional.

An x-ray image made using 12 mAs and 82 kV at 52-inch SID resulted in an exposure rate of 40 mR/min. Another image of the same part will be made at 44-inch SID. What is the exposure rate at the new distance?

Using the inverse square law and substituting known factors,

$$\frac{40}{x} = \frac{1936}{2704} \frac{(44^2)}{(52^2)}$$

$$1936x = 108,160$$

$$x = 55.86 \text{ mR/min at } 44'' \text{ SID.}$$

This illustrates the relationship between distance and x-ray intensity. As the *distance* is *decreased*, the *intensity* of the x-ray beam *increases* (according to the inverse square law). The *resulting increase in radiographic density* will require an adjustment of technical factors, specifically mAs (according to the density maintenance formula), to reproduce the original density.

In the same example (above), what new mAs value will be required at the new distance (44 inches) to maintain the original density?

Using the distance maintenance formula and substituting known factors,

$$\frac{\text{mAs}_1}{\text{mAs}_2} = \frac{D_1^2}{D_2^2}$$

$$\frac{12}{x} = \frac{2704}{1936} \frac{(52^2)}{(44^2)}$$

$$2704x = 23232$$

$$x = 8.59 \text{ mAs at } 44'' \text{ SID.}$$

At 44-inch SID, 8.59 mAs will be required to produce the same radiographic/image density that was produced at 52-inch SID using 12 mAs.

Use the Inverse Square Law to Determine New Exposure Rate at a New Distance

$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2}$$

Use the Density Maintenance Formula to Determine

What change in mAs is required to maintain the original radiographic density, by using the (direct relationship) equation:

$$\frac{\text{mAs}_1}{\text{mAs}_2} = \frac{D_1^2}{D_2^2}$$

■ SUMMARY

- **Relatively small changes in SID can have a significant effect on image/optical density.**
- **As the SID increases, exposure rate and image density decrease.**
- **With changes in SID, the inverse square law is used to calculate the new exposure rate.**
- **With changes in SID, the density maintenance formula is used to calculate the new mAs.**

C. *κV*

As kilovoltage is increased, *more* electrons are driven to the anode with greater speed and energy. More high-energy electrons will result in production of *more high-energy x-rays*. Thus, *kV* affects both quantity and quality (energy) of the x-ray beam. However, although kV and radiographic density are directly *related*, they are not directly proportional; that is, twice the radiographic density does not result from doubling the kV. The effect of kV on quantity is not proportional because an increase in kV produces an increase in photons of *all energies*.

With respect to the effect of kV on image density, there is one convenient rule (*the 15% rule*) that can be followed. If it is desired to double the radiographic density, yet impossible to adjust the mAs, a similar effect can be achieved by *increasing the kV by 15%*. Conversely, the density may be reduced to half by decreasing the kV by 15% (Fig. 11–28).
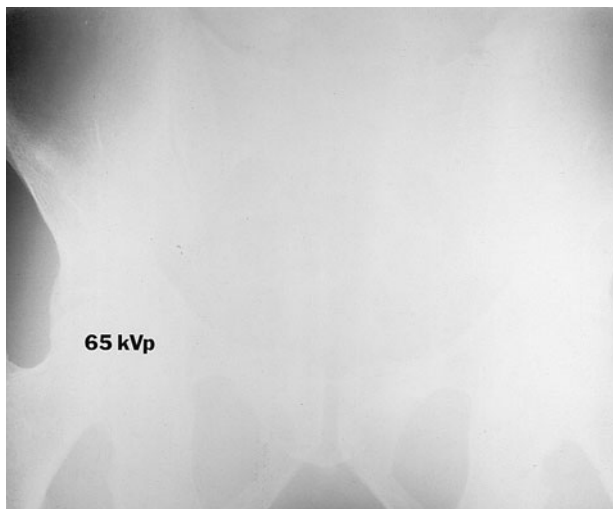
A
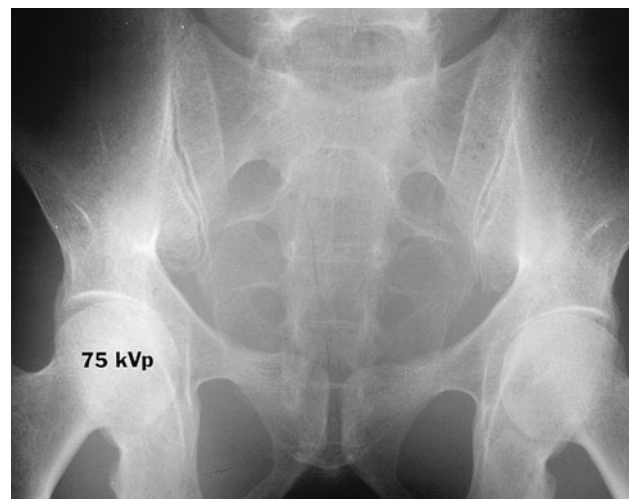
B
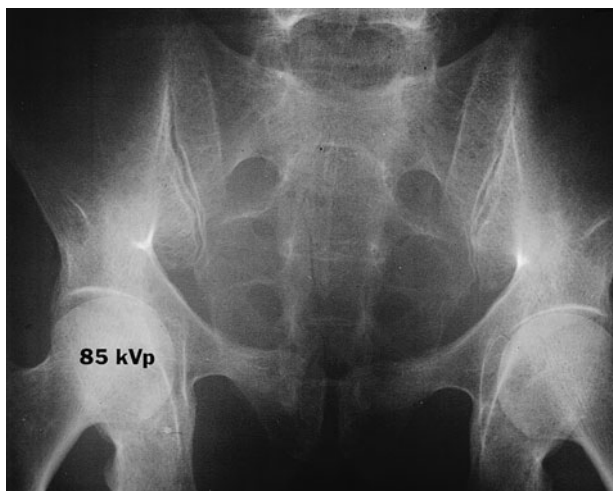
C

Figure 11–28. *Illustration of the 15% rule.* Image *B* was made using 15% more kV than image *A* and demonstrates twice the radiographic/image density of image *A*. Similarly, image *C* was made using 15% more kV than image *B* and demonstrates twice the radiographic/image density of image *B*. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

An x-ray image was made using the following technical factors: 400 mA, 25 msec, and 84 kV. It is necessary to produce another image with twice the radiographic density. The maximum mA available is 400 and the exposure time cannot be increased because of involuntary motion. What alternate kV can be employed to produce a radiograph with the desired image density?

If twice the original density is needed, the kV may be increased 15% to produce the desired effect. Fifteen percent of 84 is 12.6. Therefore, using the same mAs and increasing the kV to 97 should produce an image with twice the original density. *Note:* Changing the kV will change the scale of contrast/dynamic range (discussed in Part III).

■ *SUMMARY*

- **Increased kV produces *more* high-energy x-ray photons; i.e., exposure rate increases.**
- **An increase in kV will result in an increase in radiographic/ image density; a decrease in kV will result in a decrease in radiographic/image density.**
- **When mAs manipulation is not possible, radiographic/image density can be doubled or halved by using the 15% rule.**

D. INTENSIFYING SCREENS

Intensifying screens amplify the effect of x-rays on film emulsion by means of fluorescence. For every one x-ray photon interacting with screen phosphors, many light photons are emitted. This effect becomes more pronounced as screen speed increases.
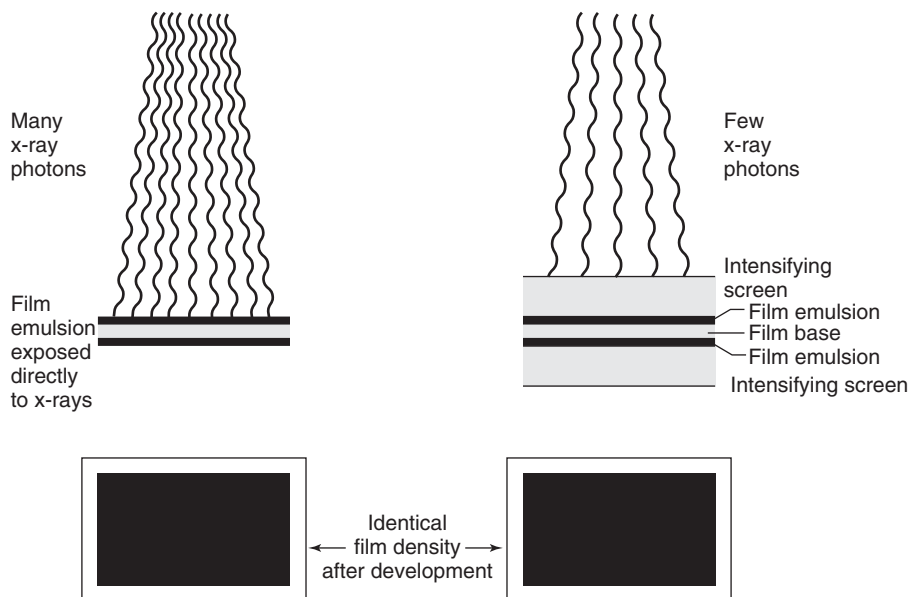
Figure 11–29. Exposure and resulting image density; *direct exposure versus intensifying screens.* By using intensifying screens, a much smaller patient dose is required to produce the same image density.

Therefore, with any given group of exposure factors, as *screen speed increases, radiographic/image density increases.*

Screen speed and radiographic/image density are directly proportional. An increase in intensifying screen speed from 200 to 400 doubles the image density and enables the radiographer to reduce the mAs to half, thus reducing patient dose (Fig. 11–29) and tube wear (heat units) considerably.

■ *SUMMARY*

- **Intensifying screens amplify the action of x-rays through their property of fluorescence.**
- **All other factors remaining constant, an increase in screen speed will result in an increase in image density.**
- **Screen speed and image density are directly proportional.**
- **Screen speed and patient dose are inversely proportional.**
- **Screen speed and x-ray tube heat production are inversely related.**
- **Screen speed and image resolution/sharpness are inversely related.**

E. GRIDS

As x-ray photons travel through a part, they either pass all the way through to expose the film/image receptor, or undergo interaction(s) that may result in their being absorbed by the part or deviated in direction. It is those that change direction (*scattered radiation*) that undermine and degrade the image.

Part III discussed the origin of scattered radiation: Compton scatter interactions. Compton scatter can also be a personnel radiation hazard, especially in fluoroscopic procedures. With respect to the radiographic image, it is responsible for the scattered radiation that reaches the film/image receptor. *Scattered radiation* adds unwanted, degrading densities to the x-ray image.

The single most important way to reduce the production of scattered radiation is to collimate. Although *collimation*, optimum *kV*, and *compression* can be used (Fig. 11–30), a significant amount of scattered radiation is still generated within the part being imaged and, because it adds unwanted non–information-carrying densities, it can have a severely degrading effect on image quality, as illustrated in the pelvis images shown in Figure 11–31.

A *grid* is a device interposed between the patient and image receptor that functions to absorb a large percentage of scattered radiation before it reaches the image receptor. It is constructed of alternating strips of lead foil and radiolucent filler material. X-ray photons traveling in the same direction as the primary beam pass between the lead strips. X-ray photons, having undergone interactions within the body and deviated in various directions, are absorbed by the lead strips; this is referred to as "cleanup" of scattered radiation (Fig. 11–32).

The use of grids is recommended for body parts measuring 10 cm and greater. The major exception to this rule is the chest, which can frequently be examined without a grid because its contents (mostly air) do not generate significant quantities of scattered radiation. Even
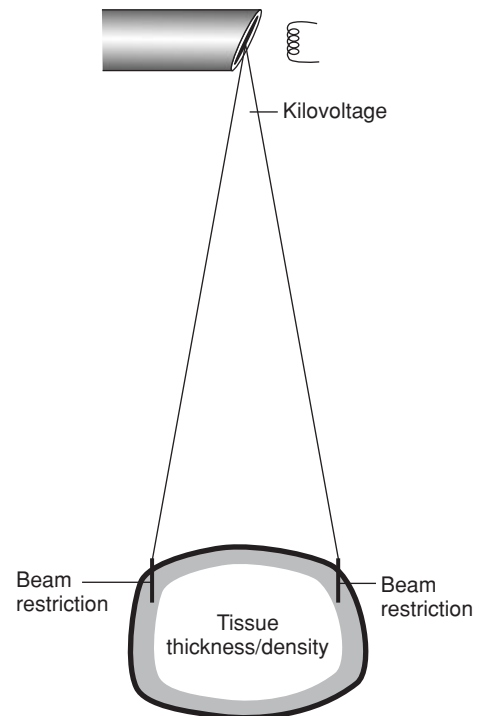
Figure 11–30. *Factors affecting the production of scattered radiation*: kV level, beam restriction, and thickness and density of tissues.
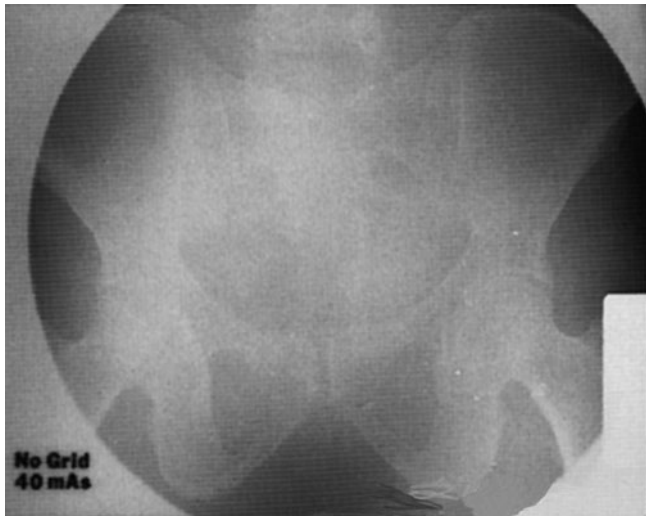
A

B

Figure 11–31. **(A)** Image made at 40 mAs without a grid. Because of the thickness and nature of the part imaged, a significant amount of scattered radiation was generated and exposed the (undiagnostic) film. **(B)** Image made using a 12:1 grid. Although an exposure increase to 400 mAs was required, a large percentage of the scattered radiation generated was removed before it reached the image receptor. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
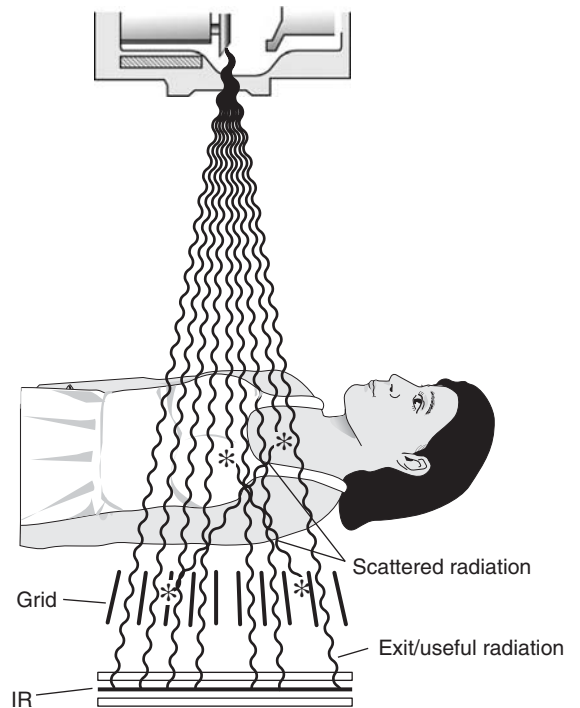
Figure 11–32. Scattered radiation generated in the object is removed (cleaned up) with the use of a grid.

so, many institutions perform most chest examinations using a grid and high-kilovoltage factors.

When imaging large body parts without the use of a grid, scattered radiation contributes to more than 50% of the total image receptor exposure. If a grid is introduced, there will be significantly *fewer* photons reaching the image receptor, hence a very significant decrease in radiographic *density*. To maintain adequate density then, the addition of a grid must be accompanied by an appropriately substantial increase in *mAs*. Before beginning a discussion of the impact of grids on technical factors, a more complete study of them is in order.

A grid may be *stationary* or *moving*. Stationary grids are the simplest type and usually consist of alternating *vertical* lead strips (i.e., a *parallel* grid) and radiolucent interspace filler material. A grid cassette is an example of a stationary grid. Another example is the "slip-on," or "wafer," grid that may be placed over a regular cassette. *Stationary grids* are useful in mobile radiography and horizontal beam (cross-table lateral) radiography; they are usually low ratio. A disadvantage of stationary grids is visibility of grid lines.

If the grid is in motion during the exposure, as it is in the *moving grid*, the grid lines are effectively blurred out of the radiographic image. The lead strips and interspace material of a moving grid are slightly *angled* so that, at a given distance from the focal spot, the angle of the lead strips will conform with the divergence of the x-ray beam. A grid with lead strips that are angled thus is called a *focused grid*; if an imaginary line is extended up from each lead strip, the point of intersection is called the *convergence line*, and the distance from the convergence line to the surface of the grid is the *focusing distance* (Fig. 11–33). That focusing distance is the ideal SID, although grids usually specify a *focal range* in which they can be safely used.

Another type of grid is the *crossed grid*; it has a second series of lead strips aligned perpendicular to the first. Crossed grids may be parallel or focused and are extremely efficient in absorbing scattered radiation; however, their use prohibits any x-ray tube angulation and requires that the x-ray tube be exactly centered to the center of the grid. Any misalignment or tube angulation can result in severe *grid*

Origin of Scattered Radiation and Methods for Controlling Its Production

- The larger the x-ray field size, the more scattered the radiation produced. *Solution:* collimate!
- The higher the kilovoltage, the greater the production of scattered radiation (a result of the higher incidence of Compton scatter interactions). *Solution:* use optimum kV.
- The thicker and more dense the body tissues, the greater the amount of scattered radiation produced. *Solution:* when possible, compression of the part or use of the prone position to decrease the effect of fatty tissue.
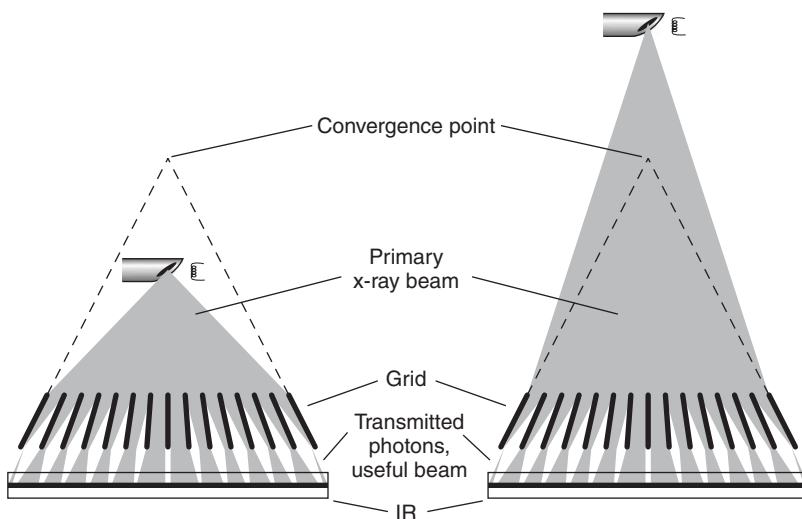
Figure 11–33. Grid cutoff will be apparent if the SID is above or below the specified focal range limits and will be characterized by density loss at the periphery of the image. This is described as an *off-focus error* or *focus–grid distance decentering.*
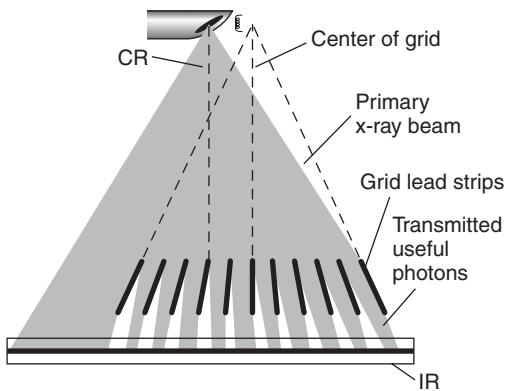
Figure 11–34. A *uniform density loss* across the radiographic image will occur if the x-ray beam is off-center laterally.

cutoff (absorption of the useful/primary beam). Crossed grids are not frequently used in general radiography.

Care must be taken to avoid errors common to the use of focused grids, including angulation errors, off-level errors, off-focus errors, off-center errors, and upside-down grid placement.

- *Angulation errors:* The x-ray tube may be safely angled in the direction of the lead strips; angulation "against" the lead strips causes *grid cutoff*; that is, absorption of the primary beam and resulting loss of density across the image (similar to that exhibited in off-level errors).
- *Off-level errors:* If the planes of the x-ray tube and grid surface are not parallel, grid cutoff will occur. This can happen, for example, when the x-ray tube is angled "against" the lead strips or if the grid cassette is tilted under the patient during mobile radiography. To avoid cutoff, the radiographer must ensure that the grid surface is perpendicular to the central ray and, if CR angulation is required, that the tube angle is parallel with the direction of the lead strips.
- *Off-focus errors:* Grid cutoff will occur if the SID is below the lower limits, or above the upper limits, of the specified focal range. This type of error is also referred to as *focus–grid distance decentering.* Off-focus errors are usually characterized by loss of density at the *periphery* of the image.
- *Off-center errors:* If the x-ray beam is not centered to the grid (i.e., if it is shifted laterally) grid cutoff will occur. This type of error is referred to as lateral decentering and characterized by a *uniform density loss* across the radiographic image (Fig. 11–34).

If the x-ray beam is both *off-center and off-focus below the focusing distance*, the portion of the image below the focus will show *increased* density; if the x-ray beam is *off-center and off-focus above the focusing distance*, the image below the focus will show *decreased* density.

- *Upside-down grid:* A focused grid placed upside down has its lead strips angled exactly opposite the path/direction of the x-ray beam. So, except for the central area where the lead strips and x-ray beam are vertical, grid cutoff will be severe (Fig. 11–35).

Two of a grid's *physical characteristics* that determine its degree of efficiency in the removal of scattered radiation are grid ratio and number of lead strips per inch.

- *Grid ratio: Grid ratio* is defined as the height of the lead strips compared to the distance between them (Fig. 11–36):

$$\text{Grid ratio} = \frac{\text{height of Pb strip}}{\text{width of interspace material}}.$$

For example, a grid having lead strips 1.5-mm tall separated by interspace material 0.15-mm wide has a grid ratio of 10:1.

As the lead strips are made taller, or the distance between them decreases, scattered radiation is more likely to be trapped before reaching the image receptor. A 12:1 ratio grid will absorb more scattered radiation than an 8:1 ratio grid.

- *Number of lead strips per inch:* The number of lead strips per inch is also referred to as *grid frequency*. The advantage of many lead strips
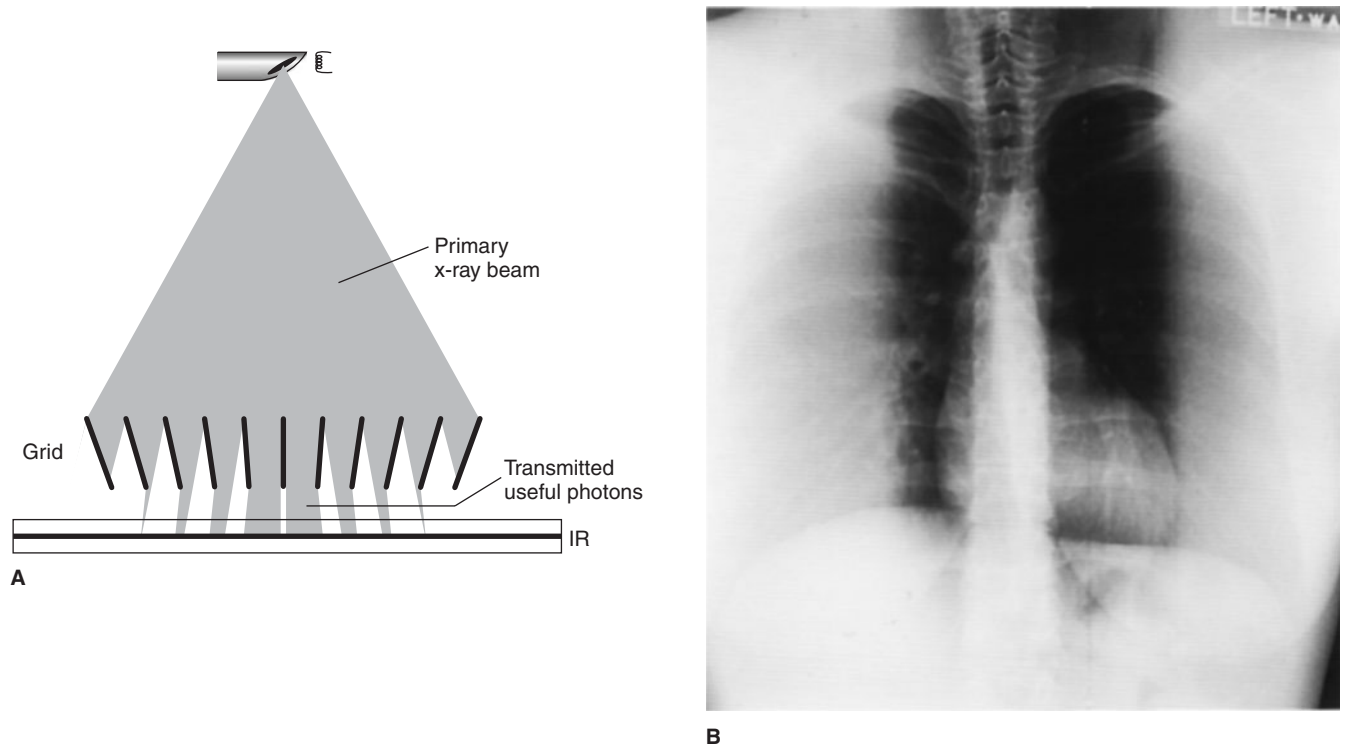
Figure 11–35. **(A)** and **(B)** An *upside-down focused grid* presents its lead strips in the opposite direction to that of the x-ray beam. This results in severe grid cutoff everywhere except in the central portion of the radiographic image.

per inch is that there is less *visibility* of the lead strips. As the number of lead foil strips per inch increases, the lead foil strips must become *thinner*, and therefore *less visible*. There is, of course, a disadvantage here. If the lead strips get thinner, more energetic scattered radiation can pass through them and reach the *image receptor*. So, to maintain the efficiency of a grid having many lead strips per inch, its grid *ratio* is often increased as well; that is, the lead strips are made taller to increase the likelihood of their trapping scattered radiation before it reaches the image receptor.

The radiolucent interspace material is most frequently made of plastic or fiber particularly in pediatric imaging and mamography; some grids use aluminum as the interspace material. Aluminum is sturdier, it gives the image a smoother appearance free of objectionable *grid lines*, and can perhaps have an additional filtering effect on scattered radiation. However, a greater increase in patient dose is required with aluminum interspaced grids. Fiber interspace material, on the other hand, can be affected by moisture and result in warping of the grid.

Other ways of expressing and measuring grid efficiency include the following:

• *Grid factor*—The *Grid factor* (*G*) of a particular grid is the ratio of the total amount of radiation (primary and scattered) incident upon the surface of the grid compared to the amount of radiation transmitted
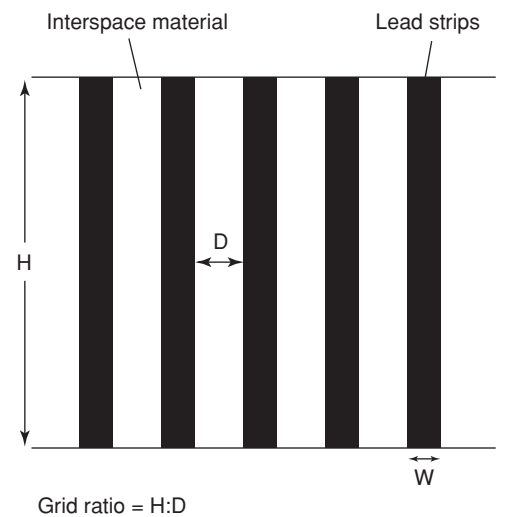
Figure 11–36. Cross section of a grid. *Grid ratio* is defined as the height of the lead strips (*H*) to width of the interspace material (*W*). Grid ratio = *H/W*.
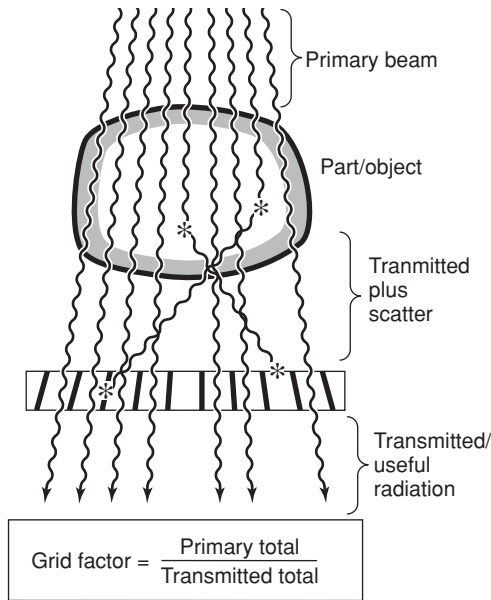
Figure 11–37. The grid factor (G) is the *grid conversion factor* and expresses the total amount of radiation striking the grid surface compared to the amount of radiation transmitted through the grid.

Grid Conversion Factors for Various Ratio Grids

Grid Ratio	Conversion Factor
No grid	1
5:1	2
6:1	3
8:1	4
10 or 12:1	5
16:1	6

through the grid:

$$G = \frac{\text{Incident total}}{\text{Transmitted total}}$$

The grid factor is the grid conversion factor; that is, that amount by which the mAs must be changed to compensate for the radiation absorbed by the grid (Fig. 11–37). This is discussed in further detail later in this section.

- *Contrast improvement factor*—The ratio of radiographic contrast obtained with a grid compared to the contrast obtained without a grid is referred to as the contrast improvement factor (CIF). Grids have a major impact on contrast resolution:

$$\text{CIF} = \frac{\text{Contrast with grid}}{\text{Contrast without grid}}.$$

- *Selectivity*—The ratio between the quantity of *primary photons transmitted* through the grid to the quantity of *scattered photons transmitted* is referred to as the selectivity (S) of the grid:

$$S = \frac{\text{Primary photon transmission}}{\text{Scattered photon transmission}}.$$

An undesirable but unavoidable characteristic of grids is that they do absorb some primary/useful photons as well as scattered photons. The higher the grid ratio, the more pronounced this will be. The higher the primary to scattered photon transmission ratio, the more desirable the grid.

- *Lead content*—This is perhaps least familiar to the radiographer because it applies little to the practical use of the grid. The definitions of *grid ratio* and *grid frequency* do not take into account the thickness of the lead strip; *lead content* does consider it. Lead content is measured in g/cm^2 and expresses the amount of lead contained within a particular grid.

How must exposure factors be adjusted to maintain appropriate density when changing from nongrid to grid? How can exposure factors be changed to preserve the density level when changing from one ratio grid to another?

In actual practice, the grid conversion factor varies slightly according to kV range used. The ARRT recognizes that different textbooks cite slightly different grid conversion factors, and has stated that the distractors in calculation problems will not be so close as to cause conflict with the keyed correct answer. The conversion factors listed in the chart to the left can be used to calculate grid conversions in exposure factor problems.

A particular examination was performed tabletop/nongrid at 40-inch SID using 7 mAs and 90 kV. To reduce the amount of image-degrading scattered radiation, another image will be made using a 12:1 ratio grid. What new mAs factor will be required in order to maintain the original level of radiographic/image density?

The grid conversion formula is

$$\frac{\text{mAs}_1}{\text{mAs}_2} = \frac{\text{Grid factor}_1}{\text{Grid factor}_2}.$$

Substituting known quantities

$$\frac{7}{x} = \frac{1}{5}$$

$$x = 35 \text{ mAs required with 12:1 grid.}$$

A lumbar spine was imaged laterally at 40-inch SID using 40 mAs and 95 kV and an 8:1 ratio grid. To improve scattered radiation cleanup, another image will be made using a 12:1 grid. What new mAs factor will be required to maintain the original level of radiographic/image density?

Using the grid conversion formula shown above and substituting known quantities,

$$\frac{40}{x} = \frac{4}{5}$$

$$4x = 200$$

$$x = 50 \text{ mAs required with 12:1 grid.}$$

An 8:1 grid is satisfactory for radiography up to 90 kV. A 16:1 grid ratio is frequently advocated for radiography greater than 100 kV. General radiographic fixed equipment generally has a 10:1 or 12:1 grid.

The use of high-ratio grids at low kV levels is discouraged because of the unnecessary patient exposure required. Higher ratio grids are more effective in reducing the amount of scattered radiation reaching the IR; however, their use requires more mAs (more patient dose, more heat buildup) and decreases positioning latitude (of the x-ray tube). Lower ratio grids (5:1, 6:1) are often used in mobile imaging because they often more (grid) positioning latitude.

Remember, to avoid detrimental changes in radiographic density, mAs adjustments are essential when changing grid ratios.

A word of caution regarding the use of an *inverted (film–screen) cassette* in place of a grid: the results are unpredictable and this practice is discouraged. Appropriate selection and careful use of a grid provides a far more predictable outcome and a diagnostically superior radiographic image. An inverted computed radiography (CR) cassette produces characteristic artifacts on the processed image.

An *air gap* introduced between the object and image recorder can have an effect similar to that of a grid. As energetic scattered radiation emerges from the body, it continues to travel in its divergent fashion and, much of the time, will bypass the image recorder (Fig. 11–38). A 6-inch air gap produces an effect similar to an 8:1 grid, while a 10-inch air gap is equivalent to a 16:1 grid. It is necessary to increase the SID to reduce the magnification caused by the air gap/OID.
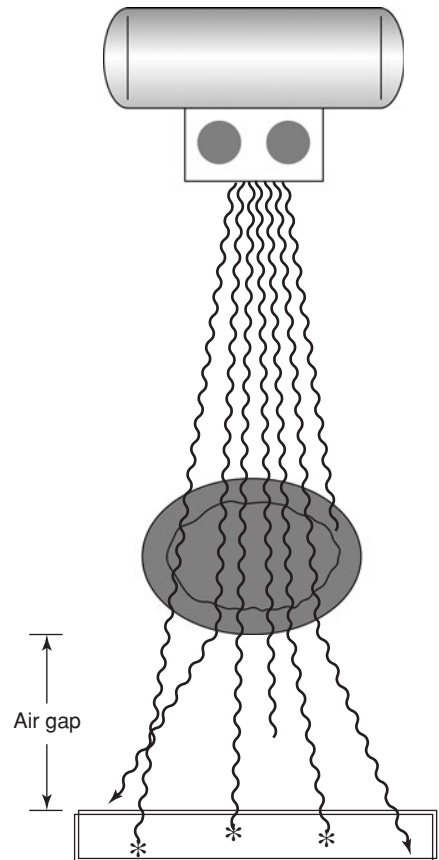
Figure 11–38. Air-gap technique. As scattered radiation emerges from the part, it continues to travel in its divergent fashion, bypassing the image receptor.

SUMMARY

- Scattered radiation is a result of x-ray photon interaction with tissue via Compton scatter processes.
- Scattered radiation adds image-degrading densities to the radiographic image (increased density and lower contrast; poor contrast resolution).
- The production of scattered radiation increases with increases in field size, kV, and thickness and volume of tissue.
- The single most important way to decrease the production of scattered radiation is to collimate.
- The amount of scattered radiation reaching the image receptor is decreased through the combined use of collimators and grids.

- **Grids are made of alternating strips of lead and radiolucent material; they are placed between the patient and image receptor to absorb scattered radiation exiting from the part.**
- **Grids may be stationary or moving, parallel, or focused.**
- **Focused grids require that**
  - **the correct surface be facing the x-ray tube (i.e., not upside down),**
  - **tube angulation parallels the lead strips,**
  - **the long axis of the x-ray tube and grid surface are parallel,**
  - **the SID should be within the stated focusing distance/range, and**
  - **the x-ray beam should not be off center (laterally) with the center of the grid.**
- **If focused grid requirements are not met, the resulting image will demonstrate a loss of density as a consequence of grid cutoff (i.e., absorption of the primary beam).**
- **The most common way of expressing grid efficiency is by grid ratio and number of lead strips per inch.**
- **Because grids remove many x-ray photons that would have contributed to image density, the addition of a grid requires a significant increase in mAs.**
- **When implementing a grid or changing grid ratio, a grid-conversion factor must be used to determine required mAs change in order to avoid undesirable changes in radiographic/image density.**

F. FILTRATION

As discussed in Chapter 8, the primary beam generally has a total filtration of 2.5 mm Al equivalent for patient protection purposes. In general-purpose radiographic tubes, the glass envelope usually accounts for approximately 0.5 mm Al equivalent, and the collimator provides approximately 1.0 mm Al equivalent. These are considered *inherent filtration*. The manufacturer adds another 1.0 mm Al (*added filtration*) to meet the minimum requirements of 2.5 mm Al equivalent total filtration for radiographic tubes operated above 70 kV.

This type of filter serves to remove the diagnostically useless x-ray photons that contribute only to patient (skin) dose. Because this radiation is "soft" (low energy) and would not reach the image receptor anyway, the x-ray tube total filtration *has no effect on radiographic/image density*. Filtration increases the *overall average energy* of the x-ray beam.

Compensating filters can be used to provide more uniform radiographic density when radiographing structures with widely different attenuation coefficients (x-ray absorbing properties) because of thickness or tissue composition. Usually made of aluminum or clear leaded plastic, they slide into tracks in the collimator housing similar to a cylinder cone, or attach magnetically to the undersurface of the collimator housing.

If an x-ray image of a foot demonstrates well-exposed tarsals, the toes will frequently be overexposed (Fig. 11–39A). If the exposure is adjusted to improve the image of the toes, the tarsals will then be underexposed. Because the foot varies so greatly in thickness and

A

B

C

D

E
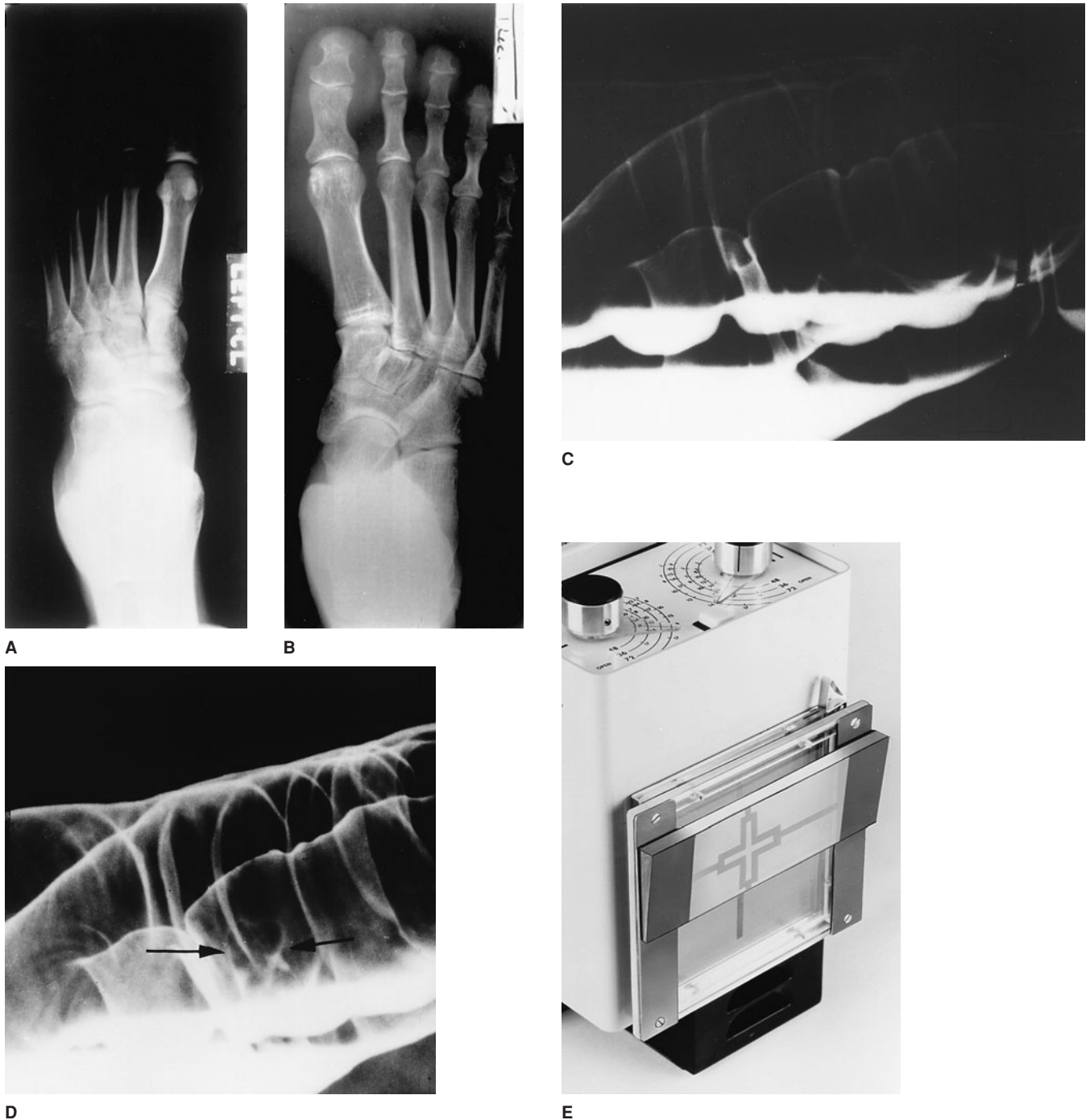
Figure 11–39. **(A)** Typical foot imaged without the use of a *compensating filter;* although the tarsals and metatarsals are well demonstrated, the phalanges are significantly overexposed. **(B)** Image made using a compensating filter whose thicker portion was placed over the phalanges to balance radiographic densities. **(C)** Lateral decubitus image of an air- and barium-filled colon. Abdominal tissues often shift to the dependent side in the decubitus position, making the "down" side thicker than the "up" side. Excessive density of the airfilled structures can obliterate pathology. **(D)** Use of a wedge-shaped compensating filter can equalize tissue density differences, thus providing more uniform radiographic/image density and improved visualization of any pathology (a polypoid lesion is demonstrated). **(E)** Compensating (wedge) filter magnetically attached to the x-ray collimator housing. (Courtesy of Nuclear Associates.)

Figure 11–40. **(A)** *Trough filter* in place for chest radiography. The thicker lateral portions of the trough reduce the intensity of the beam directed toward the lungs, while the thinner central portion does not attenuate the beam directed to the more dense mediastinal structures. **(B)** and **(C)** Two types of *wedge filters* used to "graduate" the x-ray beam intensity, with a greater number of photons directed to the thicker tarsal area and fewer photons toward the thinner areas of metatarsals and phalanges. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003.)
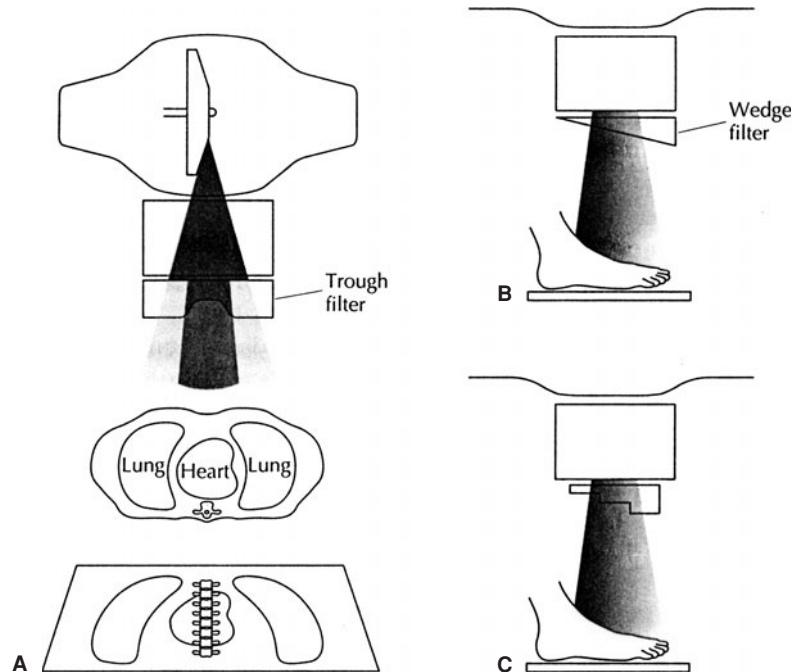
tissue density along its long axis, it is difficult to achieve uniform image density. A simple *wedge*-shaped compensating filter can remedy the situation (Fig. 11–39E and Fig. 11–40B and C). The filter is attached to the collimator housing so that the thin portion is over the tarsals and the thick portion over the toes. Exposure factors appropriate for tarsals are used, and the thick portion of the filter removes enough of the primary beam to prevent overexposure of the toes. Thus, a foot image having uniform density throughout is achieved (Fig. 11–39A and B). A wedge filter is also useful for femur examinations and decubitus abdomen images (Fig. 11–39C and D).

Another type of compensating filter is the *trough* filter (Fig. 11–40A), so named because its central portion is thin and the portions extending laterally are thicker, thus forming a central trough. A trough filter can be used in chest radiography to permit visualization of the denser mediastinal structures without overexposing the more radiolucent lungs and pulmonary vascular markings.

Another simple, yet effective, application of compensating filtration is the use of a saline or similar solution bag. The saline bag is placed over the thinner body part and serves to filter out excessive exposure. This technique is effectively employed in the AP projection of the thoracic spine; however, its use should be noted as it can cause a slight image artifact.

■ *SUMMARY*

- ■ **When anatomic parts vary greatly in thickness or tissue composition, compensating filters may be used to "even out" radiographic densities.**
- ■ **Ordinary x-ray tube filtration of 2.5 mm Al has no effect on radiographic/image density.**

- **Compensating filters slide into place by means of tracks on the collimator housing.**
- **Compensating filters are available in various shapes: their thicker portions absorb more of the x-ray beam and are therefore placed over thinner body parts, while their thinner portions (absorbing fewer x-rays) are placed over thicker body parts.**

G. PATIENT FACTORS

Normal tissue variants and pathologic processes that alter tissue thickness and composition can have a significant effect on image density. The radiographer must be aware of these variants and processes to make an appropriate and accurate selection of technical factors.

In 1916, R. Walter Mills presented a paper at the American Roentgen Ray Society meeting in Chicago (published in *American Journal of Roentgenology*, April 1917) describing "The Relation of Bodily Habitus to Visceral Form, Position, Tonus and Motility." In his paper, he coined the terms *hypersthenic, sthenic, hyposthenic*, and *asthenic* (defined in Chapter 5) to describe the various body types. He noted that most physicians came into the field prejudiced by their early anatomic teachings and had fixed conceptions, "which the revelations of the roentgen ray ruthlessly outraged."

Radiographers still use these terms today to describe *body habitus* and its normal variants. Knowledge of each of the body types and its associated tissue characteristics, position and tonus of associated organs, and so on, helps us position more accurately and select appropriate technical factors. The same body part, such as the stomach, in two different individuals will require very different central ray points of entry if one individual is hypersthenic and the other asthenic. A particular body part, such as the shoulder, might measure the same on two different individuals, yet it may not be appropriate to select identical exposure factors for each if one is a muscular sthenic build and the other a hyposthenic type with little muscle tone.

Other factors that influence radiographic density, and consequently the selection of technical factors, are age, gender, and pathology. Various abnormal pathologic conditions, disease processes, and trauma can affect tissue density and, hence, radiographic density. Normal variants of muscle development result from different lifestyles, occupations, and age, and will affect radiographic density.

Some pathologic conditions are referred to as *destructive*, such as osteoporosis and conditions involving necrosis or atrophy. These conditions can cause an undesirable increase in radiographic density unless they are recognized and appropriate changes made in exposure factors. Other conditions such as ascites, rheumatoid arthritis, and Paget disease are *additive*, and an increase in exposure factors is required to maintain adequate radiographic density.

Examples of Additive Pathologic Conditions

- Ascites
- Rheumatoid arthritis
- Paget disease
- Pneumonia
- Atelectasis
- Congestive heart failure
- Edematous tissue

Examples of Destructive Pathologic Conditions

- Osteoporosis
- Osteomalacia
- Pneumoperitoneum
- Emphysema
- Degenerative arthritis
- Atrophic and necrotic conditions

■ SUMMARY

- **Variations in tissue density will be noted as radiographic density variations in the x-ray image.**

■ **Normal tissue density differences exist as a result of body habitus, age, gender, and level of activity.**

■ **Abnormal density differences exist as a result of trauma or pathologic conditions.**

■ **The radiographer must be knowledgeable about the conditions affecting normal and abnormal changes in tissue density to make accurate selection of technical factors.**

H. GENERATOR TYPE

Three-phase x-ray generation is much more efficient than *single phase* because the voltage never drops to zero. Three-phase equipment has a small voltage ripple, and thus produces more high-energy x-ray photons (Fig. 11–41). Therefore, if two x-ray images were made of the same part and using the same factors, one made with a single-phase machine and one with a three-phase machine, the three-phase image would show considerably more radiographic density. Consequently, to reproduce similar image densities when using different generators, exposure factor adjustment is necessary.

If 92 kV and 60 mAs were used for a particular abdominal exposure using single-phase equipment, what mAs would be required to produce a similar image using three-phase, six-pulse equipment?

The correction table in the box in this section indicates that only two-thirds of the original single-phase mAs would be required to produce similar radiographic/image density with three-phase equipment. Thus

$$2/3 \times 60 = 40 \text{ mAs with } 3\text{\o} \text{ 6p equipment (note that kV} \atop \text{remains the same).}$$

It should be noted that approximately the same quantity of radiation is delivered to *the image receptor* from each x-ray machine (1\o and 3\o) to produce similar images. The entrance skin exposures, however, differ significantly (Fig. 11–42). This is because the single-phase

Correction Factors

Single Phase	Three Phase
χ mAs	$2/3\chi$ for 3φ (6p)
χ mAs	$1/2\chi$ for 3φ (12p)
χ kV	$\chi - 12\%$ for 3φ

Single phase — 100% ripple

Three phase 6-pulse — 13% ripple

Three phase 12-pulse — 4% ripple

High frequency — <1% ripple

1/60 second
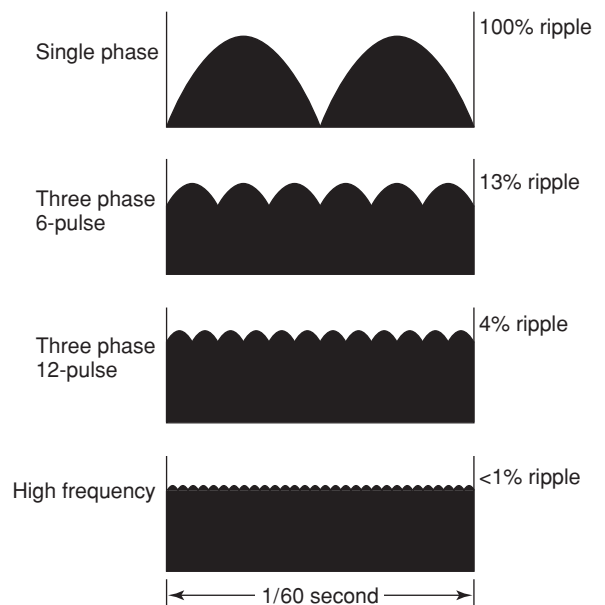
Figure 11–41. *Single-phase (1\o) and three-phase (3\o) waveforms.* Compared to the one useful impulse available per 1/60th second with alternating current, single-phase rectified current has two useful impulses, 3\o 6p rectified has six useful impulses, and 3\o 12p has 12.

Figure 11–42. Images *A* and *C* are good examples of 1ø to 3ø conversion and the difference in entrance skin exposure (ESE). Images *A* and *B* demonstrate the radiation protection factor is increasing from 70 kV at 100 mAs to 80 kV at 50 mAs; note the big difference in ESE. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

machine produces many more low-energy photons, contributing to patient skin dose, but not to image density.

When technical factors are modified for single-phase or three-phase changes, it is usually the mAs that is adjusted; however, kV adjustment is also workable. Changing from single-phase to three-phase requires a 12% decrease in kV; conversely, changing from three-phase to single-phase requires a 12% increase in kV.

Conventional 60-Hz full-wave rectified power is converted to a higher frequency of 500 to 25 000 Hz in the most recent generator design—the *high-frequency generator*. The high-frequency generator is small in size, in addition to producing an almost constant potential waveform.

■ *SUMMARY*

- ■ **Three-phase (3ø) equipment produces nearly peak potential voltage, whereas single-phase (1ø) voltage drops periodically to zero between voltage peaks.**
- ■ **mAs is usually adjusted to compensate for differences between 1ø and 3ø waveform equipment.**
- ■ **When changing from 1ø to 3ø 6p, two-thirds less mAs is required; from 1ø to 3ø 12p, one-half the original mAs is required (the reverse is true when changing from 3ø to 1ø)**

I. BEAM RESTRICTION

A change in image density will occur with changes in the size of the irradiated field, all other factors remaining constant. *Beam restriction* (i.e., reducing the volume of tissue irradiated) reduces the production of scattered radiation and, consequently, decreases radiographic density. The reverse is also true: as field size increases, image density increases as a result of increased production of scattered radiation fog. *Therefore, as changes are made in the size of the irradiated field, an accompanying change in mAs is required to maintain the same image density.*

J. ANODE HEEL EFFECT

The anode heel effect was discussed earlier with respect to focal spot size and recorded detail. Figures 11–43 and 11–44 illustrate how a portion of the divergent x-ray beam is absorbed by the anode resulting in diminished density at the anode end of the image.

When using general x-ray tubes at standard distances, the heel effect is noticeable only when imaging parts of uneven thickness, such as the femur and thoracic spine. In these cases, the heel effect may be used to advantage by placing the thicker body portion under the cathode end of the x-ray beam, thus having the effect of "evening out" tissue densities.

K. PROCESSING

Radiographic film emulsion is very sensitive to even small changes in chemical processing. A decrease in developer temperature of 2°F to 3°F

The Anode Heel Effect is Emphasized Under the Following Conditions

- At short SIDs
- With large cassettes
- With small anode angle x-ray tubes
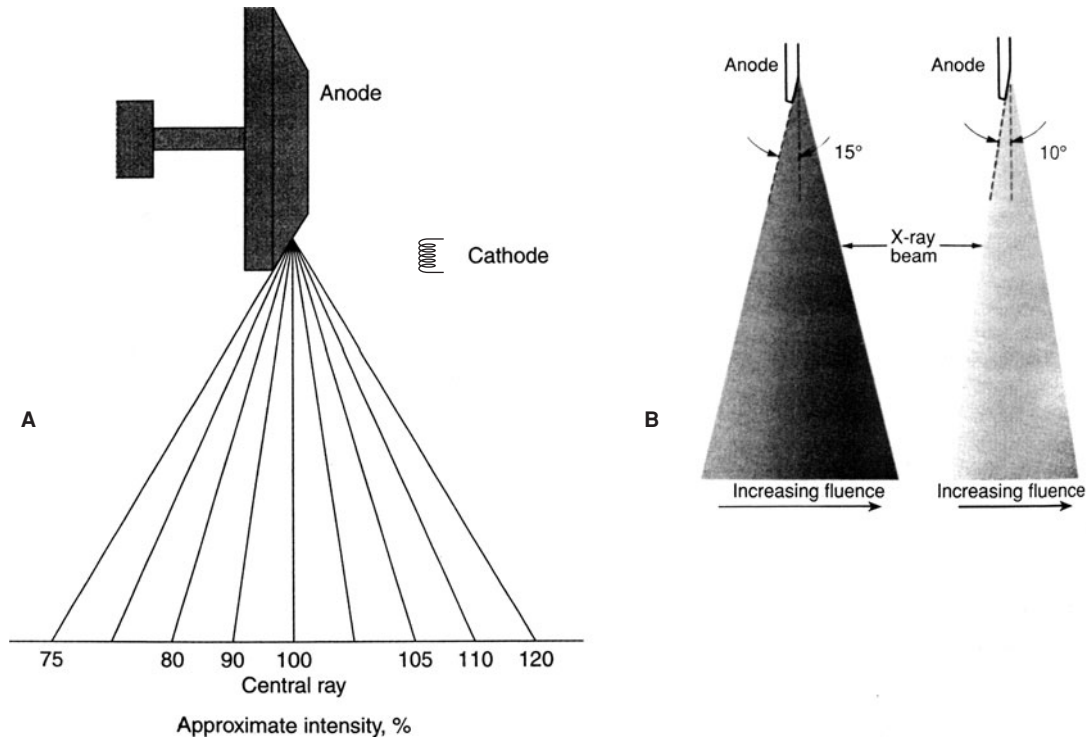
Figure 11–43. **(A)** and **(B)** *The anode heel effect.* As x-ray photons are produced within the anode, a portion of the divergent beam is absorbed by the anode's "heel." This represents a decrease in x-ray beam intensity at the anode end of the x-ray beam. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003.)
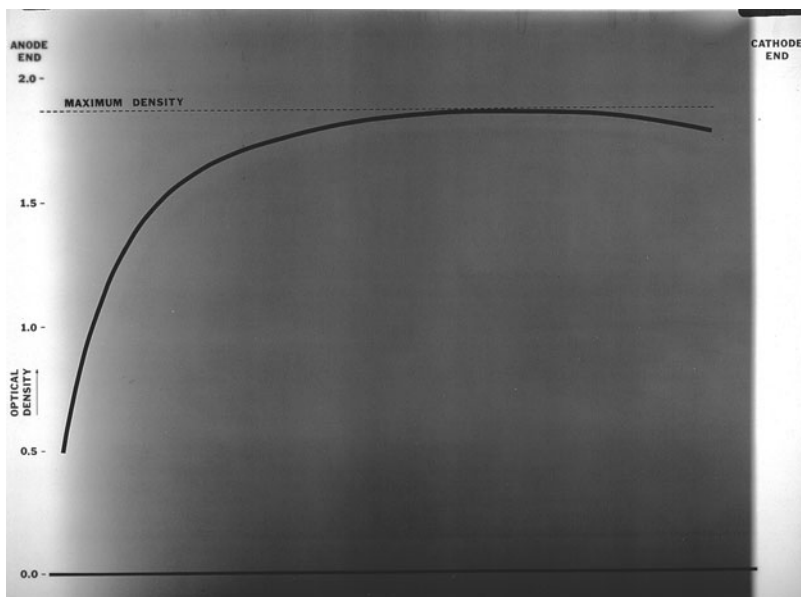
Figure 11–44. *Radiographic illustration of the anode heel effect.* Note the gradual increase in radiographic density toward the cathode end of the beam. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
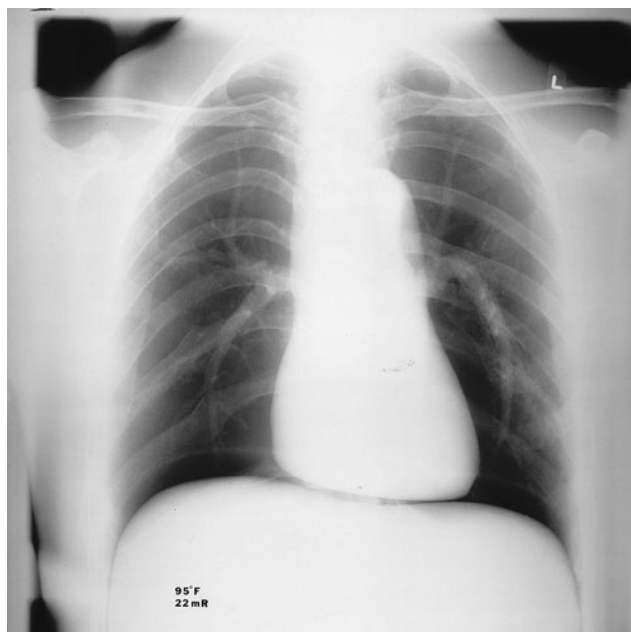
A
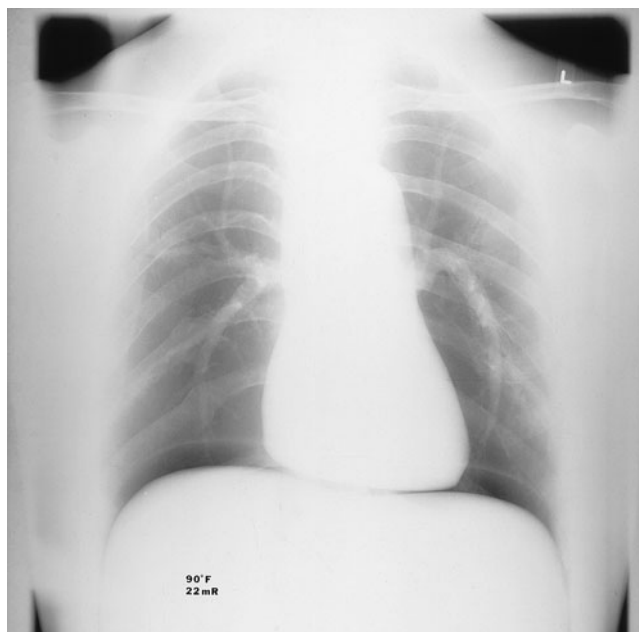
B
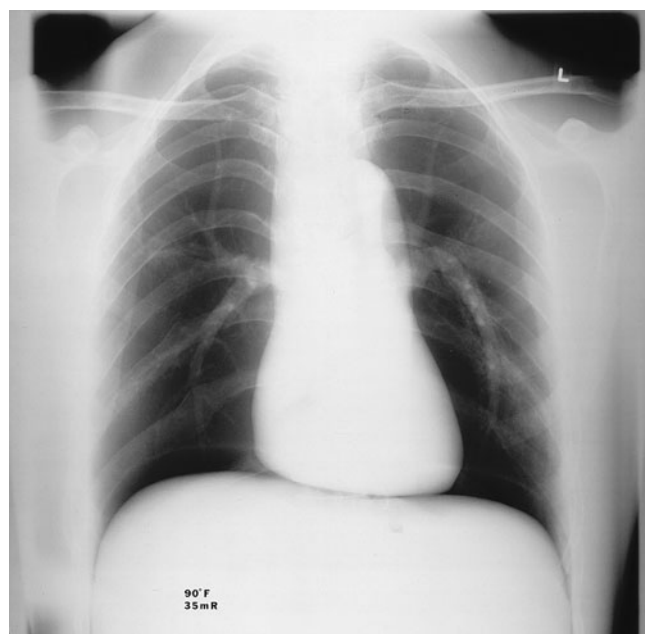
C

Figure 11–45. *Developer temperature* versus image density and patient exposure. **(A)** Radiograph of a chest phantom made using 22 mR and processed at the recommended temperature of 95°F. **(B)** Radiograph exposed and produced under the same conditions except that the developer temperature was 5° lower, at 90°F; note the significant change in radiographic density. **(C)** Radiograph using the same 90°F developer, but with exposure compensated to provide the required density; note the increase in exposure dose to 35 mR. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

will produce a dramatic decrease in radiographic density (Fig. 11–45) and, conversely, even a small rise in developer temperature results in a noticeable density increase (Fig. 11–46). Figure 11–47 illustrates the impact of developer temperature on the sensitometric curve.

Radiographic density is also directly related to length of development and replenishment rate; that is, density increases as development time increases or as replenishment rate increases.
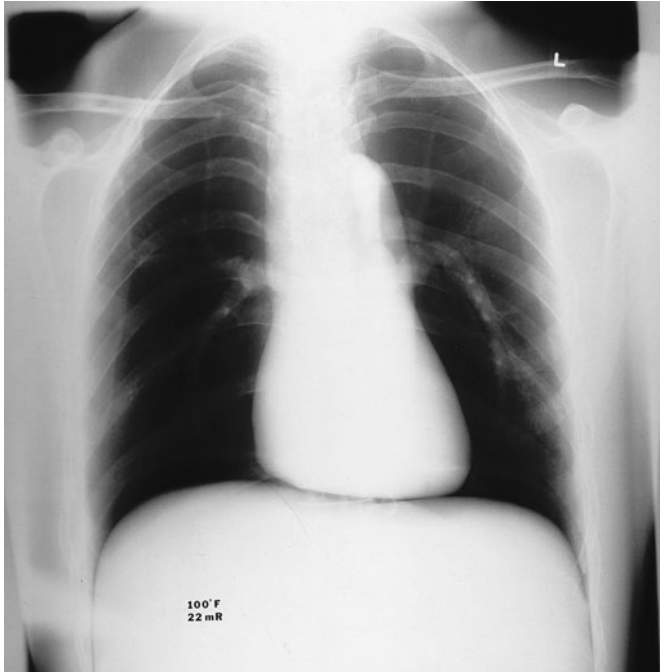
Figure 11–46. This radiograph was exposed under the same conditions as the radiograph in Figure 11–45A, but was processed at a developer temperature 5° above normal (at 100°F), producing a dark radiograph. Although a diagnostic radiograph might be produced by reducing the film exposure, higher-than-recommended processing temperatures are not advised because they can produce inconsistent results. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
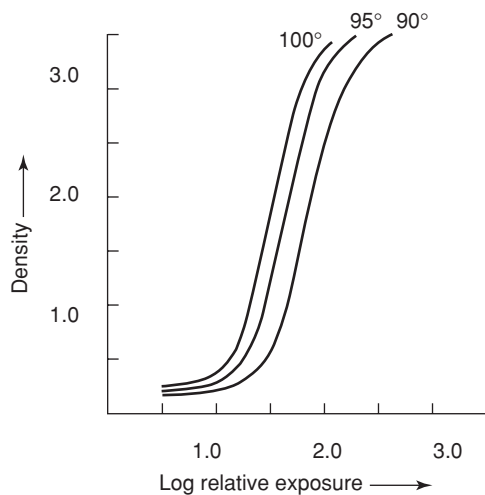
Figure 11–47. The sensitometric curve illustrates the effect of *developer temperature* changes seen in Figures 11–45 and 11–46. The relative position of the lower temperature (90°F) curve is to the right of the optimal temperature (95°F) curve; to achieve the same density, the exposure must be increased to compensate for decreased development. The 100°F curve illustrates a shift to the left of the optimal curve, illustrating that less exposure is required to compensate for decreased development. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

■ *SUMMARY*

- Changing the size of the irradiated field affects image density as a result of increased or decreased scattered radiation production.
- The anode heel effect is characterized by greater x-ray intensity (i.e., quantity) at the cathode end of the beam.
- The anode heel effect is most pronounced at short SIDs, with large image receptors, and with x-ray tubes having small anode angles.
- The anode heel effect can be used to compensate for a difference in tissue density/thickness (e.g., femur, thoracic spine).
- Radiographic density increases as developer temperature increases, and as the replenishment rate and/or length of development increase.

Chapter Review Questions

⭐ ***Congratulations!*** *You have completed a portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.*

1. Grid ratio is defined as the relationship between the height of the lead strip and the:
   - (A) width of the lead strip
   - (B) distance between the lead strips
   - (C) number of lead strips per inch
   - (D) angle of the lead strip

2. Of the following groups of exposure factors, which will produce the greatest radiographic density?
   - (A) 200 mA, 50 msec, 36-inch SID
   - (B) 400 mA, 0.05 second, 72-inch SID
   - (C) 400 mA, 0.10 second, 72-inch SID
   - (D) 200 mA, 100 msec, 36-inch SID

3. How is source–image distance related to exposure rate and image density?
   - (A) as SID increases, exposure rate increases and image density increases
   - (B) as SID increases, exposure rate increases and image density decreases
   - (C) as SID increases, exposure rate decreases and image density increases
   - (D) as SID increases, exposure rate decreases and image density decreases

4. If the radiographer is unable to adjust the mAs, yet needs to reduce the image density of a particular image by one-half, which of the following would best accomplish this?
   - (A) decrease the kV by 50%
   - (B) decrease the kV by 15%
   - (C) decrease the SID by 25%
   - (D) decrease the grid ratio

5. Exposure factors of 85 kV and 10 mAs are used for a particular nongrid exposure. What should be the new mAs if an 8:1 grid is added?
   - (A) 20 mAs
   - (B) 30 mAs
   - (C) 40 mAs
   - (D) 50 mAs

6. An x-ray image demonstrating poor contrast resolution can be attributable to insufficient:
   1. beam restriction
   2. kilovoltage
   3. mAs
   - (A) 1 only
   - (B) 1 and 2 only
   - (C) 2 and 3 only
   - (D) 1, 2, and 3

7. The term used to describe image density in *digital* imaging is:
   - (A) blackening
   - (B) gray scale
   - (C) brightness
   - (D) resolution

8. An exposure was made using 200 mA, 50 msec exposure, and 75 kV. Each of the following changes will effectively double radiographic density, except:
   - (A) change to 0.1-second exposure
   - (B) change to 86 kV
   - (C) change to 20 mAs
   - (D) change to 100 mA

9. An exposure was made at 40 inches SID using 300 mA, 0.12-second exposure and 70 kV with a 200 film/screen combination and an 8:1 grid. It is desired to repeat the image and, in order to produce improved detail, use 48-inch SID and 100 film/screen combination. Using 0.25-second exposure, and with all other factors remaining constant, what mA will be required to maintain the original radiographic density?
   - (A) 100
   - (B) 200
   - (C) 300
   - (D) 400

10. Compared to a low-ratio grid, a higher-ratio grid could have:
    1. taller lead strips
    2. more distance between the lead strips
    3. thicker lead strips
    - (A) 1 only
    - (B) 1 and 2 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

Answers and Explanations

1. (B) A grid consists of alternate strips of lead and interspace material. The lead strips are used to trap scattered radiation before it reaches the image receptor, thus decreasing the effect of scattered radiation fog on the image. *Grid ratio* is defined as the height of the lead strip to the distance between the strips (or width of the interspace material).

2. (D) Using the formula mA × second = mAs, determine each mAs. The greatest radiographic density will be produced by the combination of greatest mAs and shortest SID. Groups A and C should produce identical radiographic density, according to the inverse square law, because group C is twice the distance and four times the mAs of group A. Group B has twice the distance of group A, but only twice the mAs; it has, therefore, less density than groups A and C. Group D has the same distance as group A, and twice the mAs, making it the group of technical factors that will produce the greatest radiographic density.

3. (D) According to the inverse square law of radiation, the intensity or exposure rate of radiation from its source is inversely proportional to the square of the distance. Thus, as distance from the source of radiation increases, exposure rate decreases. Because exposure rate and radiographic density are directly proportional, if the exposure rate of a beam directed to an image receptor is decreased, the resultant image density would be decreased proportionally.

4. (B) Image/optical density is proportional to mAs. However, other methods may be used to adjust image density. When correct adjustment of mAs is not possible, a decrease in kV by 15% will effectively halve the radiographic density. SID adjustment is not recommended for making density changes as image magnification and patient dose are affected as well. Decreasing the grid ratio will increase image density.

5. (C) To change nongrid to grid exposure, or to adjust exposure when changing from one grid ratio to another, recall the factor for each grid ratio:

no grid = 1 × original mAs
5:1 grid = 2 × original mAs
6:1 grid = 3 × original mAs
8:1 grid = 4 × original mAs
12:1 grid = 5 × original mAs
16:1 grid = 6 × original mAs

Therefore, to change from nongrid to 8:1 grid, multiply the original mAs by a factor of 4. A new mAs of 40 is required.

6. (A) An image that *lacks* sufficient *contrast/has poor contrast resolution*, is one that is *too gray*—where similar tissue densities can be distinguished with difficulty or not at all. Insufficient beam restriction (i.e., not enough collimation) can certainly result in production of excess scattered radiation and therefore produce an image that is too gray/lacking sufficient contrast resolution. Insufficient kilovoltage would produce an image with *too much* (too high) contrast. The mAs factor has *no effect* on contrast scale.

7. (C) Radiographic, optical, or image density is defined as the overall amount of blackening on a radiographic *film* image or a particular portion of the film image. It provides the correct

degree of background blackening for the anatomic image. In *digital* imaging, density is referred to as *brightness.* Excessive density can obscure image details; insufficient density can mask pathology. Radiographic density is a *quantitative* factor; that is, it describes an *amount* of image blackening determined by the *number* of x-ray photons used to create the image. Thus, radiographic density is regulated by the *exposure rate* or *number* of photons reaching the film emulsion or image receptor. Gray scale refers to image contrast. The degree of *resolution* transferred to the image receptor is a function of the resolving power of each of the system components and is expressed in *line pairs per millimeter* (lp/mm).

8. (D) Image density is directly proportional to mAs. If exposure time is doubled from 0.05 (1/20) second to 0.1 (1/10) second, image density will double. If the mAs is doubled from 10 to 20 mAs, image density will double. If the kV is increased by 15%, from 75 to 86 kV, image density will double according to the 15% rule. Changing to 100 mA will halve the mAs, effectively halving the image density.

9. (D) A review of the problem reveals that *three changes* are being made: an increase in SID, a change from 200 speed system to 100 speed system, and an increase in exposure time (to be considered last). Because the original mAs was 36, reducing the speed of the system to half (from 200 to 100) will require a doubling of the mAs, to 72, in order to maintain density. Now we must deal with the distance change. Using the density maintenance formula (remember 72 is now the *old* mAs), we find that the required new mAs at 48 inches is 103. Because the problem states that we are now using 0.25-second exposure, it is left to determine what mA, used with 0.25 second, will provide 103 mAs.

$$0.25x = 103$$
$$x = 412 \text{ mA}$$

10. (A) As the lead strips are made *taller,* or the *distance between them decreases,* scattered radiation is more likely to be trapped before reaching the image receptor. For example, a 12:1 ratio grid will absorb more scattered radiation than an 8:1 ratio grid. Thickness of the lead strips refers to its lead content, which is unrelated to grid ratio. Lead content is measured in g/cm^2 and expresses the amount of lead contained within a particular grid.

III. FACTORS AFFECTING IMAGE CONTRAST/ CONTRAST RESOLUTION

A. TERMINOLOGY

Radiographic contrast exists whenever two or more different densities are present in a radiographic image. When there is a big difference between shades of densities, radiographic *contrast* is said to be *high.* When there is little difference between densities, radiographic *contrast* is *low.* An electronic/digital imaging term is *contrast resolution*—the ability to record/see adjacent similar anatomic tissues, i.e., anatomic structures having similar absorbing properties. Electronic imaging improves contrast resolution dramatically.

    Radiographic (screen/film) contrast is the sum of subject contrast and film contrast.

    Subject contrast is a result of differential absorption by tissues of varying densities and thicknesses. X-ray photons undergo attenuation

to differing degrees by various body tissues, with less exit radiation emerging from thicker, denser structures, and more exit radiation from thinner or less dense structures. Hence, subject contrast produces the various density *differences* visible on the radiographic image and is exhibited as a *scale of grays* having varying tones representative of differential tissue absorption.

Exposure factor selection and various other methods are used to *modify* the effect of differential absorption properties of tissue, thereby enabling the radiographer to produce the desired scale of contrast. The electronic/digital imaging term describing contrast scale is dynamic range; it will be discussed later in CR/DR section of this chapter.

Film/screen subject contrast is regulated by the quality (energy, wavelength, penetrability) of x-ray photons.
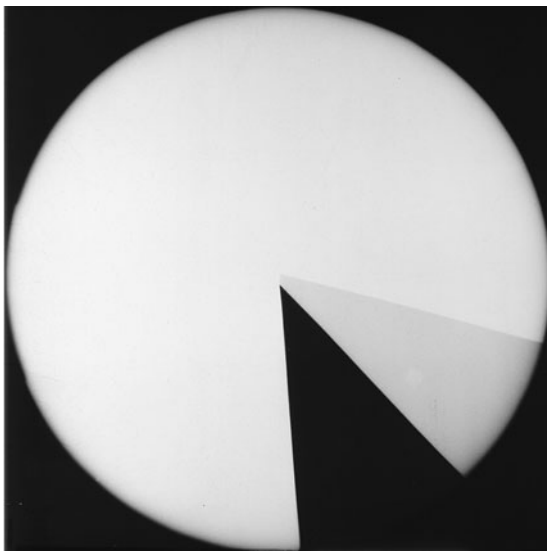
A
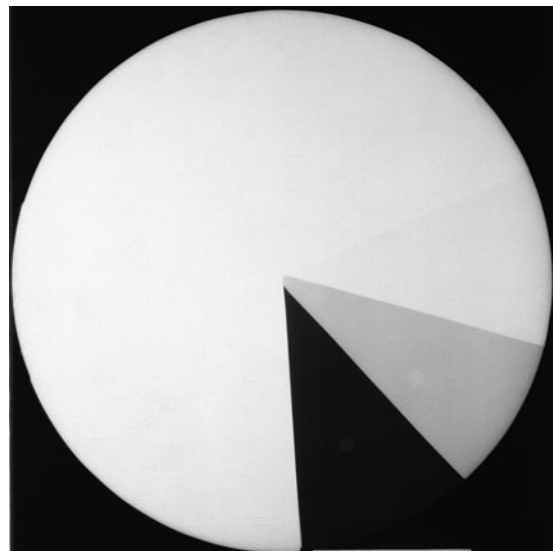
B
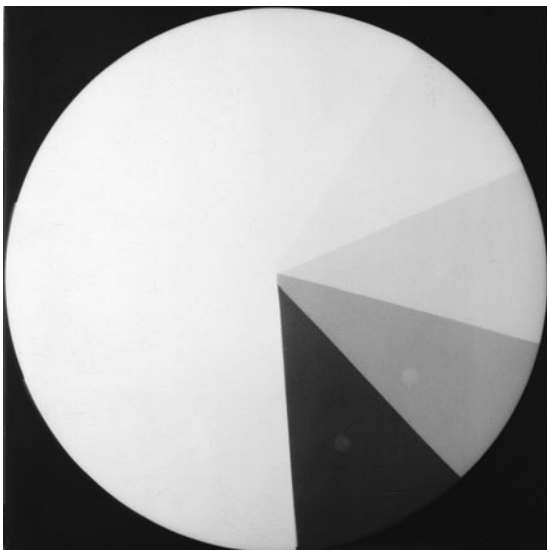
C

Figure 11–48. *Contrast functions to make details visible.* Images were made of a circular phantom having a variety of wedge-shaped thicknesses; a circular "lesion" of greater density is embedded in each wedge. Note that the level of contrast between adjacent areas is strongly related to the degree of visibility of the "lesions." **(A)** Illustrates the highest contrast; only two wedges (thicknesses) are visualized and only one "lesion" is barely visible. **(B)** The contrast scale is a little longer; a third wedge begins to be seen and two "lesions" are visualized. **(C)** Five wedges are visualized (hopefully the printing process can demonstrate them) and at least three "lesions" can be seen clearly. Methods that can be used to adjust the level of contrast between adjacent areas include (1) increasing kV, (2) using compensating filtration, and (3) using lower contrast (higher latitude) film. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Film contrast describes the response of the film emulsion to the variety of x-ray photons emerging from the irradiated part. Film contrast is affected by the manufacturing process (film type, base fog), processing conditions, and fluorescent properties of the intensifying screens. Film contrast characteristics are illustrated by the sensitometric (*D* log *E*) curve.

An x-ray image exhibiting a variety/range of different shades of gray possesses *long-scale* (low) *contrast*; that is, there is *little difference* among the various shades. One that exhibits only a few shades possesses *short-scale* (high) *contrast*.

The function of the contrast scale is to make image details visible. Most anatomic structures have an infinite number of details that compose the image and these structural details often represent a variety of tissue densities having different absorption properties. If the anatomic part is represented radiographically by only a few shades of gray, then many anatomic details are not being visualized at all. If, however, the image displays a wide range of gray tones, more anatomic details will be represented and visualized (Fig. 11–48). Hence, long-scale contrast *usually* provides more information (but short-scale, i.e., high, contrast may be required for certain examinations or body parts; see Fig. 11–49).

A number of factors affect the production of image contrast and each is discussed individually.

Contrast Terminology

Higher contrast is	**Lower contrast is**
• short-scale contrast	• long-scale contrast
It displays:	It displays:
• few, very different, image/tissue densities	• many similar image/tissue densities
It is a product of	**It is a product of**
• lower kV	• higher kV
• few, dissimilar tissue densities	• many similar tissue densities
• more, "tighter" collimation	• larger field sizes
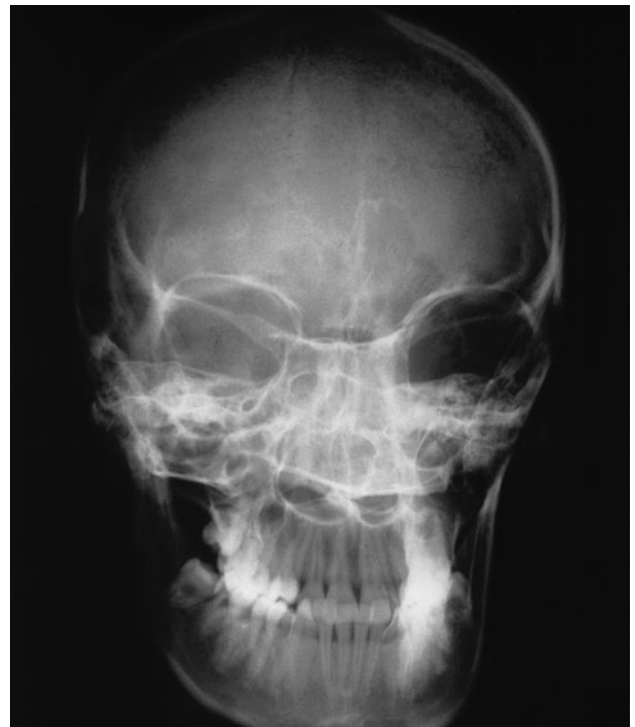
A   **B**

Figure 11–49. **(A)** Example of *high, or short-scale, contrast.* **(B)** Example of *low, or long-scale, contrast.* Rotation of the skull is also seen. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

■ *SUMMARY*

- ■ **Radiographic contrast refers to the degree of difference between image densities.**
- ■ **Screen/film radiographic contrast is the sum of subject contrast and film contrast.**
- ■ **Subject contrast is the result of differential absorption of x-rays by body tissues of various thicknesses and densities.**
- ■ **Film contrast is the result of manufacturing, processing, and intensifying screens.**
- ■ **Subject contrast is regulated by selection of x-ray beam quality (kV).**
- ■ **Radiographic images having many different shades of gray, varying slightly from one another, are said to possess long-scale (or low) contrast.**
- ■ **Radiographic images possessing few density differences, strikingly different from each other, are said to possess short-scale (or high) contrast.**
- ■ **Electronic imaging improves contrast resolution dramatically.**

B. κV

Kilovolts (kV), which governs x-ray *penetrability*, is the primary exposure factor affecting radiographic contrast. In general, as kV increases so does the scale of contrast (Fig. 11–50).
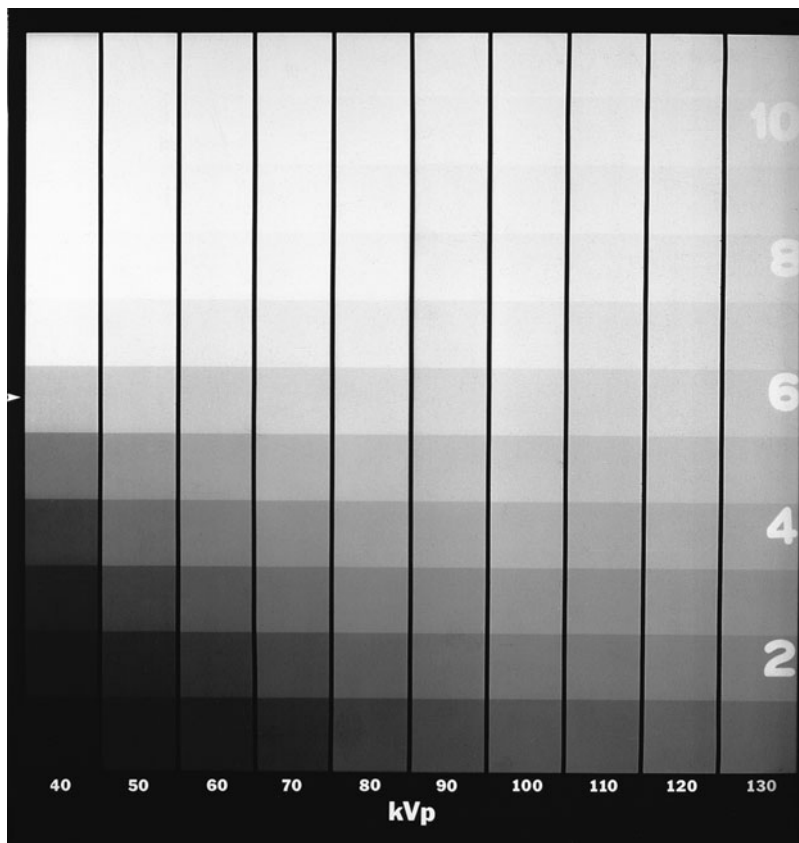
Figure 11–50. *Aluminum step wedge test.* As kV increases, a greater number of steps (and the subtle differences between them) are discernible. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

A   **B**
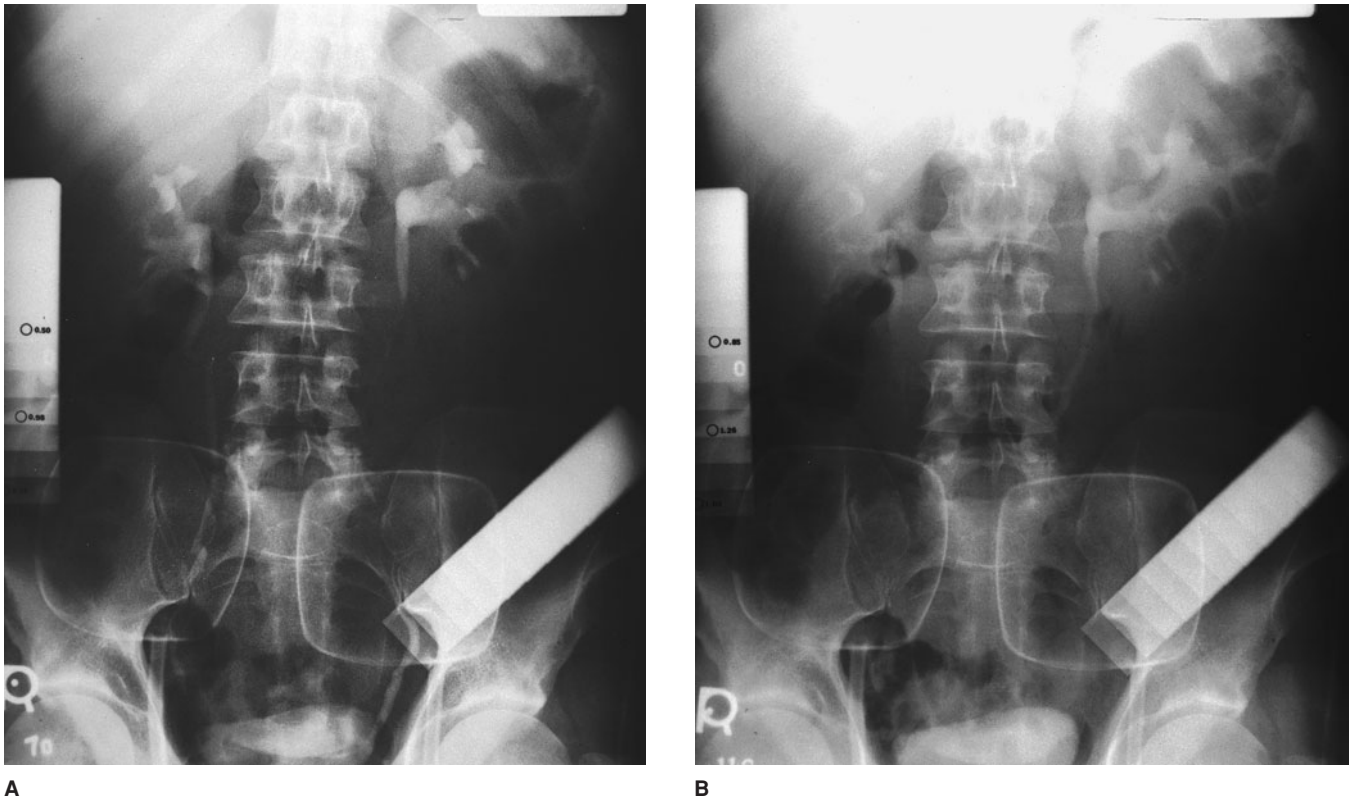
Figure 11–51. In anatomic regions having *low subject contrast* such as the abdominal viscera, artificial contrast agents are often introduced to demonstrate organs such as the kidneys. **(A)** IVU made using 70 kV. **(B)** IVU using 110 kV. The use of too high kV with iodinated media and the production of more scattered radiation has almost obliterated the contrast-filled collecting systems in image *B*. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

In general, parts having *low subject contrast* will produce long-scale radiographic contrast, and if high kV is used to image these parts, unacceptably low radiographic contrast will result.

Scattered radiation fog reduces the visibility of low contrast objects, degrading the diagnostic quality of the image and promoting poor contrast resolution. When imaging structures having *low subject contrast,* use of *lower kV* frequently helps emphasize what little contrast exists in the subject tissues.

Because kV determines the penetrating ability of the x-ray photons, *low kV* can be used to emphasize *slight differences between tissue densities*, for example, in mammography, foreign-body localization, and iodine-containing renal collecting systems (Fig. 11–51).

Anatomic parts having *high subject contrast* will produce short-scale radiographic contrast, and if low kV is used to image these parts, unacceptably high radiographic contrast will result (Fig. 11–52). Visibility of structures within the very light and very dark areas is greatly diminished. When imaging structures having *high subject contrast*, the use of *higher kV* will promote more uniform penetration of the part, thus it "evens out" big differences in tissue densities and brings about visualization of small image details (as in high kV chest radiography).

Short-Scale Contrast Results When

- Subject contrast increases
- kV decreases
- Scattered radiation decreases
- Grid ratio increases
- Film latitude decreases

A   **B**
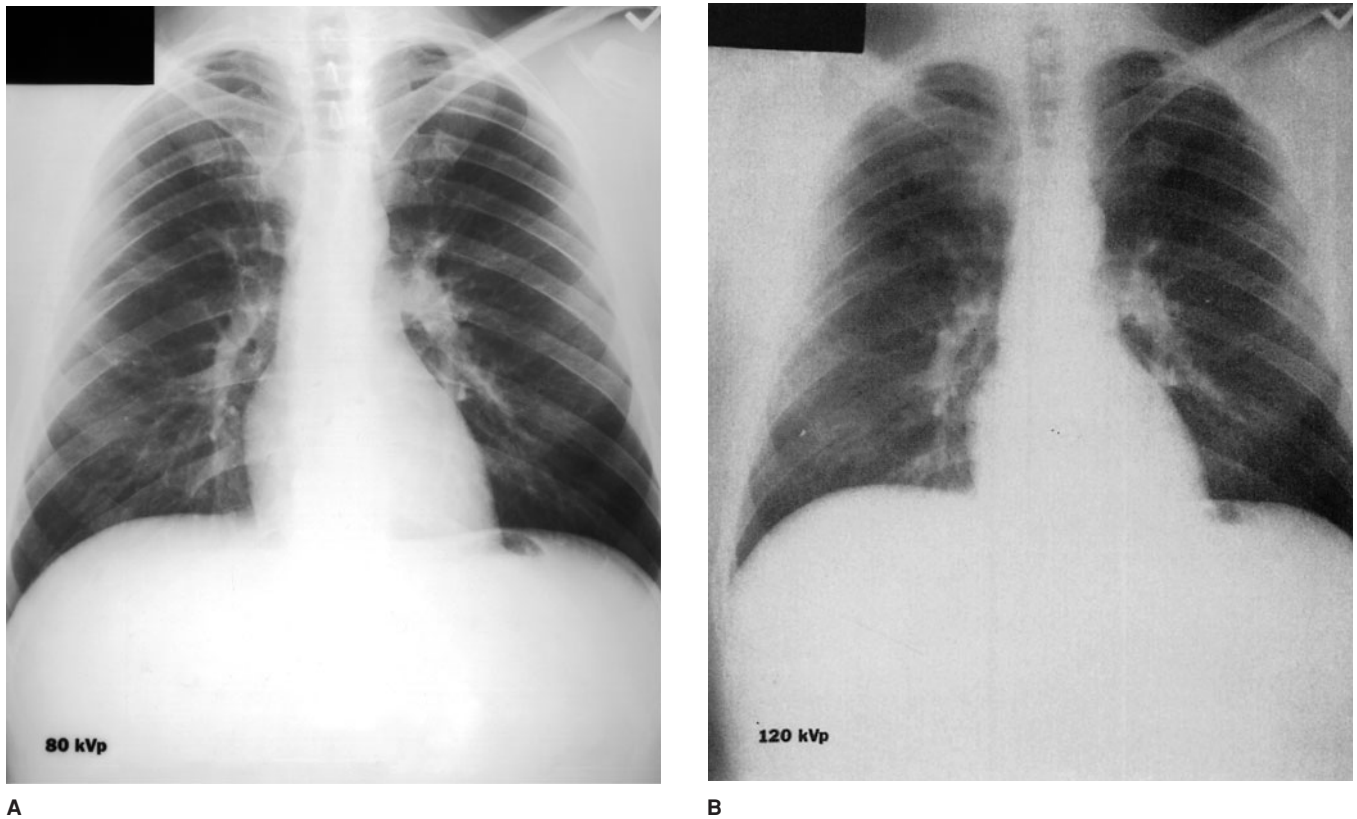
Figure 11–52. Posteroanterior (PA) chest images made using 80 kV **(A)** and 120 kV **(B)**. Image *A* PA chest image made using 80 kV demonstrates shorter scale contrast, and pulmonary vascular markings are not well visualized. **(B)** Chest image made using 120 kV demonstrates longer scale contrast, and visualization of pulmonary vascular markings *through* the bony rib details, and requires a smaller patient dose. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

C. SCATTERED RADIATION

High kV may be desirable in terms of patient dose, tube life, and making more details visible, but use of excessively high kV will result in production of excessive amounts of scattered radiation and fog, resulting in *diminished* contrast resolution/visibility of details (Fig. 11–53).

Much of the scattered radiation produced is highly energetic and exits the patient along with useful image-forming radiation. Scattered radiation carries no useful information, but adds *noise* in the form of fog, thereby impairing visibility of detail (recall Compton scatter process from Chapter 7).

Because scattered radiation can have such a devastating effect on image contrast, it is essential that radiographers are knowledgeable about methods of reducing its production. The three factors that have a significant effect on the *production of scattered radiation* are the following:

• Beam restriction
• Kilovoltage
• Thickness/volume and density of tissues
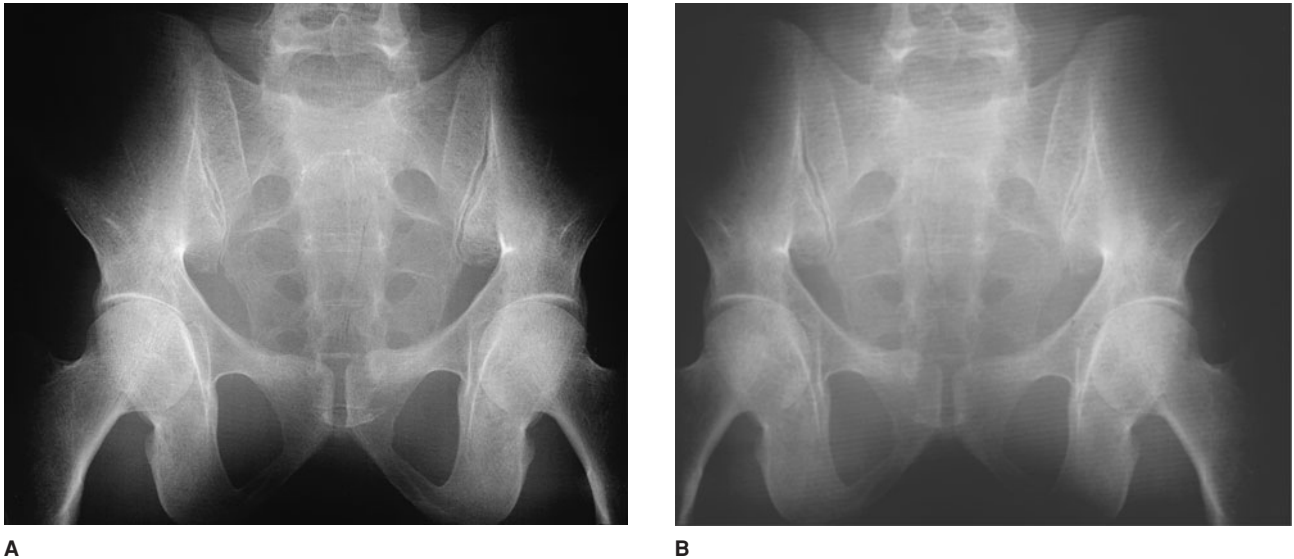
Figure 11–53. *Kilovoltage is directly related to the production of scattered radiation.* **(A)** Image made using 80 kV and 75 mAs. **(B)** Image made using 100 kV and 18 mAs, all other factors remaining the same. As kV is increased, the percentage of scattered radiation relative to primary radiation increases. Use of optimum kilovoltage for each anatomic part is helpful in keeping scatter to a minimum. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Perhaps the most important way to limit the production of scattered radiation and improve contrast is by *limiting the size of the irradiated field*; that is, through *beam restriction* (Fig. 11–54). *As the size of the field is reduced, there is less area and tissue volume for scattered radiation to be generated.*

As the volume and/or density of the irradiated tissues increase(s) so does scattered radiation (Fig. 11–55). Thicker and denser anatomic structures will generate more scattered radiation. *Compression* of certain parts can occasionally be used to minimize the effect of scatter, but close *collimation* can always be used effectively.

Introduction of an OID (*air gap*) can have a noticeable effect on image contrast. An air gap introduced between the object and image recorder can have an effect similar to that of a grid. A 6-inch air gap is equivalent to the effectiveness of an 8:1 grid; a 10-inch air gap is equivalent to the effectiveness of a 16:1 grid. As energetic scattered radiation emerges from the body, it continues to travel in its divergent fashion and, much of the time, will bypass the image recorder (see Fig. 11–38).

D. PATIENT FACTORS

Various tissue types and pathologic processes can alter tissue thickness and composition and thereby have a significant effect on radiographic contrast. Anatomic structures having high atomic numbers and pathologic conditions that increase tissue density tend to produce a higher contrast.

A   **B**
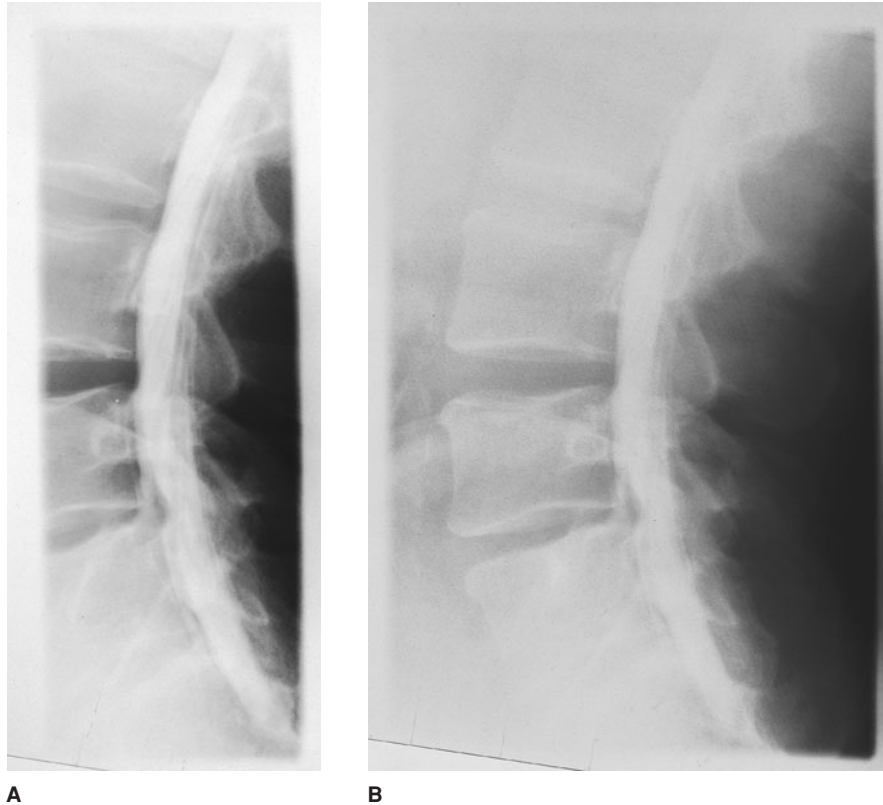
Figure 11–54. Note the striking improvement in radiographic quality in image *A* as beam restriction is increased in this lateral lumbar myelogram. Although a 50% increase in exposure was required to maintain appropriate density in image *A* (to compensate for less scattered radiation reaching the image receptor), radiation protection is maintained because the volume of irradiated tissue is decreased. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

The radiographer must be aware of the nature of pathology under investigation to make an intelligent and accurate selection of technical factors.

■ SUMMARY

- **kV selection determines the energy of x-ray photons and therefore degree of penetration of various tissues, thereby determining the contrast characteristics of the image.**
- **Images of low subject contrast structures often benefit from the use of lower kV, while high subject contrast structures can be represented with a longer range of grays by using higher kV.**
- **The use of high kV reduces patient dose and reduces the production of x-ray tube heat, but increases the production of scattered radiation fog.**
- **Radiation that has scattered carries no useful information, but rather, adds noise that impairs visibility of image details. Production of scattered radiation can be minimized by using**

A   **B**
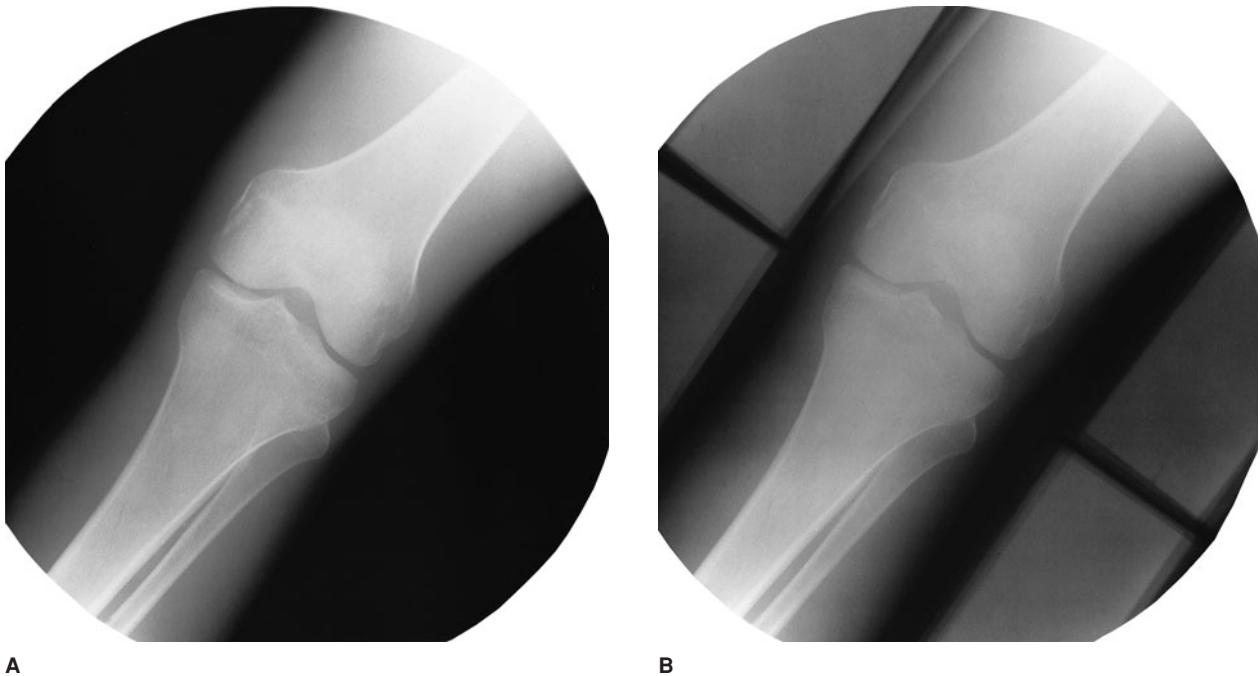
Figure 11–55. The *volume of irradiated tissue is directly related to the quantity of scattered radiation generated.* **(A)** Anteroposterior (AP) of knee. **(B)** AP with paraffin absorbers *around* the knee. The loss of contrast exhibited in *B* is caused by increased *volume* of irradiated material within the beam, resulting in increased scattered radiation fog. Note that the part need not be *thicker* to generate significant scatter, just that the total irradiated *volume* be greater. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

- **optimum kV techniques and by restricting the size of the x-ray beam as much as possible.**
- **As the thickness and density of tissues increase, so does the production of scattered radiation; tissue thickness can sometimes be minimized with compression.**
- **As normal tissues undergo pathologic change, their penetrability also changes frequently in ways characteristic of the disease process.**

E. GRIDS

An image produced with a grid usually differs considerably from an image produced without a grid. Since thicker, denser parts can generate significant amounts of scattered radiation, a grid should be used whenever a part measures 11 cm or greater in thickness. A possible exception to this rule is the chest, although much chest radiography performed today employs high kV and grids.

Although collimation, optimum kV, and compression may be used, a large amount of scattered radiation can still be generated within the part being imaged and can have a severely degrading effect on image contrast. Without the use of a grid, scattered radiation can contribute 50% to 90% of the total image exposure. The function of a grid, then, is to remove scattered radiation exiting the patient *before* it reaches the image receptor thereby improving contrast (Fig. 11–56).

A
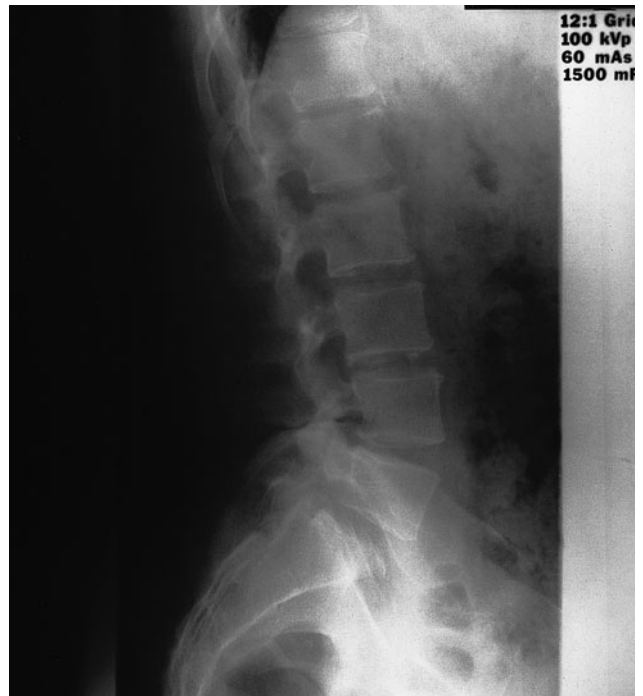
B

C

D

Figure 11–56. *Effect of grids on image contrast* and radiographic quality. **(A)** Made using 100 kV and 12 mAs without a grid; scattered radiation fog obliterates recorded detail almost entirely. **(B)** Made with 100 kV, 60 mAs, and using a 12:1 grid, all other factors remaining constant; scattered radiation is "cleaned up" and image details are more readily perceptible. **(C)** Made without a grid using 70 kV and 4 mAs. **(D)** Made with a 12:1 grid using 70 kV and 20 mAs. Note the improved contrast and detail visibility. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

As discussed earlier in this part, two of a grid's physical characteristics that determine its degree of efficiency in the removal of scattered radiation are *grid ratio* (the height of the lead strips compared to the distance between them) and number of *lead strips per inch*. Other familiar ways of expressing and measuring grid efficiency include the *grid factor* (grid conversion factor), *contrast improvement factor*, and *selectivity*. Higher ratio grids are more effective in reducing the amount of scattered radiation reaching the IR; however, their use requires more mAs (more patient dose, more heat units) and decreases positioning latitude (of the x-ray tube).

The *grid factor (G)* is the ratio of the total amount of radiation (primary and scattered) incident upon the surface of the grid to the amount of radiation transmitted through the grid:

$$G = \frac{\text{Total incident}}{\text{Total transmitted}}.$$

The *contrast improvement factor (CIF)* is the ratio of radiographic contrast obtained with a grid to that obtained without a grid:

$$\text{CIF} = \frac{\text{Contrast with grid}}{\text{Contrast without grid}}.$$

Selectivity (S) is the ratio between the quantity of primary photons transmitted through the grid and the quantity of scattered photons transmitted:

$$S = \frac{\text{Primary photon transmission}}{\text{Scattered photon transmission}}.$$

As previously discussed, the introduction of an *air gap can have an effect similar to that obtained through the addition of a grid.*

As Grid Ratio Increases

- Scattered radiation cleanup increases and contrast resolution improves
- Contrast scale decreases (higher contrast produced)
- Exposure factors (usually mAs) must increase
- Positioning latitude decreases

F. Filtration

The primary beam usually has a total filtration of 2.5 mm Al equivalent. Inherent filtration includes 0.5 mm Al from the glass envelope and 1.0 mm Al from the collimator. The manufacturer adds another 1.0 mm Al to meet the minimum requirements of 2.5 mm Al equivalent total filtration for radiographic tubes operated above 70 kV.

Filtration serves to increase the overall average energy of the beam; it "hardens" the x-ray beam. The 2.5 mm Al equivalent functions to remove the diagnostically worthless x-ray photons that contribute to patient dose. Since these photons do not have sufficient energy to reach the image receptor, the usual required filtration in the x-ray tube *has no effect on radiographic contrast* (Fig. 11–57).

The addition or removal of *compensating* filters (as discussed in Section II, F) will impact the radiographic contrast unless exposure factors are adjusted to compensate for the change.

G. Intensifying Screens

Radiographic images produced with intensifying screens possess higher contrast than those produced by direct exposure. In general,

A

B
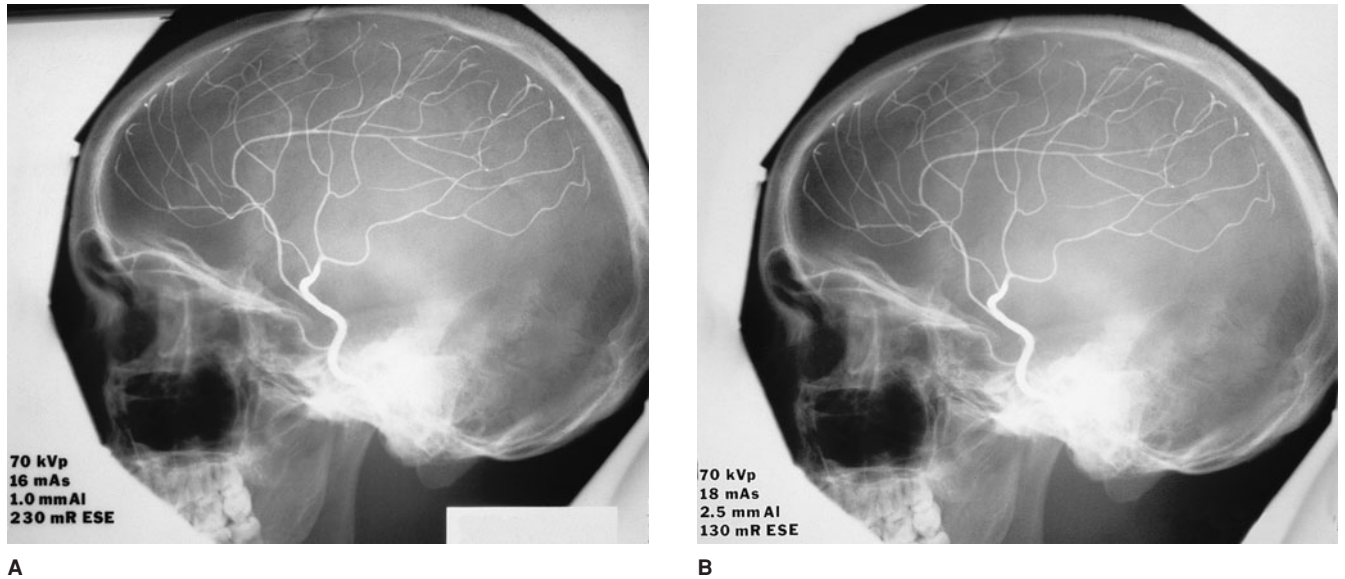
Figure 11–57. **(A)** and **(B)** *The effect of filtration on image contrast.* The contrast displayed in *A* and *B* is very similar. An increase in filtration, however, results in a lower ESE (entrance skin exposure) and greater tube load (mAs). As filtration is increased above 2.5 mm Al, minimal dose reduction occurs and tube loading is significantly increased. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

when comparing images produced using different speed intensifying screens, *the higher the screen speed, the higher the contrast*; that is, 400 speed screens will produce somewhat higher contrast than 200 and 100 speed screens, and 200 screens will produce higher contrast than 100 screens, and so on. Contrast differences among various speed screens, however, are slight.

◼ *SUMMARY*

- ◼ **X-rays scattering within a part and having enough energy to exit the body and reach the image receptor produce scattered radiation fog (noise) on the radiographic image, degrading contrast resolution.**
- ◼ **Grids function to absorb scattered radiation before it reaches the image receptor.**
- ◼ **Scattered radiation cleanup increases as grid ratio increases.**
- ◼ **The higher the grid ratio, the higher (shorter scale) the resulting contrast.**
- ◼ **X-ray tube filtration ordinarily has little effect on contrast; it functions primarily for patient protection.**
- ◼ **Compensating filters added or removed from the x-ray beam will affect contrast unless exposure adjustment is made.**

Chapter Review Questions

⭐ ***Congratulations!*** *You have completed a portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.*

1. The effects of scattered radiation on the x-ray image include the following:
   1. it produces fog
   2. it increases contrast resolution
   3. it increases grid cutoff
   (A) 1 only
   (B) 2 only
   (C) 1 and 2 only
   (D) 1, 2, and 3

2. In comparison to 90 kV, 60 kV will:
   1. permit greater exposure latitude
   2. produce shorter scale contrast
   3. produce less Compton scatter
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

3. An increase in the kilovoltage applied to the x-ray tube increases the:
   1. x-ray wavelength
   2. exposure rate
   3. patient absorption
   (A) 1 only
   (B) 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

4. All of the following are related to radiographic contrast *except*:
   (A) photon energy
   (B) grid ratio
   (C) object–image distance
   (D) focal spot size

5. Which of the following groups of exposure factors will produce the longest scale of contrast?
   (A) 200 mA, 1/20 second, 70 kV, 12:1 grid
   (B) 500 mA, 0.02 second, 80 kV, 16:1 grid
   (C) 300 mA, 30 msec, 90 kV, 8:1 grid
   (D) 600 mA, 15 msec, 70 kV, 8:1 grid

6. Which of the following anatomic parts exhibits the highest subject contrast?
   - (A) elbow
   - (B) kidney
   - (C) esophagus
   - (D) lumbar spine

7. An x-ray image that exhibits many shades of gray from white to black may be described as having:
   - (A) long-scale contrast
   - (B) short-scale contrast
   - (C) more density
   - (D) good recorded detail

8. The advantages of high-kilovoltage chest radiography include:
   1. greater exposure latitude
   2. longer scale contrast
   3. reduced patient dose
   - (A) 1 only
   - (B) 1 and 2 only
   - (C) 1 and 3 only
   - (D) 1, 2, and 3

9. Which of the following exposure factors is used to regulate radiographic contrast?
   - (A) mA
   - (B) exposure time
   - (C) mAs
   - (D) kV

10. Which of the following contribute(s) to the radiographic contrast present on the finished image?
   1. tissue density
   2. pathology
   3. beam restriction
   - (A) 1 and 2 only
   - (B) 1 and 3 only
   - (C) 2 and 3 only
   - (D) 1, 2, and 3

Answers and Explanations

1. (A) Scattered radiation is produced as x-ray photons travel through matter, interact with atoms, and are scattered (change direction). If these scattered rays are energetic enough to exit the body, they will strike the image receptor from all different angles. They therefore do not carry useful information—merely producing a gray fog over the image, producing less contrast resolution. Grid cutoff increases contrast and is caused by improper relationship between the x-ray tube and grid.

2. (C) The lower the kV range, the less energetic/penetrating the x-ray photons. If fewer photons penetrate to reach the IR, fewer grays/densities appear and shorter scale contrast results.

At lower kV levels less Compton scatter events occur—also accounting for fewer grays from scattered radiation. The lower the kilovoltage, the *less* the exposure latitude (margin of error in exposure).

3. (B) As the kilovoltage is increased, a *greater number* of electrons is driven across to the anode with *greater force.* Therefore, as energy conversion takes place at the anode, *more high-energy* (short wavelength) photons are produced. However, because they are higher-energy photons, there will be *less* patient absorption.

4. (D) As photon energy increases, more penetration and greater production of scattered radiation occurs, producing a longer scale of contrast. As grid ratio increases, more scattered radiation is absorbed, producing a higher contrast. As OID (object-to-image-receptor distance) increases, the distance between the part and image receptor acts as a grid and consequently less scattered radiation reaches the image receptor, producing a higher contrast. Focal spot size is related only to recorded detail.

5. (C) Of the given factors, kilovoltage and grid ratio will have a significant effect on radiographic contrast/contrast resolution. The mAs values are almost identical. Because an increased kilovoltage and low-ratio grid combination would allow the greatest amount of scattered radiation to reach the image receptor, thereby producing more gray tones, C is the best answer. D also uses a low-ratio grid, but the kV is too low to produce as much gray as C.

6. (A) The greatest subject contrast is found in body parts made of a few widely differing tissue densities. The elbow has but bone, some muscle, and soft tissues constituting high subject contrast. The abdomen, containing the kidneys, stomach, small and large intestines, and other viscera, is a heavy body part composed of many similar tissue densities, and thus, normally has very low subject contrast.

7. (A) Radiographic contrast is described as the difference between the densities present on an x-ray image. An image possessing many shades of gray between black and white is said to exhibit long-scale, or low, contrast. An image possessing only a few widely different shades of gray between black and white is said to exhibit short-scale, or high, contrast.

8. (D) The chest is composed of widely differing tissue densities (bone and air). In an effort to "even out" these tissue densities and better visualize pulmonary vascular markings, high kV is generally used. This produces more uniform penetration and results in a longer scale of contrast with visualization of the pulmonary vascular markings as well as bone (which is better penetrated) and air densities. The increased kV also affords the advantage of greater exposure latitude (an error of a few kV will make little, if any, difference). The fact that the kV is increased means that the mAs is accordingly reduced and, thus, patient dose is reduced as well.

9. (D) Kilovoltage regulates the energy, and therefore penetration, of the photons produced at the target (anode). The greater the photon energy, the less the total absorption by dense tissues and the more that tissue densities will be "evened out," that is, showing a longer scale of grays. Time and mA are the quantitative exposure factors controlling radiographic density.

10. (D) The radiographic subject, that is, the patient, is composed of many different tissue types of varying densities, resulting in varying degrees of photon attenuation and absorption.

This *differential absorption* contributes to the various shades of gray (i.e., scale of radiographic contrast) on the finished image. Normal tissue density may be significantly altered in the presence of pathology. For example, destructive bone disease can cause a dramatic decrease in tissue density. Abnormal accumulation of fluid (as in ascites) will cause a significant increase in tissue density. Muscle atrophy, or highly developed muscles, will similarly decrease or increase tissue density. Perhaps the most important way to improve contrast resolution and limit the production of scattered radiation is by limiting the size of the irradiated field through *beam restriction*. As the size of the field is reduced there is less tissue volume irradiated, therefore less scattered radiation will be produced.

IV. IMAGE RECEPTOR AND GRID OPTIONS

X-ray film may be described as being made of *silver bromide grains suspended in a gelatin emulsion and coated on a plastic base material*. X-ray film is still an important means of recording and storing the radiographic image and so a brief overview of the process of x-ray film production is in order here.

First, gelatin is extracted from cattle hooves and hides and rendered into a very pure, uncontaminated state. Nitric acid is combined with pure silver to form *silver nitrate*. Then, *in total darkness, silver nitrate is added to potassium bromide to form silver bromide*. Silver bromide is then combined with the gelatin mixture to form the emulsion, which is coated onto one (single emulsion film) or both sides (*duplitized*) of the film base.

The base material is a durable *polyester* plastic that will not tear, and with a dimensional stability that will be unaffected as it travels through the processor roller system and various chemical temperatures. Film base is not absolutely clear; it has a measurable density, referred to as *base fog* or *base density*. Base fog or density is the sum of environmental exposure received during production and storage as well as the density resulting from the base material tint and dye. An additional, approximately equal, amount of fog results from processing. The total *base plus fog* should not exceed 0.2 density as measured by a densitometer.

A *protective coat* of hard, clear gelatin is placed over the emulsion to help prevent emulsion abrasion.

A. FILM CONTRAST AND LATITUDE

Each type of x-ray *film emulsion* is manufactured with certain characteristics required for its particular use (e.g., latitude film, mammography film), each having its own particular response to exposure (i.e., *film latitude*). Some film emulsion is manufactured especially to produce high contrast, for example, film used in mammography and vascular procedures. Others are produced to provide a long range of grays; this type of emulsion possesses more film *latitude*; that is, it is more "forgiving" of errors in technical factors (Fig. 11–58). The study of film emulsion response to exposure is called *sensitometry* and illustrated by the characteristic Hurter and Driffield (H&D) curve.

The sensitometric/characteristic curve (Fig. 11–59) illustrates the degree of film density as a result of exposure. Density is represented by the vertical axis, log exposure by the horizontal axis. The *sensitometric*
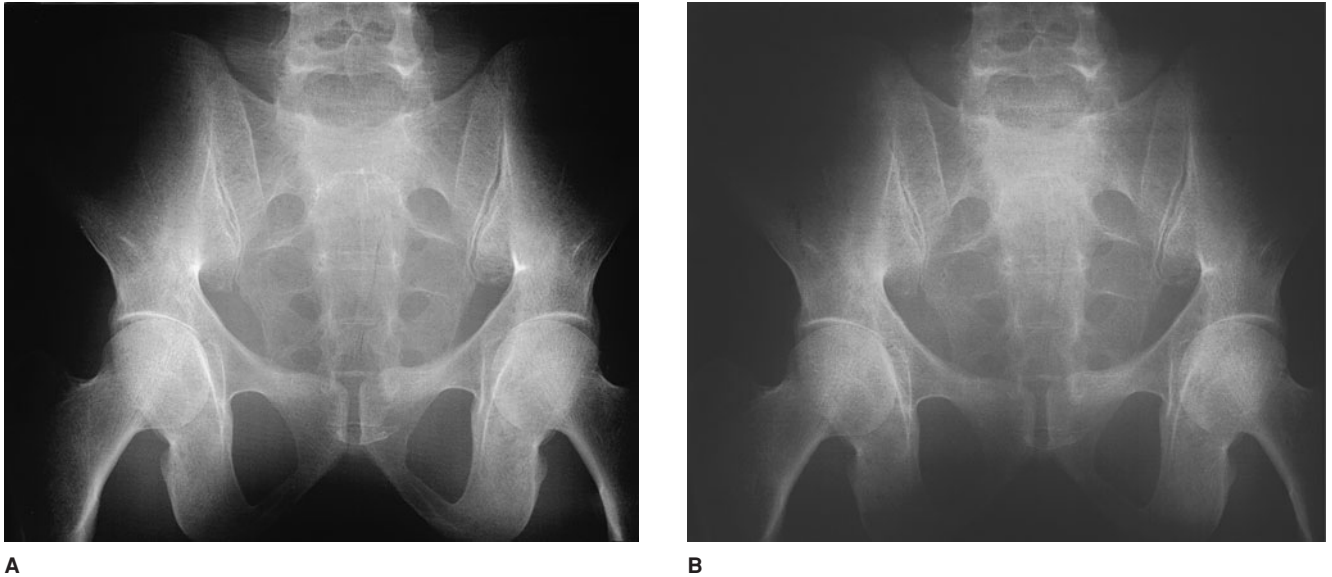
Figure 11–58. **(A)** Made using 80 kV, 75 mAs, and regular film. **(B)** Made under identical conditions and using the same factors, but with latitude (i.e., low-contrast) film. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

curve has three portions: the *toe* (D_{min}), *straight-line portion*, and *shoulder* (D_{max}). Exposures made in the toe and shoulder portions of the curve will be excessively under- or overexposed. The useful diagnostic range of densities lies between 0.25 and 2.5, corresponding to the *straight-line portion* (average gradient) of the curve and is generally regarded as the *region of correct exposure*. Exposures made outside of this region do not record diagnostically useful information.

The highest point on the sensitometric curve is where maximum density occurs and is referred to as D_{max}. Just beyond D_{max}, the curve begins to descend again, representing a decrease in density. This is the *solarization point*, where additional exposure will actually cause a reversal of the image.

Have you noticed that an unexposed and processed *duplicating* film emerges from the processor black? If regular x-ray film were used for film duplication, a black and white reversed image would result. This is because, using regular film, the print box light will pass through the whiter areas causing exposure and darkening, while little light will pass through the darker areas, causing little or no exposure on the x-ray film, hence, a reversed image. The emulsion of duplicating film, however, has been chemically brought up to the solarization point so that further exposure will cause a reversal, thus remedying the problem of reversed images with regular film.

A glance at a film emulsion's sensitometric curve will tell you about its *speed, latitude*, and *contrast*. A curve having a steep slope (*average gradient*) is likely to be fast, having little latitude and producing high contrast. A fast film responds readily to intensifying screen fluorescent light or x-rays and has the advantage of permitting a decrease in exposure factors, and ultimately, patient dose. When two or
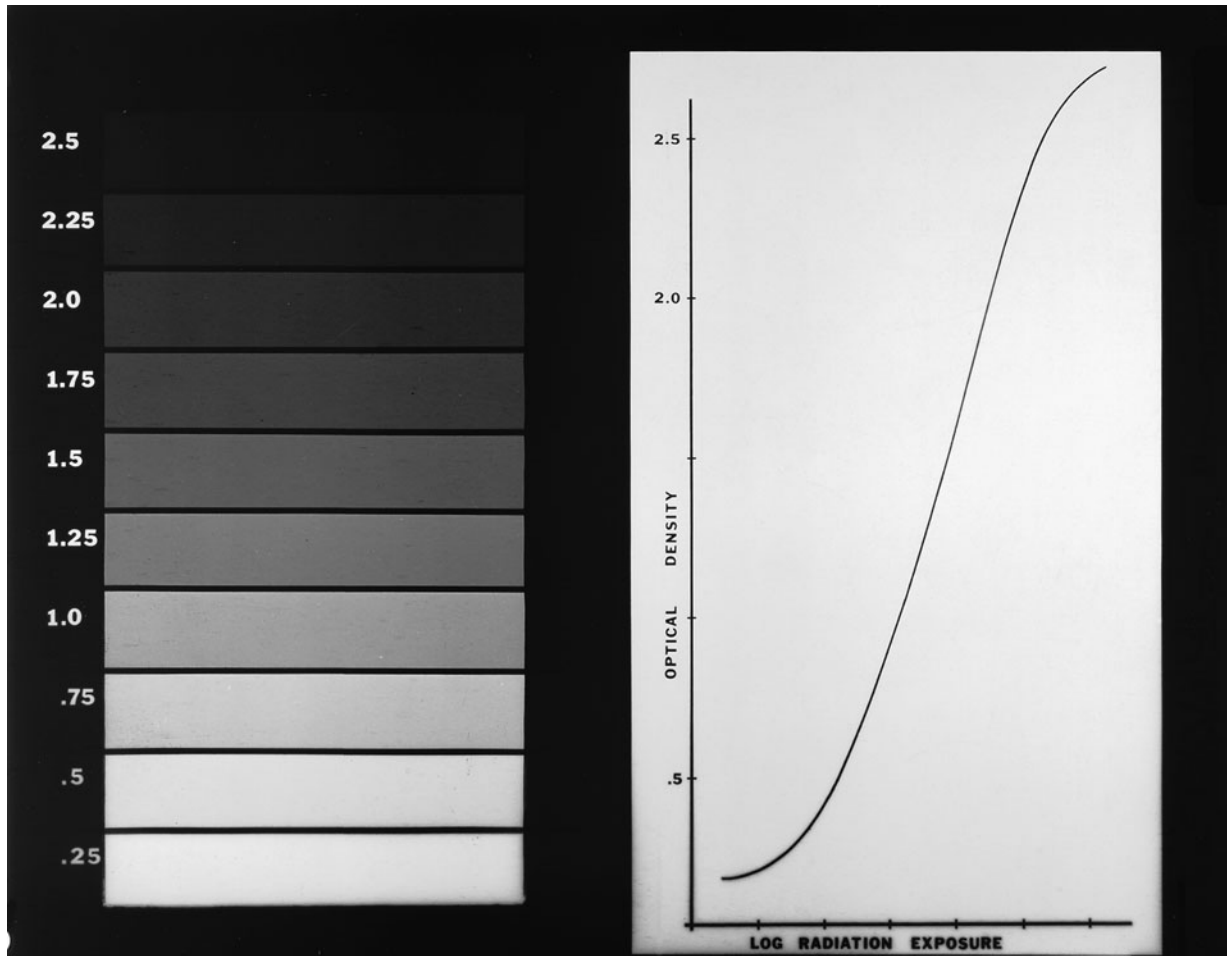
Figure 11–59. *Sensitometric* (characteristic) *curve.* Notice that the toe portion of the curve does not begin at zero; this represents the slight exposure owing to base fog. Total base plus fog should not exceed 0.2 density. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

more curves are being compared, the curve farthest to the left represents the fastest emulsion.

The average gradient of a sensitometric curve gives a good indication of that film's *contrast.* A steep sensitometric curve (average gradient) is representative of high contrast, shorter scale, contrast. *Latitude* refers to the *range* of exposure that will provide densities within the diagnostically useful range; fast film generally offers less latitude (Fig. 11–60). Film and screen protocols are generally established at the radiographer's workplace; however, the radiographer should be knowledgeable enough to use the types available to the best advantage.

B. EXPOSURE LATITUDE

While *film latitude* is related to emulsion characteristics, *exposure latitude* is related to the technical factors selected. Exposure latitude is the leeway, or margin of error one has with a given group of exposure factors; the degree of exposure latitude is generally determined by the

kilovoltage. At higher kilovoltages, a difference of a few kV will make little, if any, difference radiographically. At low kilovoltages, however, an error of just a few kV can make a very noticeable difference in the radiographic image. While the radiographer has little control over film latitude, he or she has much control of exposure latitude.

■ *SUMMARY*

- ■ **X-ray film emulsion consists of silver bromide grains suspended in gelatin.**
- ■ **Film base is made of a strong polyester plastic.**
- ■ **Base plus fog is a result of environmental factors, base tint, and processing.**
- ■ **Base plus fog should not exceed 0.2 density.**
- ■ **Various kinds of film emulsion are available from the manufacturer; emulsion characteristics differ according to their use and the desired radiographic requirements.**
- ■ **Film emulsions are made to be slow speed or high speed, low contrast or high contrast.**
- ■ **Sensitometry is the study of film emulsion response to exposure.**
- ■ **Sensitometric curves are used to illustrate and compare film emulsion response to exposure.**
- ■ **The typical sensitometric curve has a toe (D_{min}), straight-line portion (average gradient), and shoulder (D_{max}).**
- ■ **Diagnostically useful densities are within 0.25 to 2.5 on the vertical axis.**
- ■ **A sensitometric curve with a steep slope usually represents higher contrast emulsion; a sensitometric curve with a gentle slope usually represents lower contrast emulsion.**
- ■ **Exposure latitude is related to kV level: as kV increases, exposure latitude increases, and vice versa.**
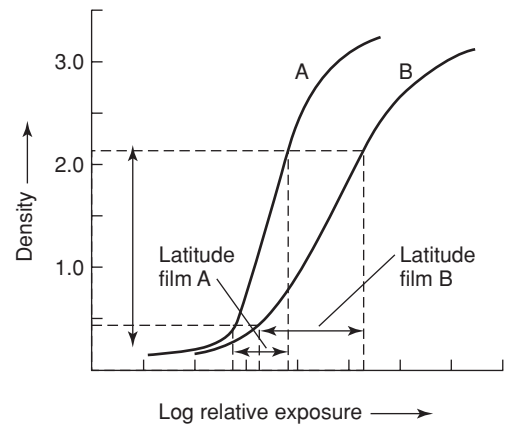
Figure 11–60. *Film latitude.* Note the differences in film latitude within the useful density range. Latitude and contrast are inversely related. **(A)** High-contrast, low-latitude film. **(B)** Low-contrast, high-latitude film.

C. Anatomic Factors

Consideration of patient habitus, tissue density, and pathology is important in the appropriate selection of radiographic accessories. For example, routine protocol may call for knee and shoulder examinations to be performed using the table or upright Bucky/grid. However, children, the elderly, and patients with degenerative or pathologic conditions may not require the use of a grid. Small, thin parts and parts undergoing degenerative changes (such as in osteoporosis) can frequently be performed tabletop (i.e., using intensifying screens without a grid), thereby significantly reducing patient dose.

Slower speed screens (e.g., 100 speed) are generally used for extremities and other structures where better detail is desired. Faster screens (e.g., 400 speed) are usually used for general radiography of larger, thicker, denser structures to reduce exposure while still maintaining reasonably good image detail.

The usual use of intensifying screens may be modified to suit the particular circumstances of the examination. With all other factors remaining the same, the use of faster screens results in less exposure dose to the patient. Faster screens permit the use of shorter exposure

times and therefore may be used for extremities of children and other examinations where motion can be a problem; they can also be helpful when the affected extremity is unusually large or casted. Slower screens are used when improved detail of a small area is desired, keeping in mind that exposure dose will be increased.

D. CONVERSION FACTORS: INTENSIFYING SCREENS AND GRIDS

There are many variables associated with the practice of radiography. It is necessary that the radiographer be able to compensate for changes in imaging system components, such as intensifying screens and grids.

Intensifying screen speed is directly related to density and inversely related to mAs. As screen speed increases, all other factors remaining constant, radiographic density increases. As screen speed increases, therefore, mAs must be decreased to maintain the original density.

For example, if 400 speed screens (having a factor of 0.5) were used with 2 mAs for a particular examination, what mAs would be required using 100 screens (having a factor of 2.0)?

$$\frac{\text{Screen speed factor}_1}{\text{Screen speed factor}_2} = \frac{\text{mAs}_1}{\text{mAs}_2}$$

$$\frac{0.5}{2.0} = \frac{2}{x}$$

$$0.5x = 4$$

$$x = 8 \text{ mAs using 100 speed screens.}$$

Grid selection is dependent on the size/nature of the part being imaged and the desired image characteristics. As grid ratio increases, scattered radiation cleanup increases and, as a result, contrast increases (i.e., contrast *scale* decreases).

Grid ratio is inversely related to radiographic density and directly related to mAs. As grid ratio increases, all other factors remaining constant, radiographic density decreases. As grid ratio increases, therefore, mAs must be increased to maintain the original radiographic density (Fig. 11–61). As discussed earlier in the chapter, conversion factors may be used when changing from nongrid to grid or from one grid ratio to another.

For example, 12 mAs was used with a 5:1 ratio grid for a particular exposure. It is desired to repeat the exposure using a 16:1 ratio grid. What new mAs factor will be required to maintain the original radiographic density?

$$\frac{\text{mAs}_1}{\text{mAs}_2} = \frac{\text{Conversion factor}_1}{\text{Conversion factor}_2}$$

$$\frac{12}{x} = \frac{2}{6}$$

$$2x = 6(12)$$

$$2x = 72$$

$$x = 36 \text{ mAs using a 16:1 grid.}$$

These conversion factors allow for mAs compensation from nongrid to moving grid, or for changing from one grid to another, all

mAs Conversions for Screen Speed Changes

Screen Speed	mAs Conversion Factor
100	2
200	1
400	1/2 (0.50)
800	1/4 (0.25)

Relationship Between Grid Ratio and mAs

Grid Ratio	mAs Conversion Factor
No grid	1
5:1	2
6:1	3
8:1	4
10/12:1	5
16:1	6
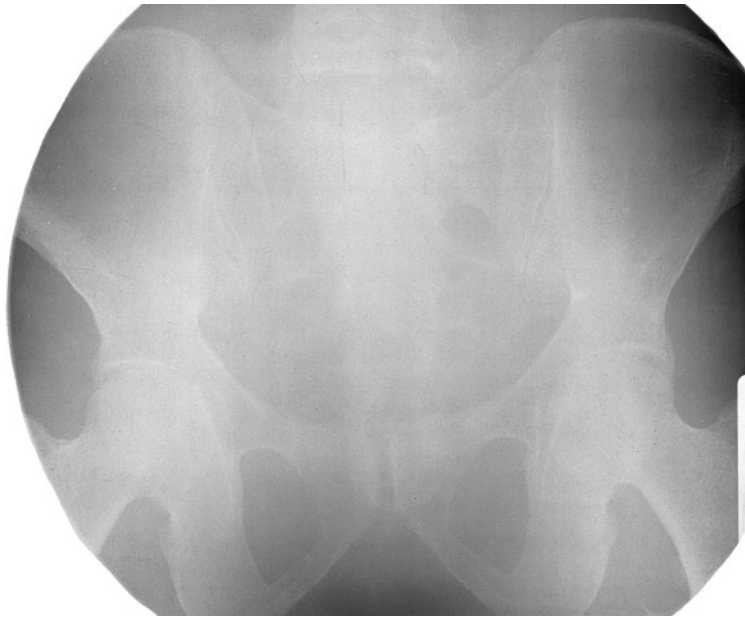
A

B

Figure 11–61. *Grids* are usually required for parts that generate large amounts of scattered radiation. **(A)** Made without a grid, using 40 mAs. **(B)** Made with a 12:1 grid and 200 mAs. Although a significant increase in exposure is required, the use of grids enables the production of diagnostic images. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

other technical factors remaining constant. Although stationary grids are somewhat less efficient in the cleanup of scattered radiation, their use rarely requires modification of the correction factor.

▪ *SUMMARY*

- ▪ **When selecting technical factors and radiographic accessories, consideration must be given to the patient's age, habitus, and pathology.**

- **Screen speed choice is dependent on patient modifying factors (age, condition), patient dose, and radiographic requirements (detail).**
- **The ratio of moving grids can differ from one radiographic room to another.**
- **Grid conversion factors are used to determine required mAs when changing from one grid ratio to another.**

V. AUTOMATIC EXPOSURE CONTROL

An *automatic exposure control (AEC)* is used to automatically regulate the amount of ionizing radiation delivered to the patient and image recorder, thereby serving to produce consistent and comparable radiographic results time after time. When AEC is installed in the x-ray circuit, it is calibrated to terminate the exposure once a predetermined (known correct) exposure has been made.

When using film/screen systems, it is essential to use the correct speed screen and film combination with the AEC—the screen and film combination that it has been programmed for. The AEC cannot compensate for a speed system that it does not "know" about. For example, if the system has been programmed for a 400 system and a 200 speed cassette is used, the image will exhibit half the expected density.

Whether using traditional or computerized imaging equipment, *exact positioning and centering* is particularly critical when using equipment with AECs. The anatomic part of interest must be positioned (centered) accurately with respect to the AEC's sensors; otherwise, the result can be over- or underexposure.

A. TYPES

In one type of AEC, there is a (radiolucent) parallel plate *ionization chamber* just beneath the tabletop, *above* the cassette (Fig. 11–62). The part to be examined is centered to the sensor and imaged. As x-ray photons emerge from the patient, they enter the chamber and ionize the air within. When a predetermined quantity of ionization has occurred, which equals the correct density, the exposure automatically terminates.

The other type of AEC is the (radiopaque) *phototimer* type in which a small fluorescent screen is positioned *beneath* the cassette. When the exit radiation emerging from the patient exposes the image receptor and exits the cassette, the fluorescent screen emits light and charges a photomultiplier tube. Once a predetermined charge has been reached, the exposure is automatically terminated.

In either case, the *manual* timer should always be used as a *backup timer*. In case of AEC malfunction, the exposure would terminate, thus *avoiding patient overexposure and tube overload*.

Another important feature of the AEC is its *minimum response/ reaction time*. This is the length of the *shortest exposure possible* with a particular AEC (10–30 ms). If less than the minimum response time is required for a particular exposure, the resulting image will exhibit excessive density. The only way to remedy this is to decrease the mA or decrease the kV. Each maneuver will result in increased exposure
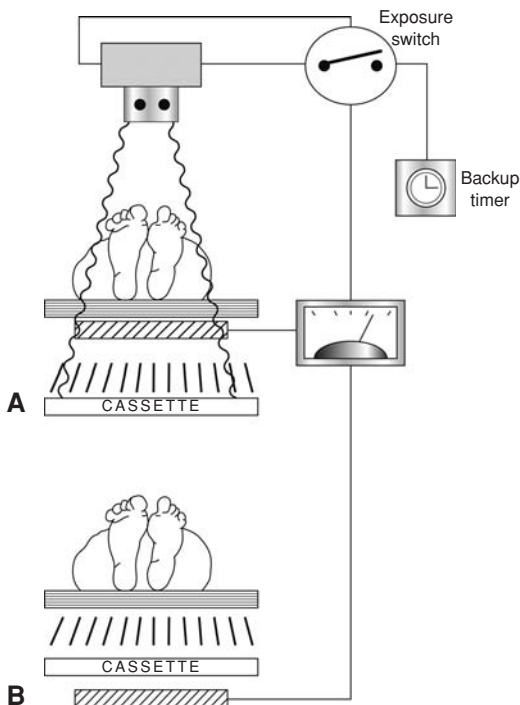
Figure 11–62. The two types of *automatic exposure devices* are the *ionization chamber* (A) and the *phototimer* (B). Note the *backup timer* that functions to terminate the exposure, should the AEC fail to operate properly.

time to within the response time capabilities of the AEC. If the contrast scale is to be maintained, then the mA adjustment is preferable.

B. POSITIONING ACCURACY

To achieve the expected radiographic density, the appropriate sensor(s)/photocell(s) must be selected and the part must be correctly positioned directly above the sensor(s) and photocell(s).

If a structure having less tissue density than the part of interest is positioned above the sensor, or if the sensor is not completely covered, the sensor will terminate the exposure sooner and the area of interest will be underexposed. Similarly, if the incorrect sensor for the anatomic part is selected, a density error will result.

On the other hand, if the sensor is positioned under a structure having greater tissue density than the part of interest (e.g., if the center sensor is used for a PA chest image), the exposure will be greater than required and an overexposed image will result.

Hence, although the exposure is "automatic," knowledge of anatomy and accurate positioning skills are essential to producing proper radiographic/image density.

C. PATHOLOGY

The presence of pathology often modifies tissue composition. Changes that occur are often spoken of as *additive* or *degenerative*. Additive pathology is that which makes tissues denser, requiring an increase in exposure factors (e.g., ascites). Degenerative pathology involves deterioration of the part (e.g., osteoporosis) and requires a decrease in exposure factors.

Because the function of an automatic exposure device is to "recognize" differences in tissue density and thickness, it will compensate for most pathologic changes by adjusting the mAs. In the event further compensation is necessary, most AECs have a *master density control* (on the control panel) that allows the radiographer to modify its output.

Normal exposure and density can usually be varied in increments of 25%, plus or minus. It must be noted that if an image is overexposed because an exposure shorter than the *minimum reaction time* (shortest possible exposure) is required, a reduction in master density control will not resolve the situation. Rather, a lower mA station should be selected so that an exposure time within the machine's capability can be used.

Examples of Additive Pathologic Conditions

- Ascites
- Rheumatoid arthritis
- Paget disease
- Pneumonia
- Atelectasis
- Congestive heart failure
- Edematous tissue

■ SUMMARY

- **The function of AECs is to produce consistent and comparable radiographic images.**
- **There are two types of AECs: ionization chamber and phototimer.**
- **Ionization chambers are located between the x-ray table and cassette; phototimers are located beneath the cassette.**
- **Backup timers are used in conjunction with AECs and function to terminate the exposure in case of AEC malfunction.**

Examples of Destructive Pathologic Conditions

- Osteoporosis
- Osteomalacia
- Pneumoperitoneum
- Emphysema
- Degenerative arthritis
- Atrophic and necrotic conditions

- ■ **Minimum reaction time is the shortest exposure time possible with a particular AEC.**
- ■ **The successful use of AECs requires accurate patient positioning and proper photocell/sensor selection.**
- ■ **Pathologic conditions may be either additive or degenerative; correct use of the AEC will compensate for pathologic conditions.**
- ■ **AECs have a master density control, usually adjustable in increments of 25%.**

VI. TECHNIQUE CHARTS

A. Optimal and Fixed kV Technique

A *fixed kV technique* chart specifies a particular kV for each body part or type of examination. A kV is selected that will provide adequate penetration and the appropriate scale of contrast. mAs is used to compensate for variation of patient size and condition.

B. Variable kV Technique

In a *variable kV technique* chart, the mAs is fixed and the kV is increased as part thickness increases. For each centimeter increase in thickness, the kV is increased by 2. Accurate measurement with calipers is required.

The variable kV technique chart is not frequently used today because it is associated with increased scattered radiation production and inconsistent contrast and density.

C. Versus AECs

Fixed kV techniques are generally used with AECs. An optimum kV for each body part (femur, abdomen, hip, chest, etc.) is selected and the exposure is automatically terminated once the predetermined correct exposure (mAs) has been reached.

D. Measurement of Part

Accurate measurement of the part to be imaged is essential with the *variable* kV technique chart, because the kV increases by 2 for every 1-cm increase in part thickness. *Fixed* kV charts may specify a specific kV for the "small," "medium," or "large" patient, which corresponds to measurements within a particular range (e.g., 10–12 cm = small, 13–15 cm = medium, 16–18 cm = large). Accurate measurement may be essential for the correct application of each method.

Structures imaged using AECs do not require measurement because the AEC automatically adjusts the exposure for tissue variations.

E. Other Considerations

Body position plays an important role in obtaining the expected radiographic results. For example, a well-exposed image of a normal adult abdomen measuring 24 cm in the recumbent AP position cannot be duplicated using the same factors if the patient is turned prone or positioned decubitus or erect.

Fixed kV Technique Chart

	Fixed kV*	Grid
Extremities	55	No grid
Skull	75	Grid
Abdomen	75	Grid
Lateral lumbar	90	Grid
Barium studies	120	Grid
Chest examinations	120	Grid

*For 3ø equipment factors; single ø will require approximately 12% higher kV.

A particular chest properly exposed on *inspiration* using a 14 × 17-inch cassette cannot be duplicated, without a change in factors, when the exposure is made on *expiration* or the field size is *collimated* to an 8 × 10-inch anatomic area.

A *plain* image of a particular abdomen requires different exposure factors from the same abdomen having a *barium*-filled stomach.

Different exposures will be required for extremities with and without *casts*.

Body parts undergoing additive or destructive *pathologic changes* can require substantial exposure changes to maintain the required density and contrast.

AECs will compensate for thickness and density differences (including those caused by position and respiration), pathologic changes, and beam restriction. However, it should be emphasized that the radiographer's skill and accuracy in *positioning* and *photocell selection* play an important role in the proper function of AECs.

VII. ELECTRONIC/DIGITAL IMAGING

Electronic imaging consists of CR and DR. As electronic/digital imaging technology continues to develop, descriptive terms also evolve. The most current terms are described and used here.

A. EMERGENCE OF DIGITAL IMAGING

Diagnostic radiography is undergoing probably its most significant changes since the discovery of x-rays. Sonography and Nuclear Medicine had made the change to electronic; CT and MRI are intrinsically electronic; thus, radiography is the last imaging modality to make the transition to electronic/digital. Incentive for the transition was initially low because screen/film systems are reliable and produce excellent image quality. Additionally, radiography's high spatial resolution and field of view (FOV) demand that electronic images carry a large amount of digital data. To illustrate: a typical PA chest image carries between 4 to 32 MB of digital data, while a single CT image holds approximately 0.5 MB. Therefore, radiographic images require lots of digital storage space, a high bandwidth in PACS, and require costly high-resolution monitors for (diagnostic) display.

Nevertheless, although many imaging offices and hospital imaging departments might still utilize traditional film/screen imaging (*traditional "projection radiography"*), it is clear that computerized/digital/filmless imaging will soon replace what many still think of as "traditional" imaging methods. The language of electronic radiography includes, but is far from limited to, terms such as *computed radiography* (CR), *digital* (both *direct*, and *indirect*) *radiography* (DR), *photostimulable phosphor* screens (PSPs), *charge-coupled devices* (CCDs), thin film transistors (TFTs), and *picture archiving and communication systems* (PACS).

B. DIGITAL IMAGE FEATURES

1. Resolution. In radiography, recorded detail and detail visibility are two major terms that have been used to describe image quality. They can be updated, particularly with respect to electronic imaging, spatial
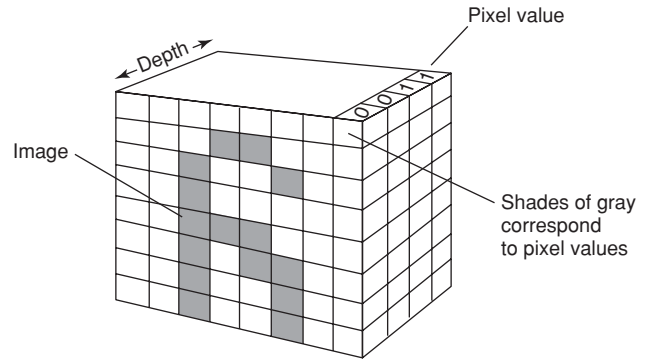
Figure 11–63. A digital image may be likened to a three-dimensional object made up of many small cubes, each containing a binary digit or bit. The image is seen on one surface of the block, whose depth is the number of bits required to describe each pixel's gray level.

resolution, and contrast resolution. One of the outstanding features of electronic imaging is its ability to provide excellent contrast resolution, which is often more important than spatial resolution.

Spatial resolution, referring to how small an object can be imaged, is usually expressed in terms of line pairs/mm. The spatial resolution of electronic imaging cannot compare with that of screen/film imaging. Screen/film resolution is so much better, but CR/DR's ability to perceive small differences in tissue densities (i.e., better contrast resolution) is more valuable, particularly when viewing soft tissues.

2. Pixel Matrix. Digital image storage is located in a *pixel* (Fig. 11–63), which is a two-dimensional "picture element," measured in the "XY" direction. The third dimension, "Z" direction, in the matrix of pixels is the *depth* that is referred to as the *voxel* (*vo*lume *el*ement) (Fig. 11–64). The depth of the block is the number of bits required to describe the *gray level* that each pixel can take on—known as the *bit depth*. Bit depth in CT is approximately 2^{12} with a dynamic range of almost 5000 gray shades, approximately 2^{14} in CR/DR with a dynamic range of more than 16 000 gray shades, and approximately 2^{16} in digital mammography with a dynamic range of more than 65 500 gray shades. The *matrix* is the number of pixels in the XY direction. *As matrix size increases, for a fixed FOV, pixel size is smaller and better image resolution results* (Fig. 11–65).

An electronic/digital image is formed by a *matrix* of pixels in *rows* and *columns*. A matrix having 512 pixels in each row and column is a 512 × 512 matrix (a typical CT image). The term *field of view* (FOV)
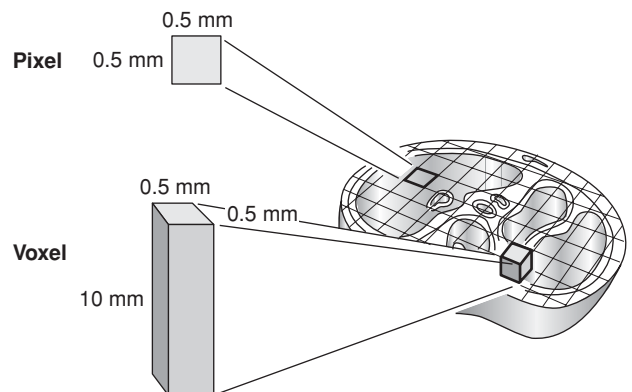
Figure 11–64. The third dimension in the matrix of pixels is the depth, which together with the pixel is referred to as the voxel (volume element).

| 16 × 16 | 32 × 32 | 64 × 64 | 128 × 128 | 256 × 256 |
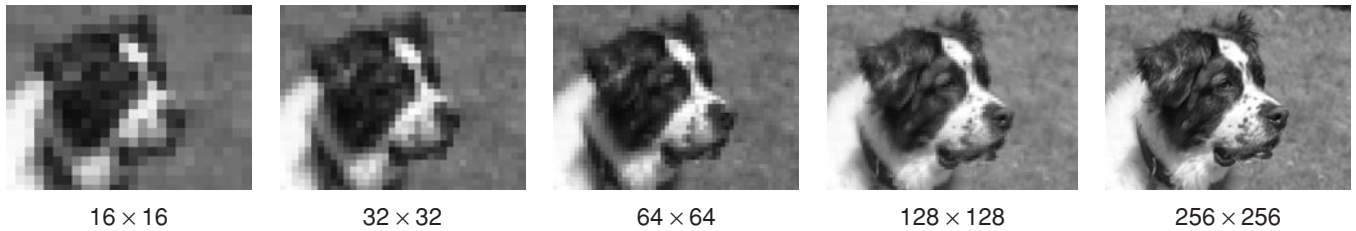
Figure 11–65. The matrix is the number of pixels in the XY direction. The larger the matrix size, the better the image resolution.

is used to describe how much of the patient is included in the matrix. Either the matrix or the field of view can be changed without one affecting the other, but changes in either will change pixel size. *As FOV increases, for a fixed matrix size, the size of each pixel increases and spatial resolution decreases*. Fewer and larger pixels result in a poor-resolution "pixelly" image, that is, one in which you can actually see the individual pixel boxes (Fig. 11–65).

3. SNR.
In describing signal-to-noise ratio (SNR), the term "signal" refers to the photons that have penetrated the part without interaction (unattenuated) and the term "noise" refers to Compton scatter and any other form of image-degrading fog. SNR is used to describe contrast resolution; the higher the SNR, the better the contrast resolution. Generally speaking, SNR increases as mAs increases, but so does patient dose. Compared to screen/film imaging, patient dose should be less in CR and DR (especially DR). Images should not be repeated because of brightness (density) or contrast imperfections. Average exposure index guidelines should be established and maintained.

4. DQE.
The *detective quantum efficiency* (DQE, i.e., ability of receptor material to perceive and interact with x-ray photons) of the PSP can be regarded as an x-ray absorption coefficient and is highly dependent on photon energy (kV) as well as the composition and thickness of the PSP layer. The PSP receptor screens in CR/DR receptors use cesium iodide, barium fluorohalide, and amorphous selenium. The DQE of these receptors is higher than that of the intensifying screens used in screen/film imaging; thus, another reason CR/DR imaging requires less patient dose than screen/film imaging.

While x-ray photons are still required to produce the images, CR and DR utilize computer technology to convert the analog image to a digital image: to "*read*" (*process*) that image, to *display and manipulate* that image, and *to store* that image (see Fig. 11–66).

C. COMPUTED RADIOGRAPHY

1. The Image Plate (IP).
Traditional x-ray *cassettes* contain a pair of intensifying screens with film sandwiched between the two screens. In computed radiography, the cassette-like device is termed as image plate (IP). Image plates have no intensifying screens or film within (Fig. 11–67), hence the term *filmless radiography*. The IPs have a *protective* function (for the flexible PSP screen within) and can be conveniently
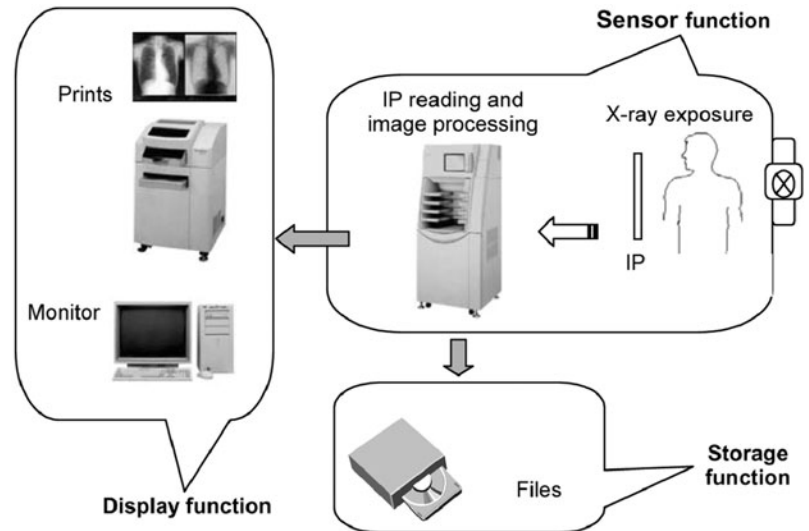
Figure 11–66. A digital imaging system is composed of various devices having separate functions: (1) the *sensor* function, x-ray exposure of a photostimulable phosphor (PSP) image plate that then goes to the scanner/reader for image processing; (2) the *display* function, image is viewed on a monitor and/or hard copy prints are made; and (3) the *storage* function, records are kept of all images for later retrieval. (Courtesy of FUJIFILM Medical Systems USA, Inc.)

Figure 11–67. A CR cassette is very similar in appearance to a conventional screen/film cassette. The CR cassette holds an image plate (the image receptor) between its front and rear panels. There is no film or intensifying screen. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation*. New York: McGraw-Hill, 2003).
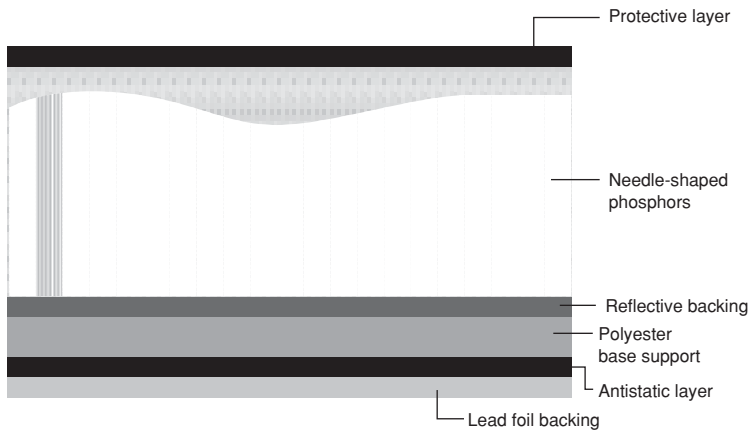
Figure 11–68. Barium fluorohalide is either granular or "needle shaped." The "needle-like" phosphors have the advantage of *better x-ray absorption* and *less light diffusion.*

placed in the bucky tray or under the anatomic part. The IPs need not be lighttight because the PSP screen inside is *not light sensitive.* One corner of the IP's rear panel has a *memory chip* for patient information; the IP also has a thin *lead foil backing* (similar to intensifying screen cassettes) to absorb backscatter.

2. The Photostimulable Phosphor (PSP). Inside the IP is the all-important *photostimulable phosphor* (*PSP*) screen, also called *storage phosphor screen* (SPS), which is the actual image receptor (IR).

The PSP screen within the IP has a layer of europium-activated barium fluorohalide ($BaFX:Eu^{2+}$; X = halogen) mixed with a binder substance. This layer serves as the *image receptor* when exposed in the traditional manner; it looks very much like an x-ray intensifying screen. The barium fluorohalide is either granular or "*needle*"-shaped. The "needle-like" phosphors have the advantage of *better x-ray absorption* and *less light diffusion* (Fig. 11–68). Just under the barium fluorohalide layer is a *reflective layer* that helps direct emitted light up toward the CR reader. Below the reflective layer is the *base*, behind that is an *antistatic layer* and then the *lead foil* to absorb backscatter. Over the top of the barium fluorohalide is a *protective layer*.

3. X-ray Absorption by PSP. When the barium fluorohalide absorbs x-ray energy, *electrons are released and they divide into two groups.* One electron group initiates *immediate luminescence* during the ex-cited state of Eu^{2+}. The other electron group *becomes trapped* within the phosphor's halogen ions, forming a "color center." These are the phosphors that ultimately form the radiographic image because when exposed to a *monochromatic* laser light source these phosphors emit *polychromatic* light, termed *photostimulated luminescence* (PSL).

The PSP layer (or SPS) can *store* its latent image for several hours, however, after approximately 8 hours noticeable image *fading* will occur. The europium activator is important for the *storage* characteristic of the PSPs; it also has a function similar to the sensitization specks within film emulsion—without europium the image will not become manifest.

Abbreviations

IP	Image plate
PSP	Photostimulable phosphor
PSL	Photostimulable luminescence
SPS	Storage phosphor screen
CR	Computed radiography
SNR	Signal-to-noise ratio
MTF	Modulation transfer function
PMT	Photomultiplier tube
PD	Photodiode
ADC	Analog-to-digital converter
EDR	Exposure data recognizer
DQE	Detective quantum efficiency
CCD	Charge coupled device
TFT	Thin film transistor
HIS	Hospital information system
RIS	Radiology information system
PACS	Picture archiving and communication system
DICOM	Digital imaging and communications in medicine
EDR	Exposure data recognition

PSP Screen Layers

- Protective coat
- $BaFX:Eu^{2+}$ phosphors in binder material
- Reflective backing
- Polyester base support material
- Antistatic layer
- Lead foil backing

Figure 11–69. The *recording, reading*, and *erasure* cycle of a CR image plate. The IP is exposed to x-ray photons, scanned/read, and then erased for reuse. (Courtesy of FUJIFILM Medical Systems USA, Inc.)

4. Reading the PSP. After exposure, the IP is placed into the CR *reader* (see Fig. 11–69), where the PSP screen is automatically removed. The latent image on the PSP screen is changed to a *manifest image* as it is moved at a *constant* speed and scanned by a narrow *high-intensity helium–neon laser* or a *solid-state* laser to obtain the pixel data. The longer wavelength light from the newer *solid-state lasers* has the advantage of being unlikely to interfere with the light being emitted by the PSPs (Fig. 11–70). This appropriate (red, 430–550 nm) wavelength is absorbed by the "color center" and the electrons trapped there, causing *photostimulated luminescence* (PSL) to occur during the excited state of Eu^{2+}.

The phosphors are activated by a monochromatic laser light, however, PSL is a *different* color (bluish-purple, blue-green, etc.). These two lights (PSL and laser) must not interfere with each other. To improve the image SNR, the PSL (carrying the x-ray image) must be a different wavelength/color than, and physically separate from, the laser excitation light. An *optical filter* is used that permits *transmission* of the PSL, but *attenuates* the laser light; this filter is mounted in front of a *photomultiplier* tube (PMT).

The PMT or photodiode (PD) is used to detect the PSL and convert it to electrical signals (see Fig. 11–70). The electrical energy is sent to an *analog-to-digital converter* (*ADC*) where it becomes the *digital* image that is displayed, after a short delay, on a high-resolution monitor and/or printed out by a laser printer ("hard copy"). The digitized
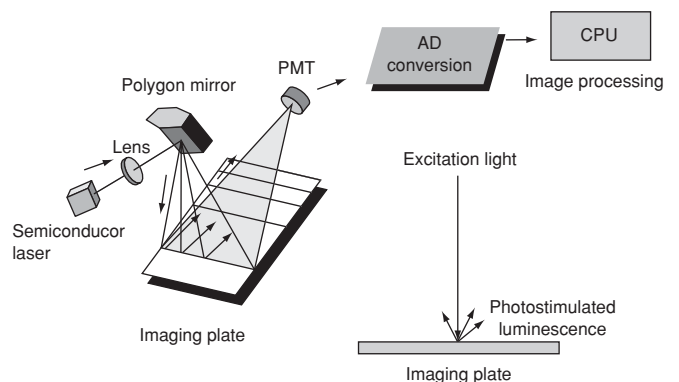
Figure 11–70. The latent image on the PSP screen is changed to a manifest image as it is moved at a constant speed and scanned by a narrow high-intensity helium–neon laser or a solid-state laser to obtain the pixel data. (Courtesy of FUJIFILM Medical Systems USA, Inc.)

images can also be manipulated in postprocessing, electronically transmitted, and stored/archived. Postprocessing manipulation can include *edge enhancement*; this technique can be used to improve the visibility of structures such as chest tubes by accentuating their edges.

Once the PSP storage plate reading process is completed, any remaining data stored on the PSP are erased by exposing it to high-intensity light (called "erasure"); the PSP storage plate is then ready for reuse (see Fig. 11–69).

As previously mentioned, image "*fading*" will occur if there is delay in reading the PSP. This is because after a time, trapped photo-electrons are released from the "color center" and are therefore unable to participate in PSL. PSL intensity *decreases* in the interval between x-ray exposure and the image reading process. If the exposed PSL is not delivered to the reader/processor for 8 hours, PSL decreases by approximately 25%. Fading also increases as environmental temperature increases.

5. PSP Sensitivity. PSP storage plates are very sensitive (more than film emulsion) not only to x-rays but ultraviolet, gamma, and particulate radiation. Environmental conditions are therefore an important consideration in the storage of PSP screens and their IPs. Building materials such as concrete, marble, etc. constantly emit natural radiation; bedrock in some geographic areas contributes significantly to background radiation. If PSP storage plates are stored for extended periods of time, the possibility of artifacts must be considered. These artifacts typically appear as randomly placed small black spots. *If an IP and its PSP storage plate has been stored, unused, for an extended period of time (i.e., for 48 hours), the PSP storage plate should be erased prior to use.*

The mechanical consistency and accuracy of the laser optics and transport systems of the CR reader is extremely important for image quality—inconsistent scanning motion can result in a wavy, or otherwise distorted, image. This is sometimes referred to as "laser jitter" and should be evaluated monthly as part of the CR QA monitoring.

6. Dynamic Range and Exposure Latitude. In CR, there is a *linear* relationship between the exposure given the PSP storage plate and its resulting luminescence (see Fig. 11–71) as it is scanned by the laser. One of the biggest advantages of CR is the *dynamic range* it offers.
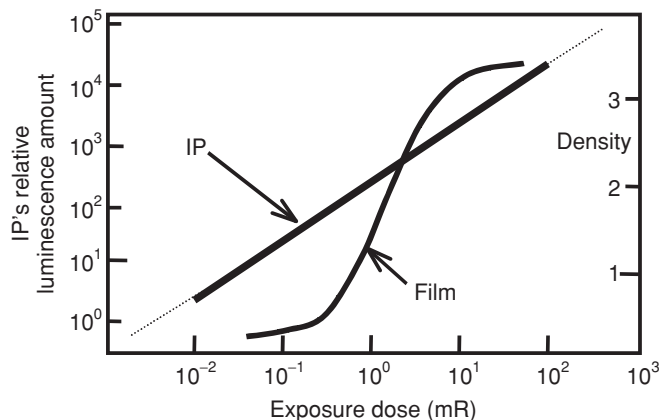
Figure 11–71. It compares the sensitometric curve of a typical film emulsion with that of a PSP/IP. The *wide dynamic range* (scale of contrast) of the PSP/IP enables the correct detection of slight differences in x-ray absorption characteristics among various tissue densities. (Courtesy of FUJIFILM Medical Systems USA, Inc.)

Earlier in this chapter we studied the sensitometric curve of typical film emulsion and saw that there is a certain "range of correct exposure," limited by the toe and shoulder of the curve, that determines the emulsion's *latitude* characteristics. The term *latitude* is used in film/screen (F/S) imaging; the term *dynamic range* is used in CR. CR's wide dynamic range permits visualization of anatomic details having only slightly different absorption differentials, and also permits the use of the exposure data recognizer (EDR), which automatically adjusts image density and contrast to meet diagnostic requirements.

This affords much greater *exposure latitude*; technical inaccuracies can be effectively eliminated. Overexposure of up to 500% and underexposure of up to 80% are reported as recoverable, thus eliminating most retakes (see Fig. 11–72). *This surely affords increased efficiency; however, this does not mean that images can be exposed arbitrarily*. The radiographer must keep dose reduction in mind. The same exposure factors as screen/film systems, or less, are generally recommended for CR.

Whereas CR uses cassettes, DR does not. CR's use of cassettes offers an advantage in terms of *flexibility*. The use of cassettes allows for continued use of existing equipment, and CR is convenient for mobile radiographic applications, for tabletop/nongrid work, and for crosstable/horizontal beam work.

D. Indirect and Direct Digital Radiography

1. CR/DR Differences. While CR utilizes traditional x-ray tables and cassette-like devices (IPs) to enclose and protect the flexible PSP screen, *digital radiography* requires the use of somewhat different equipment. DR does not use cassettes/IPs or a traditional x-ray table; it is a *direct-capture*, or *indirect-capture*, system of x-ray imaging (see Fig. 11–73). DR eliminates cassettes and their handling, DR affords the advantage of immediate display of the image (compared to CR's slightly delayed image display), and DR exposures can be lower because of the detector's higher *DQE* (i.e., ability to perceive and convert x-ray photons). DR, like CR, also offers the advantage of image preview and postprocessing.

2. Indirect-Capture DR. One type of *indirect*-capture flat-panel detector uses *cesium iodide* or *gadolinium oxysulfide* as the *scintillator,* i.e., that which captures x-ray photons and emits light. That light is then transferred via a photodetector coupling agent—a *charge coupled device* (CCD) or *thin film transistor* (TFT).

a. CCD Method. Each CCD chip within the CCD array flat-panel detector has many pixel electronics on its photosensitive silicon surface. As CsI or GdOS *scintillation* falls upon each pixel, electrons are liberated and built up within the pixel—the greater the light intensity, the greater the number of electrons. The image is still analog at this point. As the electronic charge within each pixel is read out, an electronic signal is produced and transmitted to the *analog-to-digital converter* (ADC) for digitization. This method provides spatial resolution of up to 5 lp/mm.

Terminology Comparison

S/F Imaging	CR/DR Imaging
Latitude	Dynamic range
Contrast	Contrast resolution
Density	Brightness
Recorded detail/ sharpness	SNR
Resolution	Spatial frequency

CR Spatial Frequency/Resolution Increases As

- PSP crystal size decreases
- Laser beam size decreases
- Monitor matrix size increases

A **B** **C**

D **E** **F**
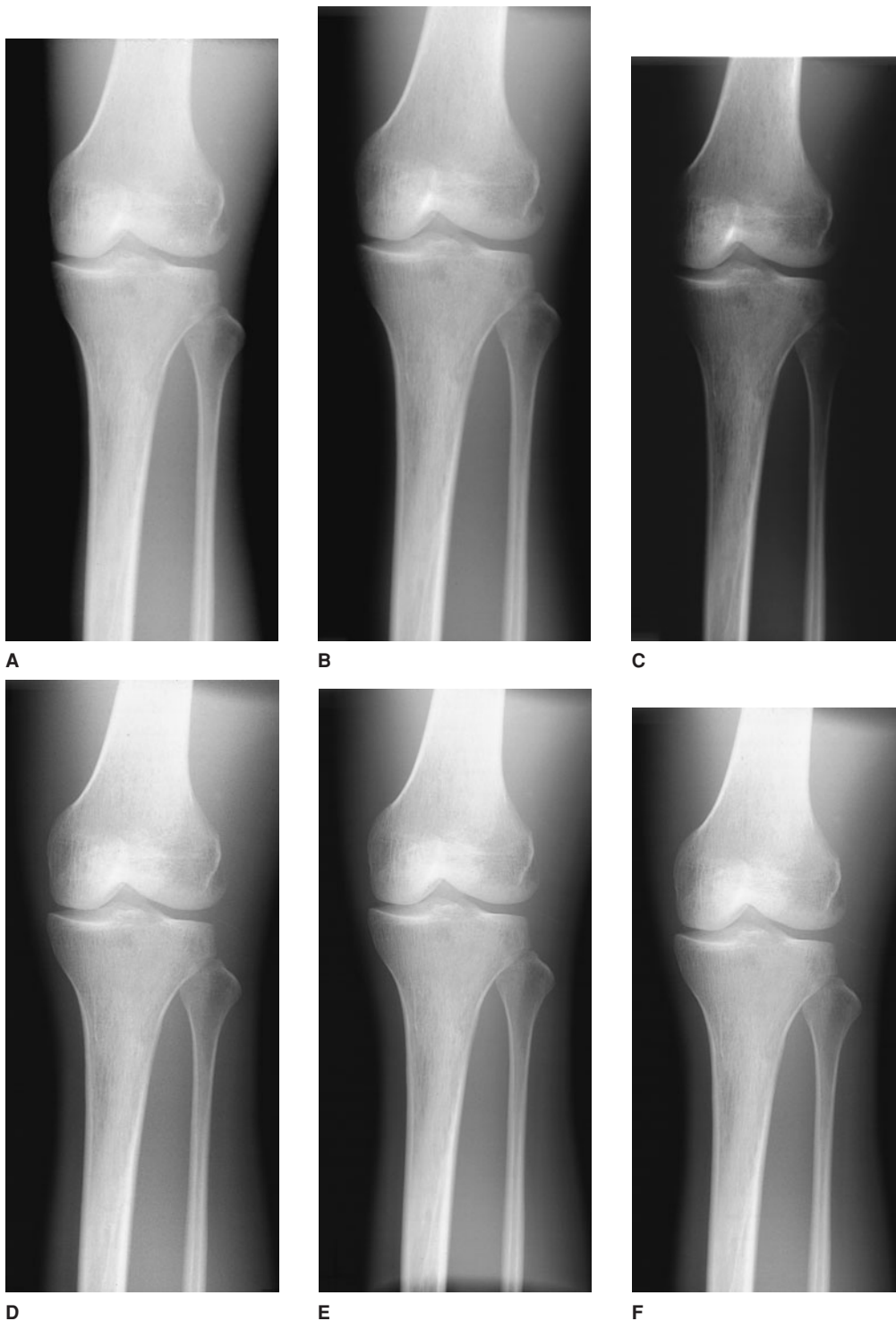
Figure 11–72. CR affords much *greater exposure latitude*; technical inaccuracies can be effectively eliminated, but *exposure* dose must always be considered. In the images seen above, *A*, *B*, and *C* were made with conventional screen/film using at 65 kV and at 3.2, 6.3, and 12.5 mAs, respectively. Density changes are easily identified. Images *D*, *E*, and *F* were made with CR again using 3.2, 6.3, and 12.5 mAs, respectively. The images are identical—demonstrating how *technical inaccuracies can be effectively eliminated* with CR. Although the radiographic/image densities are identical, the *exposure dose* is not! An approximation of the exposure dose can be determined from the *exposure indicator*: an "S" (sensitivity) number, "EI" (exposure index), or other "relative exposure index," depending on the manufacturer use.

Figure 11–73. Direct-capture (cassetteless) digital radiographic unit. (Courtesy of FUJIFILM Medical Systems USA, Inc.)

b. TFT Method. A thin-film transistor is composed of glass with *amorphous selenium* (i.e., selenium in fluid form rather than crystalline) on both sides. CsI or GdOS scintillation light must be able to pass through the detector material to reach the ADC. As silicon is opaque, glass is the most commonly used (though delicate) interface because it is highly transparent and compatible with the system. Since glass is not a semiconductor like silicon, a thin film of amorphous selenium (a-Se) is deposited on top and bottom—the transistors are made using this thin layer; hence, the name "*thin-film transistor.*" The electrical signal is transmitted to the ADC.

In both indirect-capture flat-panel detector methods *scintillation* light is captured, read by a *photodetector* (CCD or TFT), changed to an electronic signal, and transmitted to the ADC for digitization.

3. Direct-Capture DR.

In *direct*-capture flat-panel detector systems, x-ray energy is converted to an electrical signal in a single layer of material such as the semiconductor a-Se. Electric charges are applied to both surfaces of the a-Se, electron-hole pairs are created, and charges are read by TFT arrays located on the surfaces. The electrical signal is transferred directly to the ADC. The number of TFTs is equal to the number of image pixels.

Thus, the direct-capture system *eliminates the scintillator step* required in indirect DR. Since selenium has a relatively low Z number (compared to gadolinium [$Z = 64$] or cesium [$Z = 55$]), a-Se detectors are made thicker to improve detection, thus compensating for the low x-ray absorption of selenium. There is no diffusion of electrons (as there is light diffusion in intensifying screens), so spatial resolution is not affected in this manner.

E. EXPOSURE INDICATION

CR offers *wide latitude* and *automatic optimization of the radiologic image.* When AEC is not used, CR can compensate for approximately 80% underexposure and 500% overexposure—this is termed exposure data recognition (EDR). This can be an important advantage particularly in trauma and mobile radiography. The radiographer must still be vigilant in patient dose considerations—overexposure, though correctable via EDR, results in *increased patient dose*; underexposure results in decreased image quality because of increased image *noise*.

CR systems provide some type of *exposure indicator*, its name varies according to manufacturer: an *S* (sensitivity) number, *EI* (exposure index), *REX* (reached exposure index), or other identifying exposure index depending on the manufacturer used. The manufacturer usually provides a chart identifying the acceptable *range* the exposure indicator numbers should be within for various examination types. For example, a high *S* number is often related to *under* exposure, while a high *EI* number is related to *over* exposure.

F. INFORMATION SYSTEMS AND NETWORK INTERFACES

Hospital information system (HIS) is a computer system that serves to track patient information: admission and discharge, diagnostic and treatment services, pharmaceutical and equipment information, billing information, and employee information. Functions of a *radiology information system* (RIS) include procedure ordering and scheduling, patient database maintenance, reporting and transcription, and billing. RIS can be a separate system, part of HIS, or part of PACS. Neither HIS nor RIS stores images; that is the function of PACS.

An organization of computers *networked* together and capable of *storing* (archiving) and *transmitting* (communication) medical images is called a *PACS*. The PACS functions to obtain the images (*image acquisition*), to present the images for analysis (*image display and interpretation*), to store the images conveniently for future viewing (*image archival and retrieval*), and to provide a means of image transmission (*image communication*). This network can be limited to a single hospital or it can include distant sites. A PACS network is usually coupled with the *RIS* containing patient information regarding scheduling and imaging information and the *HIS* containing all other patient demographics. Patient confidentiality and unauthorized access, especially when networked with the Internet for image transmission, are serious concerns. Encryption software is used to prevent unlawful access to restricted information.

The recognized standard for format, services, and communication protocol affecting the transfer, storage, and display of diagnostic images in PACS and teleradiology systems has been established as *Digital Imaging and Communications in Medicine* (DICOM). Equipment from various vendors that conforms to the DICOM standard can be used together effectively to build PACS and teleradiology systems.

PACS Features

- Image acquisition
- Image display and interpretation
- Image archival and retrieval
- Image communication

■ *SUMMARY*

- **There are two types of technique charts: fixed kV type and variable kV type.**
- **The fixed kV type chart uses an optimal kV for each anatomic part; its advantage is consistency of image contrast.**
- **The variable kV type chart increases/decreases the kV by 2 for each 1-cm increase/decrease in body thickness; thus, accurate part measurement is necessary.**
- **AECs will compensate for tissue thickness and density differences (including those caused by body position and respiration), pathologic changes, and beam restriction.**

- The use of AECs requires accurate positioning and correct photocell selection.
- Electronic radiography includes computed radiography, indirect digital radiography, and direct digital radiography.
- MTF is used to describe spatial resolution; SNR is used to describe contrast resolution.
- CR/DR's ability to provide better contrast resolution than screen/film is more valuable than the somewhat less spatial resolution it provides.
- As matrix size increases, for a fixed FOV, pixel size is smaller and better spatial resolution results.
- As FOV increases, for a fixed matrix size, the size of each pixel increases and spatial resolution decreases.
- CR and indirect DR convert x-rays to light then to an electric signal; x-ray image on the monitor is somewhat delayed.
- Direct DR uses no cassette, no scintillation/fluorescent screen—x-rays interact with a-Se creating a charge that is interpreted by the TFT; x-ray image on the monitor is immediate.
- The electric signal from CR/DR is sent to the ADC; from there to the computer monitor.
- In CR, photostimulable phosphor ($BaFX:Eu^{2+}$) screens emit retained x-ray energy as visible light when stimulated by a laser beam.
- CR image "fading" can occur if there is delay in reading/processing the IP/PSP.
- If an IP and its PSP storage plate has been stored, unused, for an extended period of time, the PSP storage plate should be *erased* prior to use.
- CR offers wide latitude and automatic optimization of the radiologic image.
- CR/DR can compensate for approximately 80% underexposure and 500% overexposure.
- PACS is a system of computers networked together and capable of *storing* and *transmitting* medical images.

Chapter Review Questions

⭐ ***Congratulations!*** *You have completed your review of a large portion of this chapter. You may go on to the "Registry-type" multiple-choice questions that follow. For greatest success, be sure also to complete the short-answer questions found at the end of this chapter.*

1. The use of optimum kV for small, medium, and large body parts is the premise of:
   (A) fixed kV, variable mAs technique chart
   (B) variable kV, fixed mAs technique chart
   (C) fixed mAs, variable body part technique
   (D) fixed mAs, variable SID technique

2. The function(s) of automatic beam limitation devices include:
   1. increasing contrast resolution
   2. absorption of scattered radiation
   3. changing the quality of the x-ray beam
   (A) 1 only
   (B) 2 only
   (C) 1 and 2 only
   (D) 1, 2, and 3

3. What transforms the violet light emitted by the PSP into the image seen on the CRT?
   (A) the photostimulable phosphor
   (B) the scanner/reader
   (C) the ADC
   (D) the helium–neon laser

4. The sensitometric curve is used to illustrate the relationship between the:
   (A) source-to-image-receptor distance and the resulting radiographic/image density
   (B) exposure reaching the phosphors and the resulting fluorescence
   (C) exposure given to the film and the resulting radiographic/image density
   (D) kV used and the resulting radiographic/image density

5. What portion of an IP records the CR image?
   (A) the photostimulable phosphor
   (B) the scanner/reader
   (C) the film emulsion
   (D) the helium–neon laser

6. Image fading in CR can occur if:
   1. unexposed PSPs are unused for extended periods
   2. exposed PSPs are not processed soon after exposure
   3. exposed PSPs are exposed to high temperatures
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

7. If a part measuring 15 cm was imaged using 12 mAs and 72 kV, a similar part measuring 17 cm could be correctly exposed using:
   (A) 6 mAs 72 kV
   (B) 24 mAs 72 kV
   (C) 12 mAs 76 kV
   (D) 12 mAs 68 kV

8. Which of the following can be used to determine the sensitivity of a particular film emulsion?
   (A) sensitometric curve
   (B) dose–response curve
   (C) reciprocity law
   (D) inverse square law

9. The x-ray detection system that does not have a scintillation component is:
   (A) indirect DR using CCD
   (B) indirect DR using TFT
   (C) direct DR
   (D) CR

10. Which of the following pathologic conditions would require an increase in exposure factors?
    (A) pneumoperitoneum
    (B) obstructed bowel
    (C) renal colic
    (D) ascites

Answers and Explanations

1. (A) The optimum kV (or fixed kV) technique separates patients into small, medium, and large categories, and assigns an optimum (or best) kV for that particular body part. Patient thickness (measurement in centimeters) determines mAs. This method of establishing exposure factors results in less variation in the scale of contrast than the variable kV method of technique selection.

2. (A) Beam restrictors function to limit size of the irradiated field. In doing so, they limit the volume of tissue irradiated (thereby decreasing the percentage of scattered radiation generated in the part) and help reduce patient dose. Because less scattered radiation is produced, less fog affects the x-ray image thus improving contrast resolution. Beam restrictors do not affect the quality (energy) of the x-ray beam, that is, the function of kV and filtration. Beam restrictors do not absorb scattered radiation, that is, a function of grids.

3. (C) The exposed IR is placed into the CR reader, where the PSP screen is automatically removed. The latent image appears as the PSP is scanned by a narrow high-intensity *helium–neon laser, or solid-state laser,* to obtain the pixel data. As the PSP is scanned in the CR reader, it releases a violet light—a process referred to as *photostimulated luminescence.*

   The luminescent light is converted to electrical energy representing the *analog* image. The electrical energy is sent to an *analog-to-digital converter* (*ADC*) where it is digitized and becomes the *digital* image that is eventually displayed (after a short delay) on a high-resolution monitor and/or printed out by a laser printer. The digitized images can also be manipulated in postprocessing, electronically transmitted, and stored/archived.

4. (C) The sensitometric (or Hurter and Driffield [H&D]) curve is used to illustrate the relationship between the exposure given to the film and the resulting density. The relationship between the source-to-image-receptor distance and resulting density is expressed in the inverse square law of radiation. The effect of kV on contrast can be illustrated using a penetrometer (aluminum step-wedge).

5. (A) Inside the IP is the *photostimulable phosphor* (*PSP*) image storage plate. This PSP with its layer of europium-activated barium fluorohalide serves as the *image receptor* as it is exposed in the traditional manner and receives the latent image. The PSP can *store* the latent image for several hours; after approximately 8 hours, noticeable image fading will occur. Once the

CR cassette is placed into the CR reader, the PSP screen is automatically removed. The latent image on the PSP is changed to a manifest image as it is scanned by a narrow high-intensity *helium–neon, or solid state,* (monochromatic) *laser* to obtain the pixel data. As the PSP is scanned in the reader, it releases a (polychromatic) violet light—a process referred to as *photo-* (or light-) *stimulated luminescence.*

6. (C) Image "*fading*" will occur if there is delay in reading the IP/PSP. This is because after a time, trapped photoelectrons are released from the "color center" and are therefore unable to participate in PSL. PSL intensity *decreases* in the interval between x-ray exposure and image reading/processing. If the exposed PSL is not delivered to the reader/processor for 8 hours, PSL decreases by approximately 25%. Fading also increases as environmental temperature increases. Since PSPs are very sensitive to exposure/fogging, when unexposed IPs are unused for extended periods, they should be erased before use.

7. (C) Using the variable kV method, a particular mAs is assigned to each body part. As part thickness increases, the kV (penetration) is also increased. The body part being imaged must be carefully measured and *for each centimeter increase in thickness, 2 kV is added* to the exposure.

8. (A) The sensitometric curve is used to show the relationship between the exposure given the film and the resulting film density. It can therefore be used to evaluate a particular film emulsion's response (speed, sensitivity) by determining how long it takes to record a particular density. A dose–response curve is used in radiation protection and illustrates the quantity of dose required to produce a particular effect. The reciprocity law states that a particular mAs, regardless of the combination of mA and time, should produce the same degree of blackening. The inverse square law illustrates the relationship between distance and radiation intensity.

9. (C) In both *indirect*-capture flat-panel detector methods scintillation light is captured, read by a photodetector (CCD or TFT), changed to an electronic signal, and transmitted to the ADC for digitization. In *direct*-capture flat-panel detector systems, x-ray energy is converted to an electrical signal in a single layer of material such as the semiconductor a-Se. Electric charges are applied to both surfaces of the a-Se, electron-hole pairs are created, and charges are read by TFT arrays located on the surfaces. The electrical signal is transferred to the ADC. The number of TFTs is equal to the number of image pixels. Thus, the direct-capture system eliminates the scintillator step required in indirect DR.

10. (D) Because pneumoperitoneum is an abnormal accumulation of air or gas in the peritoneal cavity, it would require a decrease in exposure factors. Obstructed bowel usually involves distended, gas-filled bowel loops, again requiring a decrease in exposure factors. With ascites, there is an abnormal accumulation of fluid in the abdominal cavity, necessitating an increase in exposure factors. Renal colic is the pain associated with the passage of renal calculi; usually no change from the normal exposure factors is required.

Chapter Exercises

⭐ ***Congratulations!*** *You have completed the entire chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You can refer back to the indicated pages to check your answers and/or review the subject matter.*

1. What are some variables that contribute to difficulty in selection of exposure factors? What equipment features can help? What precautions must one observe when using these features? *(p. 301).*

2. Define recorded detail; list other terms that can be used to refer to recorded detail *(pp. 302, 303).*

3. To what does the term *resolution* refer; how is it measured and expressed *(p. 302)?*

4. What does one "line pair" consist of? *(p. 302).*

5. Differentiate between *detail* and *distortion (p. 302).*

6. How are the terms *magnification,* *elongation,* and *foreshortening* related to *distortion*? *(p. 302).*

7. Discuss the difference between detail and visibility of detail/contrast resolution. *(p. 303).*

8. What are the geometric factors affecting recorded detail *(p. 305)?*

9. What is the relationship among OID, recorded detail, and magnification; among SID, recorded detail, and magnification *(p. 305)?*

10. What are the two types of shape distortion? How can shape distortion be avoided *(p. 302)?*

11. How is object unsharpness, with respect to its three-dimensional shape and OID, an inherent part of every radiographic image *(pp. 306–307)?*

12. Distinguish between actual and effective/projected/apparent focal spot size; what is the line focus principle *(pp. 308–309)?*

13. How is actual focal spot size related to recorded detail? How does the size of the projected focus vary along the length of the image receptor *(p. 308)?*

14. How are focal spot size and anode angle related to x-ray tube heat-loading capacity *(p. 310)?*

15. Discuss the difference between voluntary and involuntary motion, and describe the most effective means of avoiding each *(pp. 312–313)?*

16. Why is motion intentionally introduced in some radiographic examinations? Give some examples *(p. 313).*

17. What is the relationship between the fluorescent light from intensifying screens and the total exposure received by the film emulsion *(p. 316)?*

18. What is the purpose of a thicker *rear* intensifying screen *(p. 316)?*

19. Discuss how phosphor type and size, active or phosphor layer thickness, and reflective backing affect the speed on intensifying screens *(p. 317).*

20. What is lag or afterglow; how can it affect the radiographic image *(p. 317)?*

21. What are the three most commonly used rare earth phosphors *(p. 317)?*

22. What is the importance of spectral matching *(p. 317)?*

23. How is intensifying screen speed related to recorded detail? With what type of intensifying screens is quantum mottle usually associated *(pp. 318–319)?*

24. What is the importance of screen and film contact? How is its accuracy tested *(p. 318)?*

25. Define radiographic density; describe optical density (OD); what is the term used in digital imaging to describe density *(p. 325)?*

26. Describe how radiographic density and mAs are related to the intensity and exposure rate of the x-ray beam *(pp. 326–327).*

27. What is the reciprocity law, and how is it related to radiographic density? Give examples *(p. 327).*

28. What change in mAs is required to make a perceptible change in radiographic density *(p. 327)?*

29. How is SID related to x-ray beam intensity and technical factors (specifically mAs)? What law expresses this relationship *(p. 329)?*

30. How is kV related to x-ray beam intensity and radiographic density *(p. 331)?*

31. What is the 15% rule? Give examples *(p. 331).*

32. What is the relationship among radiographic density, mAs, and intensifying screen speed? Give examples *(p. 0).*

33. What three factors determine the quantity of scattered radiation produced? How can each be modified to limit the production of scattered radiation *(pp. 333–335)?*

34. How do grids affect the amount of scattered radiation reaching the image recorder? How do they impact radiographic density *(pp. 333–335)?*

35. What is a stationary grid? Give some examples of its use. What are its disadvantages *(p. 335)?*

36. What is a moving grid? How does its construction generally differ from the stationary grid? What is its advantage over a stationary grid *(p. 335)?*

37. Define convergence line, focusing distance, focal range, crossed grid *(p. 335).*

38. Define grid cutoff, lateral decentering, focus–grid distance decentering *(p. 335–336).*

39. Describe grid ratio, number of lead strips per inch, lead content; describe their relationship to *cleanup* and radiographic density *(p. 336).*

40. Of what material(s) is grid interspace material usually made? How is each related to efficiency, patient dose, sturdiness *(p. 337)?*

41. Describe contrast improvement factor and selectivity *(p. 338).*

42. Describe how the grid-conversion factor can be used to determine the required mAs adjustment *(p. 338–339).*

43. How can an air gap influence radiographic density *(p. 339)?*

44. What is inherent filtration? Of what does it consist *(p. 340)?*

45. What is added filtration? Of what does it consist *(p. 340)?*

46. What is the primary purpose of total filtration? What effect does it have on radiographic density *(p. 340)?*

47. Describe why and how compensating filters are used, how they affect radiographic density; give examples of common usage *(pp. 340–342).*

48. Describe how body position, condition, and pathology affect radiographic density *(p. 343).*

49. Differentiate between and give examples of destructive and additive pathologic conditions *(p. 343).*

50. How are different types of x-ray generators related to changes in radiographic density? How is mAs (or kV) changed when changing from single-phase equipment to 3ø 6P or 3ø 12P equipment? Which technical factor is preferable to change *(p. 344)?*

51. How can beam restriction affect radiographic density *(p. 346)?*

52. How can the anode heel effect impact radiographic density? Under what conditions is the heel effect most noticeable *(p. 346)?*

53. How can automatic processing affect radiographic density *(pp. 346–349)?*

54. What is the function of radiographic contrast? What are its two components? What is *contrast resolution (pp. 353–354)?*

55. Describe the difference between long-scale and short-scale contrast. What is the single most important technical factor regulating radiographic contrast *(pp. 354–356)?*

56. What is subject contrast and how is it related to beam quality *(pp. 353–354)?*

57. Describe the impact of scattered radiation on radiographic contrast/contrast resolution; what is the most important way to limit the production of scattered radiation *(p. 359)?*

58. What kinds of pathologic conditions impact radiographic contrast *(p. 359)?*

59. How does the use of grids affect radiographic contrast/contrast resolution *(p. 361)?*

60. Of what material(s) are film base and film emulsion made *(p. 368)?*

61. To what three sources is base-plus-fog attributable? What is the maximum permissible base-plus-fog density *(p. 368)?*

62. Explain what is meant by film latitude; give examples of uses for high-contrast film and low-contrast (latitude) film *(p. 368).*

63. What do we call the study of film emulsion's response to exposure? How can this response be illustrated *(p. 368)?*

64. Draw a simple sensitometric curve and label its toe, straight-line portion, shoulder, D_{max}, and solarization point *(pp. 369–370).*

65. Explain what is meant by exposure latitude; what technical factor regulates exposure latitude *(pp. 370–371)?*

66. Describe the two types of AECs. Include in your description *(p. 374):*
    (A) the location of each, relative to the tabletop and cassette
    (B) operation of each and how exposure is terminated

67. Explain the importance of the backup timer used in AEC *(p. 374).*

68. Explain the importance of proper AEC photocell selection; describe typical errors in photocell selection and the subsequent radiographic results *(p. 0).*

69. Explain how to correct a radiographic image overexposed as a result of requiring an exposure shorter than the minimum reaction time *(pp. 374–375).*

70. Why are fixed kV technique charts preferred over variable kV technique charts *(p. 376)?*

71. Discuss why exposures made using an AEC do not require measurement of the part being examined, and why positioning accuracy is essential to proper function of the AEC *(p. 376).*

72. What are the types of electronic imaging? How do they differ from one another? What traditional x-ray image quality terms correlate to the terms *spatial resolution* and *contrast resolution (p. 377)?*

73. Describe the difference between a traditional x-ray cassette and the IP used in CR *(pp. 379–380).*

74. How does the sensitometric curve of CR differ from the sensitometric curve of traditional screen/film radiography *(p. 383, Fig. 11–)?*

75. How does the PSP record the x-ray image? *(p. 381).*

76. How is the exposed PSP "read" *(p. 382)?*

77. What kind of laser is used to stimulate the PSP? Of what importance is its motion? *(p. 383).*

78. What is the value of postprocessing? *(p. 383).*

79. What are some advantages of CR over traditional screen/film radiography? *(pp. 383–384).*

80. What is image *fading*? How can it be avoided? *(p. 381).*

81. Why should PSPs be erased prior to use if they have been unused for an extended period? *(pp. 382–383).*

82. Cite differences between indirect and direct digital radiography. *(p. 384).*

83. What are the two indirect digital methods; describe how each works**?** *(p. 384).*

84. What step of indirect digital radiography is eliminated in direct digital radiography? *(p. 386).*

85. Discuss automatic optimization of the x-ray image offered by electronic imaging. How much over/underexposure can be corrected? In what way can the radiographer be made aware of over/underexposure? *(p. 386).*

86. What is PACS? Identify its functions and component parts *(p. 387).*

Image Processing and Quality Assurance

<div align="right">12</div>

I. FILM STORAGE CONSIDERATIONS

A. STORAGE CONDITIONS

The conditions under which x-ray film is stored can have considerable impact on the final x-ray image. The most common result of improper film storage is *fog*, which has a severely degrading effect on image quality.

Films should be stored at a temperature no greater than 70°F. Excessive heat can accelerate the deterioration process and cause film fog. Atmospheric humidity should be kept between 40% and 60%. Excessively low humidity is conducive to the production of static electricity discharge (Fig. 12–1). High humidity levels encourage the production of fog. An unopened (i.e., hermetically sealed) bag of film protects the film from humidity but not excessive temperatures.

Boxes of film must also be stored away from chemical fumes that can fog film emulsion. Film can be fogged if stored too close to radiographic rooms or radionuclides.

Each box of x-ray film is identified with an expiration date before which the film must be used to avoid age fog. When replenishing film supply, film boxes should be rotated so that the oldest film is used first. (Use the *fifo* system: *fi*rst *in*, *fi*rst *o*ut.)

Film boxes should be stored in the upright position. If film boxes are stacked on one another, the sensitive emulsion (especially in the central portion) can be affected by pressure from the boxes above. Pressure marks (i.e., areas of fog) are produced and result in loss of contrast in that area of the x-ray image. Larger size film boxes are particularly susceptible to this problem.

The *film bin* is a lighttight storage area where opened boxes of film are available for reloading empty cassettes. If a single door separates the darkroom from exterior white light, it is wise to have an automatic interlock system in place that prevents opening of the darkroom door while the film bin is open.

Figure 12–1. Plus-density artifact resulting from static electric discharge. (Courtesy of Stamford Hospital, Department of Radiology.)

B. SAFELIGHT ILLUMINATION

Adequate and safe darkroom lighting is an essential part of ensuring quality x-ray images. A source of white light is required for cleaning and routine maintenance. The white light often has a safety device to help prevent accidental film exposure. *Safelight* illumination must be appropriate for the type film used and bright enough to provide adequate illumination and still not expose the sensitive emulsions (exposed film emulsion is approximately eight times more sensitive than unexposed emulsion).

A frequently used *safelight* is the Kodak Wratten Series 6B, a brownish *safelight filter*, with a 7.5- to 15-W frosted light bulb placed 4 feet above the work surface; it is used with blue sensitive film. Another available safelight, which is somewhat brighter, is the Kodak GBX all-purpose filter, which provides a more reddish illumination. This type of filter is often placed in the darkroom so that its light is directed upward toward the ceiling and reflected back down, thus reducing the chance of safelight fog. Neither type can be used with laser film.

Routine darkroom maintenance includes regular cleaning of all surfaces and walls and checks for white light leaks. When checking for light leaks, all darkroom lights must be turned off, adequate time given for eyes to adjust to the darkness, and then a careful visual inspection made for white light leaks.

■ SUMMARY

- Film should be stored in a cool and dry environment, under 70°F and between 40% and 60% humidity.
- Excessive temperatures cause film fog.
- Excessively low humidity encourages buildup of static electricity.
- Film should be stored away from radiation and chemicals.

- **The film box expiration date should be noted, and oldest film used first.**
- **Film boxes should be stored upright to avoid production of pressure marks.**
- **Kodak Wratten Series 6B and GBX darkroom filters are the most frequently used.**
- **Safelights should be placed 4 feet from the work surface with 7.5- to 15-W light bulbs.**

II. CASSETTES

A. ROUTINE CARE

Routine documented care of all imaging system components is part of an efficient *quality assurance* program.

Cassettes require care and maintenance inside and out. They should be stored *upright*, according to size (i.e., 14″ × 17″, 10″ × 12″, etc.) and speed (i.e., 100, 400). Stacking cassettes on top of each other or jammed in a passbox renders the cassettes more susceptible to damage. Cassettes should be *inspected visually* for damage and cleanliness. The inside of cassettes should be *cleaned regularly* to keep them lint and dust-free; screens should be cleaned with special antistatic cleaner appropriate for the type of screen used; incorrect cleaner can affect the speed of screens.

Screens must also be *tested periodically* for screen–film contact with a *wire-mesh test*. The cassette to be tested is placed on the x-ray table, the wire-mesh device on *top* of the cassette, and an exposure made of approximately 5 mAs (milliampere-seconds) and 40 kV (kilovolts). The processed film should be viewed at a distance of at least 6 feet. Any *blurry* areas are indicative of poor screen–film contact and representative of diminished image detail. The areas of poor contact will also exhibit an increase in density and loss of contrast.

B. ARTIFACTS

Radiographically speaking, an *artifact* is a fault, blemish, or aberration in an x-ray image. It can be the result of improper handling, automatic processing, or use of defective radiographic accessories.

Cassettes, screens, and film must be handled carefully to avoid leaving fingerprints or producing other film artifacts. Hands should be kept clean and dry, free from residue-leaving creams and powder from gloves. Film should be handled carefully by the corners when loading and unloading cassettes. The technologist should not *slide* film into or out of the cassette, as the friction can cause static electricity buildup. Cassettes should be numbered or otherwise identified so that artifact causing problems can be located and removed (Fig. 12–2).
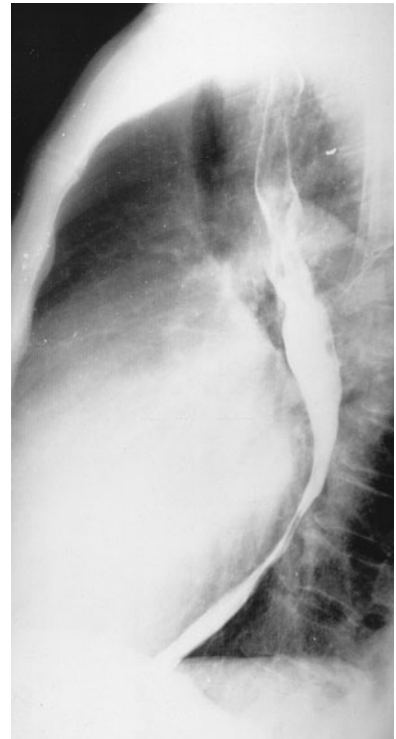
Figure 12–2. Dirty and dusty screens. Small particles of dust, or other foreign objects, on intensifying screens keep the fluorescent light from reaching the film emulsion; hence, a clear (unexposed) area corresponds to each foreign particle. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

■ *SUMMARY*

- **Cassettes should be stored upright according to size and speed.**

- Cassettes should be tested periodically for adequate screen–film contact.
- Intensifying screens must be cleaned periodically with anti-static screen cleaner.
- Inadequate cleaning can result in white pinhole-type film artifacts.
- Rough, improper handling or storage of cassettes can lead to damage resulting in poor screen–film contact.
- Film must be handled carefully and properly to avoid artifacts such as static electricity, scratches, fog, or crescent marks.

III. IMAGE IDENTIFICATION

A. ESSENTIAL INFORMATION

Every image *must* (for *medicolegal* reasons) include certain specific patient information:

- Patient's name or identification number
- The side marker, right or left
- The examination date
- Name of the institution

Other pertinent information *may* be included:

- Patient's age or date of birth
- Attending physician
- Time of day

Radiographer ID is often considered as a modern medicolegal requirement. When multiple images are taken of a patient on the same day, it is important that the time the images were taken be included on the image. This permits the physician to chronologically follow the patient's progress.

B. TYPES OF SYSTEMS

There are a number of *film identification* systems. Cassettes are purchased with a *lead blocker* in a specified corner to shield the underlying film from x-ray exposure. This unexposed corner of the film is then "flashed" with essential patient information. Some identification devices are used only in the darkroom because the film is removed from the cassette before the information is flashed onto it. Another type of image identification device allows recording of patient information in normal lighted conditions with the film or PSP/IP inside the specially designed cassette. In CR cassettes, one corner of the rear panel usually has a *memory chip* for patient information.

■ SUMMARY

- Medicolegal implications require that every image include the patient's name or identification number, left- or right-side marker, examination date, and name of institution.
- When multiple images are taken of a patient the same day, the time of day should be indicated on each image.

- ■ **Some image identification systems can be used only in a darkroom.**
- ■ **Other film/CR identification systems use special cassettes and are used in daylight conditions.**

IV. FILM PROCESSING

Film emulsion consists of silver bromide (halide) crystals suspended in gelatin. *Sensitization specks* are added to increase the sensitivity of the silver salts. *Positive silver ions* form the inner portion of the emulsion, whereas the *negative bromine ions* form the outer layer. At the time of exposure, the outer, negative bromine ions are energized, and their valence electrons ejected and absorbed by the (now negatively charged) sensitivity speck. The inner, positive silver ions migrate to the negative charges and become metallic silver. Thus, the *latent* (exposed but invisible) *image* is formed. This is referred to as the Gurney–Mott theory of latent image formation. The development process transforms the latent image to a *manifest* (visible) black metallic silver *image.*

Automatic film processing is carried out by a machine that *transports* the x-ray film through the necessary chemical solutions, at the same time providing *agitation, temperature regulation*, and *chemical replenishment.* Within the processor are the *developer, fixer*, and wash tanks, followed by the dryer.

Rapid processing is accomplished by the use of increased solution temperatures, which requires that a *hardener* be added to the developer to control excessive emulsion swelling.

Each of the processor systems accomplishes specific functions; a basic understanding of these systems is required so that the processor can be used correctly and efficiently. A properly maintained and monitored processor will ensure consistent radiographs that will retain their quality images over a long period of time (good *archival quality*).

A. CHEMISTRY OVERVIEW

The *developer* functions to convert the latent (invisible) image into the manifest (visible) silver image by *reducing the exposed silver bromide crystals to black metallic silver.* Important factors affecting the development process are *time* (length of development), *temperature* (of the developer solution), and solution *activity* (strength, concentration).

The developer solution has an alkaline nature for optimal function of the reducing agents. Sodium or potassium *carbonate* provides the necessary alkalinity and serves as an *activator* (or accelerator) by swelling the gelatin emulsion so that the reducing agents are better able to penetrate the emulsion and reach the exposed silver bromide crystals.

The *reducing agents* are *hydroquinone*, which works slowly to build up blacks in the film areas of greater exposure, and *phenidone*, which quickly produces the gray tones in areas of lesser exposure. With respect to sensitometry, hydroquinone controls the shoulder (D_{max}) of the characteristic curve, and phenidone controls the toe (D_{min}) area.

The developer solution, particularly the hydroquinone, is especially sensitive to oxygen. If the developer oxidizes, it becomes weaker

and less effective. The *preservative, sodium sulfite* or *cycon*, is added to the developer to prevent its rapid oxidation. The *solvent* for the concentrated chemicals is water, used to dilute the concentrate to the proper strength.

Rapid processing is achieved through the use of high temperatures that accelerate the development process; however, high temperatures can cause excessive emulsion swelling. Because excessive swelling can result in roller transportation problems, a hardener, traditionally *glutaraldehyde*, is added to the developer to control the amount of emulsion swelling.

A *restrainer*, or antifog agent, is added to the developer to limit its activity to only the exposed silver crystals. The typical restrainer is *potassium bromide*. Without the restrainer, the developing agents would attack the *unexposed* crystals, creating *chemical fog*. Potassium bromide is frequently referred to as "starter solution" because it is added only to fresh, new developer. As films are developed, bromine ions are released from the emulsion into solution; thus, potassium bromide is not found in replenisher solution.

The function of the *fixer* (*hypo*) is to clear the film of the unexposed, undeveloped silver bromide crystals. This process serves to protect the film from further exposure. The *fixing* or *clearing agent* is *ammonium thiosulfate.*

The fixer is an acidic solution that functions to neutralize any residual developer carried over and provide the required acid medium for the hardener. *Acetic acid* provides the required acidic medium.

The fixer contains a hardener whose function is to shrink and reharden the gelatin emulsion, thus protecting it from abrasion and promoting *archival quality.* The most commonly used hardeners are *potassium alum* or *aluminum chloride.* Fixer preservative is the same as that found in the developer, that is, sodium sulfite.

The function of the *wash* is to rid the film of residual chemicals. Should chemicals remain in the emulsion (e.g., as a result of defective wash cycle), the film will discolor with age. Since radiographic records are kept for a number of years, it is important that they have sufficient archival quality.

Cold-water processors are, in general, less efficient in removing chemicals than warm-water processors, but the cold water helps maintain proper developer temperature. Agitation during the wash process and large quantities of water help rid the emulsion of chemical residue.

■ *SUMMARY*

- **Developer solution reduces the exposed silver bromide crystals to black metallic silver.**
- **The development process is greatly affected by development time and solution temperature and activity.**
- **Sodium or potassium carbonate provides the necessary alkalinity and functions as the solution activator by swelling the gelatin emulsion.**
- **Reducing agents are phenidone and hydroquinone.**
- **Sodium sulfite or cycon preserves the developer solution from excessive oxidation.**

- ■ **Glutaraldehyde is a hardener, added to developer solution to control excessive swelling.**
- ■ **Potassium bromide serves as an antifog agent and restrains the developer from attacking the unexposed silver bromide crystals.**
- ■ **Potassium bromide is starter solution and is not required in replenisher solution.**
- ■ **The fixing or clearing agent (ammonium thiosulfate) removes unexposed silver bromide crystals from the emulsion, preventing further exposure.**
- ■ **Acetic acid provides the necessary acid medium for the fixer solution.**
- ■ **Potassium alum or aluminum chloride serves to harden the film emulsion.**
- ■ **The fixer preservative is sodium sulfite.**
- ■ **Adequate washing of residual chemicals from the film emulsion is essential for good archival quality.**

B. TRANSPORT SYSTEM

The *transport system* functions to convey the film through the different processor sections by means of a series of rollers (Fig. 12–3) driven by gears, chains, and sprockets. This is accomplished without damage to the film and at a prescribed speed, which determines the length of time film spends in each solution. The roller system also provides constant, vigorous agitation of the solution at the film surface. The entire conveyance system consists of the *feed tray, crossover rollers, deep racks, turnaround assemblies*, and *receiving bin.*

Film is aligned against one side of the feed tray as it is introduced into the processor. A sensor initiates solution replenishment as the film enters, and replenishment continues as the length of the film passes the sensor. Films should be fed into the processor along their short edge; feeding the film in "the long way" leads to overreplenishment and increased radiographic density.
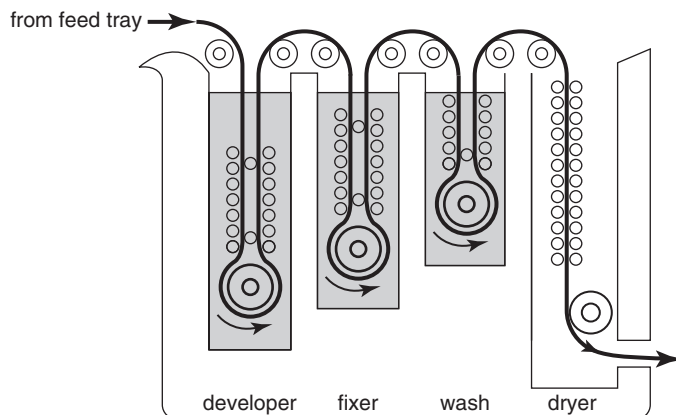
Figure 12–3. Major components of an automatic processor. A series of rollers conveys film through each processor section.
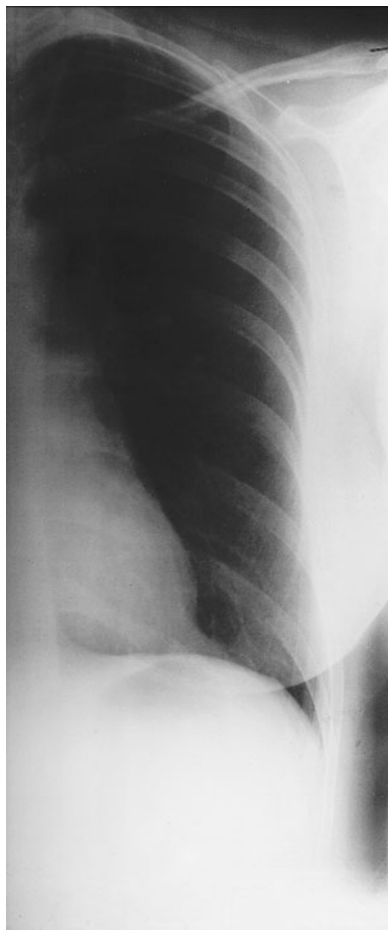
Figure 12–4. Because adjacent rollers are positioned closer together at their periphery, roller pressure on film emulsion is greater at film edges. This can cause a plus-density mottled appearance (*wet-pressure sensitization marks*) along film edges. If developer hardener or replenisher is insufficient, allowing excessive emulsion swelling, this artifact can occur across the length of the film. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Crossover racks are out of solution and bridge the gaps between developer and fixer, fixer and wash, and wash and dry sections of the processor. Crossover rollers must be kept free of crystallized solutions that can cause film artifacts as the soft emulsion passes by (Fig. 12–4). The last set of rollers in each solution section has a *squeegee* action on film emulsion, thus removing excess solution before film enters the next tank.

When the processor is not in use for a period of time, it is advisable to leave the lid open so that moisture can escape. Because the crossover rollers are out of solution, chemicals carried onto them by film can crystallize and should be cleaned off before the processor is used again.

Turnaround assemblies are located at the bottom of the deep racks and serve to change the film direction as it changes from downward to upward motion. Guide shoes, or deflector plates, are also located where film must change direction. They will occasionally scratch film, leaving characteristic *guide-shoe marks*, when they require adjustment.

When returning rollers to the processor after cleaning, care must be taken to seat them securely in their proper position. Transport problems (processor jam-up) will result if racks are misaligned.

C. REPLENISHMENT SYSTEM

As films travel from one processor solution section to another, chemical solution is carried away in the swollen film emulsion. It is the function of the processor *replenishment* system to keep solution tanks full. If solution level is allowed to lower, film immersion time decreases and radiographic density and contrast changes will occur. Transport problems can also arise from inadequate replenishment; that is, if insufficient developer replenisher, the inadequate addition of hardener will result in excessive emulsion swelling. The essentially "thicker" film has difficulty transporting between the closely distanced rollers.

As film travels through the fixer, it accumulates residual developer solution; fixer solution also accumulates unexposed silver cleared from the emulsion. Wash water accumulates fixer. In these ways, the activity of each solution is depleted through continual use. Diminished solution activity can have the same effects as low solution levels. The replenishment system assures that proper solution concentration is maintained.

D. TEMPERATURE REGULATION

The temperature regulation system functions to control the temperature of each section of the automatic processor. Developer is the most important solution temperature to regulate; in a 90-second processor, developer temperature is usually maintained at 92°F to 95°F. Once the correct developer temperature is established, it must be constantly maintained. Even a minor fluctuation (i.e., 0.5°F) in developer temperature can cause a visible change in radiographic density and contrast.

Developer temperature is thermostatically controlled and developer solution is circulated through a heat exchanger under the fixer tank. Thus, the fixer temperature is regulated (in cold-water processors) by heat conducted from the developer solution. In older processors having stainless steel tanks, fixer temperature is regulated by heat convection from the neighboring developer solution.

E. RECIRCULATION SYSTEM

As replenishment chemicals are added to solution, the *recirculation system* provides agitation necessary for uniform solution concentration. As temperature adjustments are made, the recirculation system agitates solution to promote temperature uniformity. *Agitation* provided by the system also functions to keep fresh solution in contact with film emulsion. The recirculation system also functions to filter debris, such as gelatin particles, from the solutions.

F. WASH AND DRYER SYSTEMS

Thorough removal of chemical solutions from the film emulsion is required for good *archival film quality* and is provided by the wash section of the automatic processor. Agitation of the water makes the process more efficient. Any residual chemicals will eventually result in film stain. *Residual fixer* will eventually stain the film a yellowish brown that ultimately obscures the image and diminishes the archival quality. Films can be tested (usually by the film manufacturer or distributor) to determine their degree of fixer retention.

The dryer section functions to remove water from the film by blowing warm, dry air over the film surface. Dryer temperature is usually 120°F to 130°F, sufficient to shrink and dry the emulsion without being excessive. Excessive heat and overdrying can cause film damage. If films emerging from a properly heated dryer are damp, the problem may be excessive emulsion swelling and water retention as a result of inadequate developer or fixer replenisher (hardener).

G. SILVER RECOVERY

X-ray film is expensive and can represent a large part of a radiology department annual budget. Approximately half of the film's silver remains in the emulsion after exposure and processing. The other half (unexposed silver) is removed from the film during the fixing process, and most of it is recoverable through *silver recovery* methods. A drain is connected to the fixer tank, and fixer is allowed to flow directly into a *silver recovery unit* or to a large centrally located receptacle.

Silver recovery is desirable for financial and ecological reasons. Fixer silver is toxic to the public water supply and environmental legislation makes persons responsible for its direct passage into sewer lines, or other means of improper disposal, subject to severe fines and penalties.

There are three types of silver recovery methods. Used fixer enters a *metallic displacement* (or metallic replacement) cartridge and metallic silver is precipitated onto the steel wool within. This method of silver recovery is most useful for low-volume locations.

Electrolytic silver recovery units (cells) pass an electric current through the fixer solution, causing silver to be plated onto the cathode cylinder of the unit. The silver is periodically removed by scraping it from the stainless steel cathode. Electrolytic cells are best used in locations having medium-to-high volume.

There are a number of chemicals that will *precipitate* metallic silver. In the presence of one of these chemicals (e.g., sodium borohydride), metallic silver falls to the bottom of the tank and forms a

sludge. This method of silver recovery is generally used only by large institutions having large, centralized receptacles or by professional silver dealers, who employ special techniques for separating the sludge or removing the entire tank.

H. PROCESSOR MAINTENANCE

The biggest advantage of automatic processors is their contribution to radiographic consistency. Testing and monitoring procedures serve to indicate potential problems before they arise. Developer, fixer, and wash temperature should be checked twice a day. *Preventive maintenance* is frequently provided for by a commercial cleaning and parts replacement service.

Sensitometry is the measure of film response to exposure and processing and is used to monitor quality control. A particular box of film is designated for testing purposes only, and a special device (*sensitometer*) is used to precisely and consistently expose the film. Once the film is processed and its densities are read (with a densitometer) and compared to known correct readings, any variation in film density must be owing to processor variation.

If solution levels in processor and replenisher tanks are frequently low, a bigger problem may exist and should be brought to the attention of the processor service company. *Preprocessed* films should *not* be used to clean rollers, because they may contain residual fixer that will contaminate the developer solution.

The more effective the processor quality control program, the less troubleshooting will be required. Nevertheless, it is important that the radiographer be able to recognize and resolve some common processor problems.

I. TROUBLESHOOTING: COMMON PROCESSOR PROBLEMS AND THEIR CAUSES

Transport problems (jam-ups)

- Inadequately maintained (dirty) rollers
- Too rapid film feeding, overlapping
- Misaligned crossover or other racks
- Inadequate developer replenisher (hardener)

Excessive density (processor related)

- Developer temperature elevated
- Insufficient dilution of developer

Inadequate density (processor related)

- Developer temperature too low
- Excessive dilution of developer

Damp films

- Dryer temperature too low
- Faulty dryer blower
- Inadequate fixing
- Inadequate developer replenisher (hardener)

Fog (darkroom related)

- Unsafe safelight
- Contaminated developer
- Outdated film
- Improper film storage conditions
- Darkroom light leak

■ *SUMMARY*

- The *transport system* functions to convey the film through the different processor sections by means of a series of rollers.
- The transport system consists of the *feed tray, crossover rollers, deep racks, turnaround assemblies*, and *receiving bin.*
- The last set of rollers in each solution section has a *squeegee* action on film emulsion, thus removing excess solution before film enters the next tank.
- *Turnaround assemblies* are located at the bottom of the deep racks; they serve to change the film direction from downward to upward motion. *Guide shoes* are also located where film must change direction.
- The *replenishment* system keeps solution tanks full.
- The replenishment system assures that proper solution concentration is maintained.
- Developer temperature is usually maintained at 92°F to 95°F.
- Developer temperature is *thermostatically controlled* and developer solution is circulated through a *heat exchanger* under the fixer tank.
- The *recirculation system* provides agitation necessary for uniform solution concentration and keeps fresh solution in contact with the emulsion.
- Thorough removal of chemical solutions from the film emulsion is required for good *archival film quality* and is provided by the *wash* section of the automatic processor.
- Dryer temperature is usually 120°F to 130°F, sufficient to shrink and dry the emulsion without being excessive.
- Unexposed silver is removed from the film during the fixing process and most of it is recoverable through *silver recovery* methods; silver recovery is desirable for financial and ecological reasons.
- There are three types of silver recovery methods: *metallic displacement, electrolytic*, and *precipitate.*
- *Sensitometry* is the measure of film response to exposure and processing and is used to monitor quality control.

V. PROCESSING DIGITAL/ELECTRONIC IMAGES

The processing of digital images is very different from processing screen–film images. Digital imaging is covered in *Chapter 11* and in *Part V: Equipment Operation and Quality Control.*

Any screen–film image can be scanned and *digitized* by a film digitizer device.

Figure 12–5. A CR cassette is very similar in appearance to a conventional screen–film cassette. The CR cassette holds an image plate (the image receptor) between its front and rear panels. There is no film or intensifying screens. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003).

A. COMPUTED RADIOGRAPHY

As discussed earlier, *computed radiography* uses special flexible photostimulable phosphor screens (Fig. 12–5) inside image plates (IPs) to record the radiologic image. No film is used, hence the term *filmless radiography*. An IP is exposed just like a screen–film cassette. Upon exposure, a latent image is produced on the storage phosphor screen (SPS), or photostimulable phosphor (PSP). The *PSP* within the IP is processed in a special *reader*, i.e., scanned with a narrow laser beam to obtain the pixel data, which is then displayed on the display monitor as the radiographic image. The PSP is then exposed to additional light to remove any residual image and the IP is ready for reuse. Thus, the PSP undergoes three cycles: x-ray exposure, reading, and erasure (Fig. 12–6).

B. HISTOGRAMS AND LUTs

In digital imaging, as in film/screen radiography, there are numerous density values that represent various tissue densities, for example, bone, muscle, fat, blood-filled organs, air/gas, metal, contrast media,
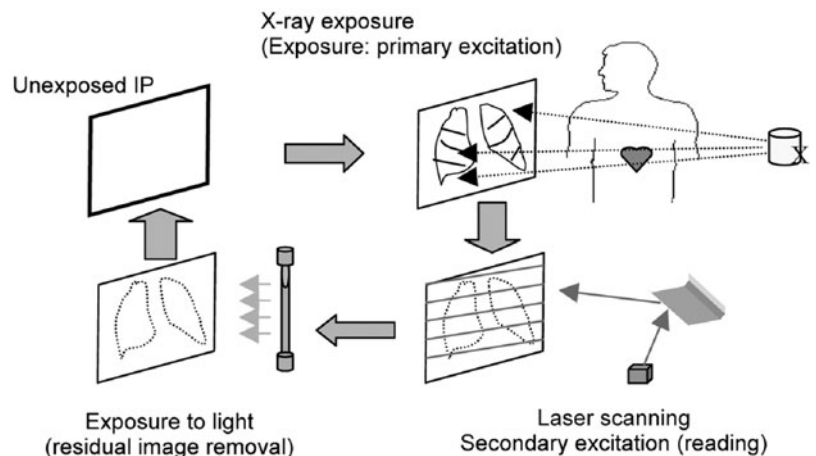
Figure 12–6. A PSP image plate undergoes three cycles: x-ray exposure, reading, and erasure. (Courtesy of FUJIFILM Medical Systems USA, Inc.)

A

Level: 231

Count: 632

Pixels: 200000

B
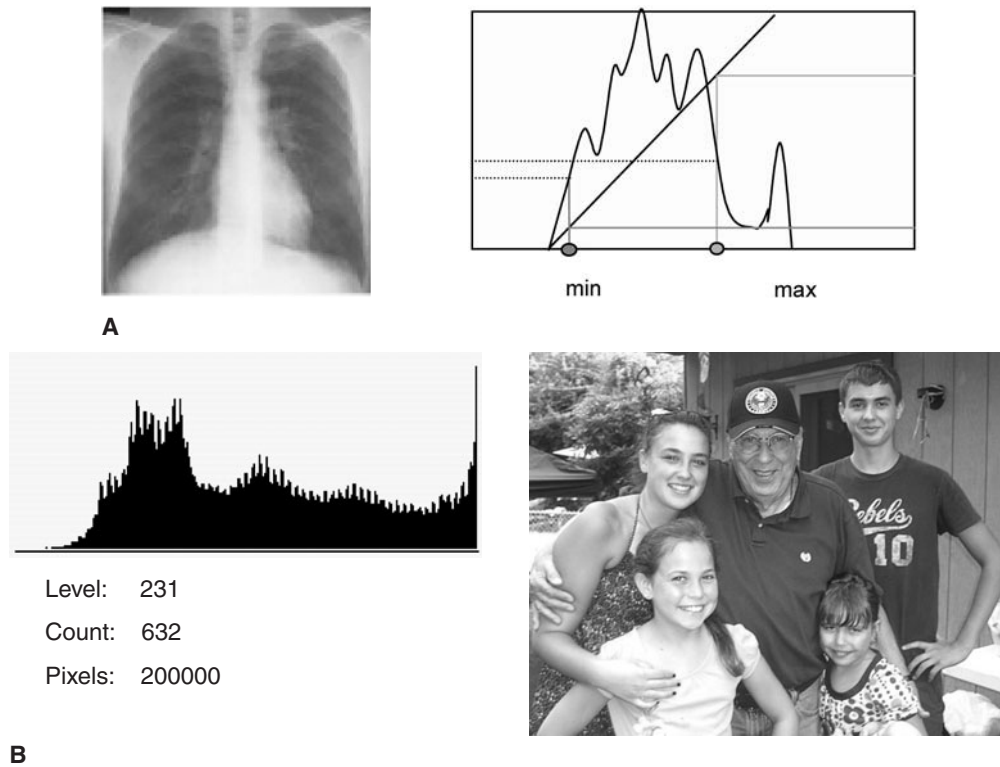
Figure 12–7. **(A)** PA chest histogram; a graphic representation illustrating the distribution of pixel values. (Courtesy of FUJIFILM Medical Systems USA, Inc.) **(B)** Many of today's digital cameras can also display the histogram distribution of pixel values for typical family photos.

pathologic processes, etc. In CR, the CR reader recognizes all these values and constructs a gray-scale *histogram* of them representing the anatomical characteristics of the imaged part. Thus, all PA chest histograms will be similar, all lateral chest histograms will be similar, all pelvis histograms will be similar, etc.

A histogram is a *graphic representation* of pixel value distribution (Fig. 12–7A and B). The radiographer has selected a *processing algorithm* by selecting the anatomical part and particular projection on the computer/control panel. The CR unit then matches that information with a particular *Lookup Table* (*LUT*)—a characteristic curve that best matches the anatomical part being imaged. The observer is able to review the image and, if desired, change its appearance (through "windowing")—doing so changes the LUT. Hence, *histogram analysis* and use of the appropriate *LUT* together function to produce predictable image quality in CR.

It is important to note that *histogram appearance* can be affected by a number of things. Degree of accuracy in *positioning and centering* can have a significant effect on histogram appearance (as well as patient dose) as seen in Figure 12–8: because of poor collimation, the average exposure level has changed, as well as the exposures' latitude; these changes will be reflected in the images' informational numbers ("S number," "exposure index," etc). Other factors affecting histogram appearance, and hence these informational numbers, include selection

Example A **Example B**

Properly collimated   Noncollimated beam

Normal Histogram   Wider Histogram
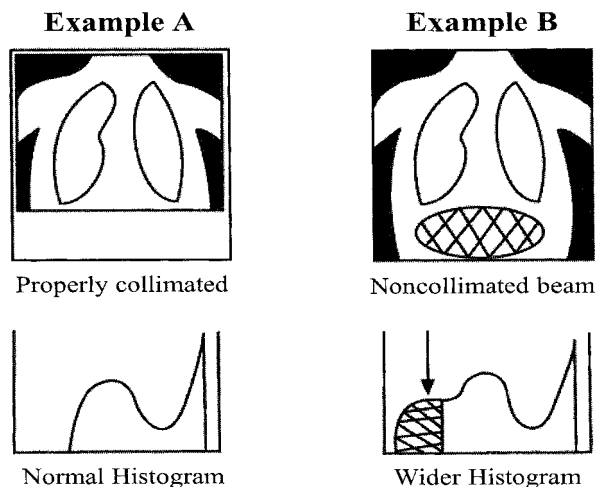
Figure 12–8. Courtesy of FUJIFILM Medical Systems USA, Inc.

of the *correct processing algorithm* (e.g., chest vs. femur vs. cervical spine), changes in *scatter, SID, OID*, and *collimation*. In short, anything that affects scatter and/or dose. One other factor is *delay in processing* from time of exposure. Processing delay can result in *fading* of the image. Normal examination times and short delays between projections will generally not be a problem.

The image seen on the monitor, then, is the "default" image—one that has been obtained using parameters that have been prescribed consistent with department preferences.

C. PARTITION PATTERN AND EXPOSURE FIELD RECOGNITION

The CR reader identifies PSP areas of interest (anatomy). It distinguishes the orientation and number of images (Fig. 12–9). When there is more than one image on a PSP and each image is analyzed separately, the process is termed *partition pattern recognition.*

If the CR reader identifies the collimated borders and analyzes only that exposure within the borders, that process is termed *exposure field recognition.* If the entire PSP was analyzed, the histogram would be skewed and the resulting image far from optimum.

D. POSTPROCESSING/IMAGE MANIPULATION

Additionally, the radiographer can *manipulate*, i.e., change and enhance, the digital image displayed on the display monitor through *postprocessing*. One way to alter image contrast and/or density is through *windowing*. The term *windowing* refers to some change made to *window width* and/or *window level*, i.e., a change in the LUT. Change in window *width* affects change in the number of gray shades, i.e., *image contrast*. Change in window *level* affects change in the image brightness, i.e., *optical density* (Fig. 12–10). Therefore, windowing and other postprocessing mechanisms permit the radiographer to affect changes in the image and to produce "special effects" such as *contrast enhancement, edge enhancement, image stitching* (useful in scoliosis examinations), and image inversion, rotation, and reversal.
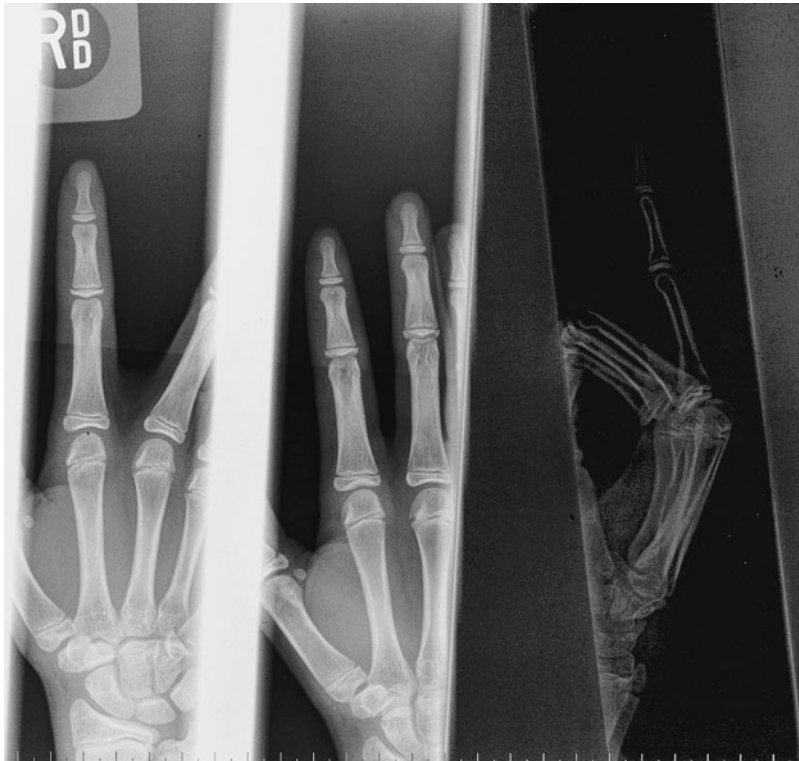
Figure 12–9. The "partition pattern recognition process" in CR will determine if the image is divided and, if so, how it is divided. In the CR image above, one image was not recognized. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003.)

E. IMAGE COMMUNICATION AND INTERPRETATION

Using a *picture archiving and communications system* (PACS) and *teleradiology*, digital images can be sent anywhere there is the equipment to receive and display them.

Interpretation of digital images can be made from the display monitor ("soft copy display"). In addition, "hard copies" can be made on film using a laser printer. A *laser camera* records the displayed image by exposing a film with laser light; it can also record several images on one film. The laser printer is connected for immediate processing of the images.

■ SUMMARY

- ■ *Computed radiography* uses special detector screens called photostimulable phosphor (*PSP*) screens.
- ■ The exposed PSP is placed in the CR reader and scanned with a narrow laser beam.
- ■ Pixel data from the reader is displayed on the monitor as the radiographic image.

Figure 12–10. Changes in *window width* and *window level*. Image **A** (center) has a window width of 1810 and window level of 761. In image **B,** the window width is increased to 4174; in image **C,** the window width is decreased to 732, leaving window level unchanged. The changes in image *contrast* are evident. Next, images D and E are compared to A. In image **D,** the window level is increased to 1497; in image **E,** it is decreased to 325. This time the changes in image *density* are obvious.

- A histogram is a *graphic representation* defining all the gray-scale values of a particular image.
- A *processing algorithm* is selected when the radiographer selects the part and projection on the computer.
- A *Lookup Table* (*LUT*) is like a characteristic curve for a particular anatomical part and is modified by the radiographer during any windowing of the image.
- *Histogram analysis* and the appropriate *LUT* together function to produce predictable image quality in CR.
- The CR image can be *manipulated* by the radiographer (i.e., "windowing," modifying the LUT) to change contrast and/or density.
- When more than one image is made on a PSP, the CR reader can analyze using the *partition pattern recognition* method or the *exposure field recognition* method.
- With *picture archiving and communications system* (PACS) and *teleradiology*, digital images can be sent anywhere there is equipment to receive and display them.
- "Hard copies" can be made on film using a laser printer.

Chapter Exercises

⭐ ***Congratulations!*** *You have completed the entire chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You can refer back to the indicated pages to check your answers and/or review the subject matter.*

1. What are the ideal conditions for x-ray film storage ***(p. 397).***

2. Describe the possible effect of excessive temperature and of very low humidity ***(p. 397).***

3. Describe how each of the following can affect radiographic film ***(pp. 397–398).***
    (A) chemical fumes
    (B) radiation
    (C) storage past the expiration date
    (D) stacking boxes of film upon each other
    (E) film bin or darkroom with light leaks
    (F) safelight too close to work bench
    (G) too high wattage safelight

4. Explain correct care of cassettes and intensifying screens ***(p. 399).***

5. How can suspected flaws in film–screen contact be detected ***(p. 399)?***

6. List at least five radiographic artifacts and identify their cause ***(pp. 398–399)?***

7. What information *must* every radiographic image include? Describe two types of film identification systems ***(p. 400).***

8. Define latent image; manifest image ***(p. 401).***

9. List five advantages of automatic processing over manual processing. What modification of manual processing helps achieve rapid processing ***(p. 401)?***

10. What is the main function of the developer solution? What are the three important factors in the development process ***(p. 401)?***

11. Identify the chemical associated with each of the following developer constituents and describe its function(s) ***(p. 402).***
    (A) reducing agents (two)
    (B) preservative
    (C) activator and accelerator
    (D) restrainer

    (E) hardener

    (F) solvent

12. What are the main functions of the fixer solution *(p. 402)?*

13. Identify the chemical associated with each of the following fixer constituents and describe its function(s) *(p. 402).*
    (A) fixing and clearing agent
    (B) activator
    (C) hardener
    (D) preservative
    (E) solvent

14. List the order in which film travels through each of the four sections of the automatic processor *(p. 403).*

15. List five functions of the transport system. What can result from transport problems *(pp. 403–404)?*

16. Describe the appropriate care of crossover racks *(p. 404).*

17. Describe the location of the rollers having squeegee action and explain their purpose *(p. 404).*

18. What is the usual cause of wet-pressure sensitization marks occasionally found along film edges *(p. 404, Fig. 12–4)?*

19. Name and describe the location of the structures that function to guide film in the proper direction through the processor roller systems *(p. 404).*

20. What are the two functions of the processor replenishment system? What can be the result of inadequate replenishment *(p. 404)?*

21. Describe the importance of temperature-regulation systems in automatic processing *(p. 404).*

22. List four functions of the processor recirculation system *(p. 405).*

23. What are the functions of the processor wash and dry sections? What can result from an inadequate wash process; inadequate drying *(p. 405)?*

24. Explain the economic and ecologic importance of silver recovery. Describe the three types of silver recovery methods *(p. 405).*

25. List at least seven common radiographic problems associated with processing and identify their cause *(pp. 406–407).*

26. Describe what is meant by the term *filmless radiography* *(p. 408).*

27. What device functions to transfer the x-ray image from the photostimulable phosphor (PSP) to the display monitor? *(p. 408)?*

28. What does a histogram represent in CR *(pp. 408–409)?*

29. What is the purpose of an LUT in CR? How does the radiographer modify the LUT *(p. 409)?*

30. How does the radiographer select a processing algorithm *(pp. 409–410)?*

31. What is windowing? What does a change in window width and/or window level affect *(p. 410)?*

32. What can change the appearance of the histogram, and therefore its analysis *(p. 409)?*

33. In what two ways can a CR reader identify and analyze multiple images on one IP? *(p. 410)?*

34. What system is used to send digital images anywhere there is equipment available to receive and display them *(p. 411)?*

35. What device is used to make "hard copies" of images seen on display monitors *(p. 411)?*

Chapter Review Questions

1. The developer temperature in a 90-second automatic processor is usually approximately:
   - (A) 75°F–80°F
   - (B) 80°F–85°F
   - (C) 85°F–90°F
   - (D) 90°F–95°F

2. The exposed PSP is subjected to a narrow laser beam:
   - (A) on the display monitor
   - (B) in the CR reader
   - (C) in the cassette
   - (D) on the film emulsion

3. The histogram demonstration of pixel value distribution can be changed/affected by the following:
   1. selection of processing algorithm
   2. processing delay
   3. centering
   - (A) 1 only
   - (B) 1 and 2 only
   - (C) 2 and 3 only
   - (D) 1, 2, and 3

4. The amount of replenishment solution added to the automatic processor is determined by:
   1. size of the film
   2. position of film on tray feeding into processor
   3. length of time required for film to enter processor
   (A) 1 only
   (B) 1 and 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

5. Types of postprocessing of electronic/digital images include:
   1. image stitching
   2. contrast enhancement
   3. windowing
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

6. What is the likely cause of films emerging from the automatic processor in a damp condition?
   (A) air velocity too high
   (B) unbalanced processing temperatures
   (C) insufficient hardening action
   (D) excessive hardening action

7. The invisible latent image is converted into a visible manifest image in the:
   (A) developer
   (B) stop bath
   (C) first half of the fixer process
   (D) second half of the fixer process

8. Poor storage or handling practices that can result in film fog include:
   1. outdated film
   2. exposure to excessive temperatures
   3. exposure to chemical fumes
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

9. Which of the following devices functions to produce hard copies of digital images?
   (A) digitizer
   (B) laser printer
   (C) histogram
   (D) display monitor

10. A CR histogram is a graphic representation of:
    (A) gray scale values of the imaged part
    (B) a characteristic curve of the imaged part
    (C) D_{max}
    (D) D_{min}

Answers and Explanations

1. (D) The advantages of automatic processors are quicker, more efficient operation, and consistent results. Quicker operation is attained with increased solution temperatures. The usual temperature of a 90-second developer is 90°F to 95°F. Excessively high developer temperature can cause chemical fog.

2. (B) Computed radiography uses special detector plates inside cassettes to record the radiologic image. No film is used, hence the term *filmless radiography*. The CR cassette is exposed just like a conventional screen–film cassette. Upon exposure, a latent image is produced on the photostimulable phosphor (PSP) screen, which is located inside the IP. The IP is placed in the CR processor, and the PSP is automatically removed. A special *reader* scans the PSP with a narrow laser beam to obtain the pixel data, which can then be displayed on a monitor as the radiographic image.

3. (D) Histogram appearance can be affected by a number of things. *Positioning and centering accuracy* can have a significant effect on histogram appearance. Other factors affecting histogram appearance include selection of the *correct processing algorithm* (e.g., chest vs. femur), changes in *scatter, SID, OID*, and *collimation*. In short, anything that affects scatter and/or dose. Another factor affecting histogram appearance is *delay in processing* from time of exposure. Processing delay can result in *fading* of the image.

4. (D) When a film first enters the processor from the feed tray, a microswitch signals the replenishment pump to begin sending replenisher solution into the processor. Replenishment continues until the microswitch senses the end (edge) of the film and terminates pump action. So, as long as film is being fed into the processor, replenishment solution will be added. There is, therefore, more replenisher added with larger size films. There is also more replenisher added when rectangular films are fed into the processor "the long way" because the processor is sensing, for example, 17 inches of film rather than 14 inches of film. Film should be put through the processor consistently according to the particular department's preference or routine. A change in film direction can lead to over- or underreplenishment and, hence, a change in film density.

5. (D) The radiographer can manipulate, that is, change and enhance, the digital image displayed on the monitor through *postprocessing*. One way to alter image contrast and/or density is through *windowing*. Windowing refers to some change made to *window width* and/or *window level*, i.e. a change in the LUT. Change in window *width* affects change in the number of gray shades, that is, *image contrast*. Change in window *level* affects change in the image brightness, that is, *optical density*. Therefore, windowing and other postprocessing mechanisms permit the radiographer to affect changes in the image and to produce "special effects" such as

contrast enhancement, edge enhancement, image stitching (useful in scoliosis examinations), and image inversion, rotation, and reversal.

6. (C) If the fixer fails to sufficiently reharden the gelatin emulsion, water will remain within the still-swollen emulsion. The dryer mechanism will be unable to completely rid the emulsion of wash water, and the film will emerge from the processor damp and tacky. On the other hand, excessive hardening action may produce brittle radiographs. High air velocity usually encourages more complete drying. Unbalanced processing temperatures can result in blistering of the emulsion.

7. (A) The invisible silver halide image is composed of exposed silver grains. These are "reduced" to a visible black metallic silver image in the developer solution. The fixer solution functions to remove unexposed silver halide crystals from the film.

8. (D) All of those effects listed can result from poor storage practices. Film should be rotated with the oldest being used first to avoid fog from outdated film. By protecting film from chemical fumes and from excessive temperatures, fogging of the sensitive emulsion is prevented.

9. (B) Conventional screen–film images can be scanned and digitized by a special machine called a *film digitizer.* Interpretation of digital images is made from the display monitor; this is referred to as "soft copy display." "Hard copies" can be made with a *laser printer.* A laser camera records the displayed image by exposing a film with laser light; it can also record several images on one film. The *laser printer* is connected for processing of the images.

10. (A) As in traditional radiography, numerous density values represent various tissue densities, for example, bone, muscle, fat, blood-filled organs, air/gas, metal, contrast media, pathologic processes, etc. In CR, the CR scanner recognizes these numerous values and constructs a *gray-scale histogram* of these values represented in the imaged part. A histogram is a *graphic representation* defining all these values. The radiographer selects a *processing algorithm* by selecting the anatomical part and particular projection on the computer. The CR unit then matches that information with a particular *Lookup Table* (*LUT*)—a characteristic curve that best matches the anatomical part being imaged. Hence, *histogram analysis* and use of the appropriate *LUT* together function to produce predictable image quality in CR.

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Image Evaluation (Screen–Film and Electronic)

13

I. EVALUATION STANDARDS AND IMAGE CHARACTERISTICS

A. OVERVIEW

It is important to look at x-ray images with a critical eye, evaluating each of the components that contribute to their overall quality. The goal is to have as much information as possible, transferred as accurately as possible, from the part being radiographed to the image receptor.

B. RECORDED DETAIL AND DISTORTION

The x-ray image should illustrate maximum transference of information without visible loss of image detail. As discussed earlier, recorded detail can be lost, or distortion introduced, as a result of patient motion, excessive OID, insufficient SID, inappropriate screen–film combination, or too large a focal spot size. Shape distortion is evidenced as a result of improper alignment of x-ray tube, part, and film.

Spatial resolution in *CR* is impacted by most of the above and the size of the photostimulable phosphor, the size of the scanning laser beam, and monitor matrix size. High-resolution monitors (2–4 K) are required for high-quality, high-resolution image display. Using a *picture archiving and communications system* and *teleradiology*, digital images can be sent anywhere there is the equipment to receive and display them.

Graininess on digital images can be caused by underexposure, incorrect processing algorithm selection (from the anatomical menu), inadequate collimation, and grid cutoff.

DR does not use cassettes or a traditional x-ray table; it is an *indirect-capture* or *direct-capture* system of x-ray imaging. DR uses solid-state detector plates as the x-ray image receptor to intercept the x-ray beam. One type of *indirect* capture flat panel detector uses *cesium iodide* or *gadolinium oxysulfide* as the *scintillator,* i.e., that which captures x-ray photons and emits light. That light is then transferred

Causes of CR Graininess

- Underexposure
- Incorrect processing algorithm
- Excess SR; inadequate collimation
- Grid misalignment; cutoff

via a *charge coupled device* or *thin film transistor*. In *direct* capture flat panel detector systems, x-ray energy is converted to an electrical signal in a single layer of material such as the semiconductor a-Se. Electric charges are applied to both surfaces of the a-Se, electron-hole pairs are created, and charges are read by *thin film transistor* arrays located on the surfaces. The electrical signal is transferred directly to the ADC.

Thus, the direct-capture system eliminates the scintillator step required in indirect DR. Since selenium has a relatively low *Z* number (compared to gadolinium [$Z = 64$] or cesium [$Z = 55$]), a-Se (amorphous Selenium) detectors are made thicker to *improve detection*, thus compensating for the low x-ray absorption of selenium. There is no diffusion of electrons (as there is light diffusion in intensifying screens), so *spatial resolution* is not affected in this manner.

DR affords the advantage of *immediate* display of the image; the CR image is somewhat *delayed*.

It must be emphasized that while the biggest advantage of electronic imaging is its *dynamic range*, patient overexposure can result if the radiographer fails to keep exposure factors within the system's recommended exposure index.

C. DENSITY AND CONTRAST

X-ray images must display adequate *background optical density* and a *scale of grays* sufficient to make various *tissue densities* visible. Appropriate exposure factors, imaging accessories, and consideration of patient condition, size, and pathology are required.

In *electronic imaging (CR/DR)*, the radiographer can *manipulate* digital image displayed on the CRT through *postprocessing*. One way to alter image contrast and/or brightness (density) is through *windowing*. This refers to some change made to *window width* and/or *window level*. Change in window *width* affects change in the number of gray shades, that is, *image contrast*. Change in window *level* affects change in the image *brightness*—referred to in screen–film imaging as *optical density*. Windowing and other *postprocessing* mechanisms permit the radiographer to produce "special effects" such as edge enhancement, image stitching (useful in scoliosis examinations), and image inversion, rotation, and reversal.

One of the biggest advantages of electronic imaging is the dynamic range (in screen–film imaging referred to as *latitude*) it offers. Whereas in screen–film imaging, there is a "range of correct exposure" limited by the toe and shoulder of the characteristic curve; in electronic imaging, there is a *linear* relationship between the exposure given the PSP and its resulting luminescence as it is scanned by the laser. This affords much *greater exposure latitude*; technical inaccuracies can be effectively eliminated (Fig. 13–1). Overexposure of up to 500% and underexposure of up to 80% are reported as recoverable, thus eliminating most retakes.

D. SCREENS AND GRIDS: SELECTION AND USE

In screen–film imaging, intensifying screen speed is appropriate for the particular examination. Slower screens are often employed for examinations of the extremities (e.g., 100 speed), while faster screens (e.g., 400 speed) are used for larger body parts. If a grid is required,

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CR Resolution Increases As

- PSP crystal size decreases
- Laser beam size decreases
- Monitor matrix size increases
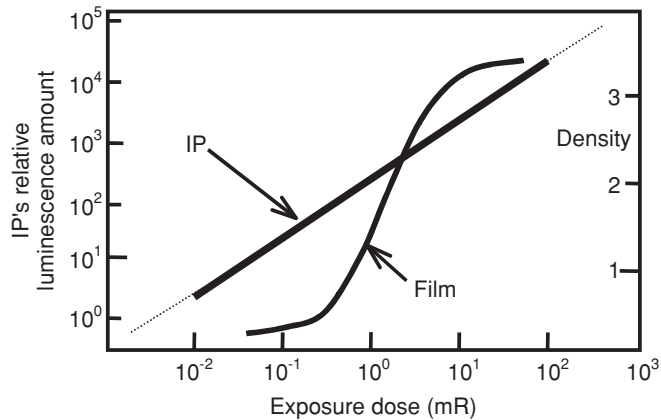
Figure 13–1. Compares the characteristic curve of a typical film emulsion with that of a PSP. The *wide dynamic range* (scale of contrast) of the PSP enables the correct detection of slight differences in x-ray absorption characteristics among various tissue densities. (Courtesy of FUJIFILM Medical Systems USA, Inc.)

the appropriate ratio should be selected—a *grid ratio* that is appropriate for the kV (kilovolts) level employed. X-ray tube centering, angulation, and SID should be suitable for the particular type grid used.

In electronic imaging, CR uses image plates (IPs), DR does not. CR's use of IPs offers an advantage in terms of *flexibility*. The use of IPs allows for continued use of existing equipment, and CR is convenient for mobile radiographic applications, for tabletop/nongrid work, and for crosstable/horizontal beam work. As previously mentioned, image "*fading*" can occur if there is delay in reading the PSP. If an IP and its PSP storage plate have been stored, unused, for an extended period of time (i.e., for 48 hours), the PSP storage plate should be erased prior to use.

Care and maintenance of CR is discussed in Chapter 15. It is important to protect CR IPs from unwanted exposure—such exposure can cause artifacts on subsequent images. IPs are subject to double exposure just as screen–film cassettes.

True *DR* does not use IPs or a traditional x-ray table with Bucky tray; it is a *direct-capture* system of x-ray imaging.

E. IMAGE IDENTIFICATION

All essential medicolegal information should be visible on each radiograph: patient name or identification number, side marker, date, and institution.

F. ANATOMIC PART, COLLIMATION, SHIELDING

The radiograph must include the anatomic *areas of interest* in the desired position and projection. To ensure patient protection, there must be visible evidence of *collimation. Shielding* should be evident when the reproductive organs are in the collimated primary beam, or within 5 cm of it, when the patient has reproductive potential, and when diagnostic objectives permit.

Electronic Imaging

- brightness/density changes with changes in window *level*.
- contrast changes with changes in window *width*.
- has wide dynamic range
- has greater exposure latitude
- fading can occur with delayed processing.
- IPs are very sensitive to x-ray fog.

II. IDENTIFYING AND CORRECTING ERRORS

It is essential that the radiographer be aware of the impact each of the imaging components has on the finished radiographic image. The radiographer must be able to recognize and correct imaging errors.

Each radiograph should be evaluated according to the standards addressed above. If the image is suboptimal in any category, steps must be taken to determine the cause, correct the error, and ensure that the error will not be repeated.

It is impossible to address and illustrate here all possible errors in technical factor selection, equipment use and positioning, patient variables, artifacts, and processing—in screen–film imaging and in CR/DR. Some have been illustrated in earlier portions of this volume and others are illustrated here. Patient positioning errors are addressed in Part II. Try to identify the illustrated error, and then check your answer with that given in the caption.

In CR/DR, we are learning about new kinds of artifacts and errors unique to digital imaging. Some of the more common ones are presented here. It is important to remember that IPs are sensitive to electromagnetic radiation such as ultraviolet and gamma radiations, as well as particulate radiation such as alpha and beta particles. Exposure of the sensitive PSPs to environmental radiation can result in image *artifacts* appearing as black spots. Therefore, *IPs that have not been used for a long time should be subjected to the erasure process before use.*

A. TECHNICAL FACTOR SELECTION

See Figures 13–2 through 13–5.

A

B
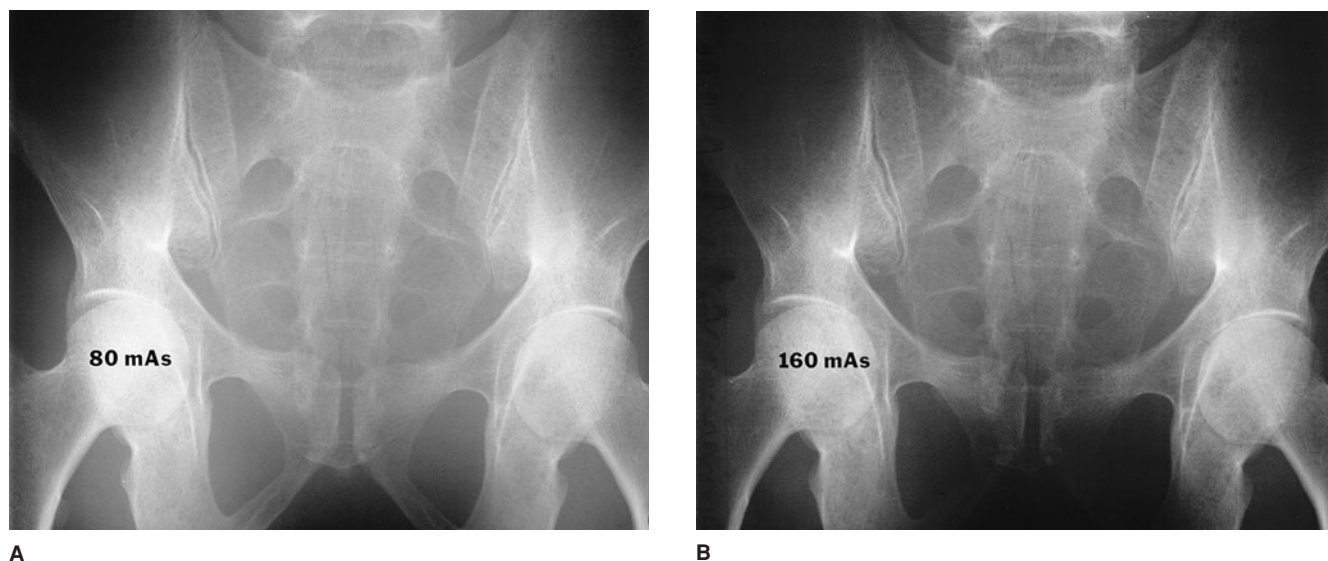
Figure 13–2. *Excessive optical density;* improper selection of *mAs* (milliampere-seconds). Both images were made at 100-cm SID using 75 kV. **(A)** Image correctly exposed at 80 mAs. **(B)** Image exposed at 160 mAs demonstrates excessive density. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
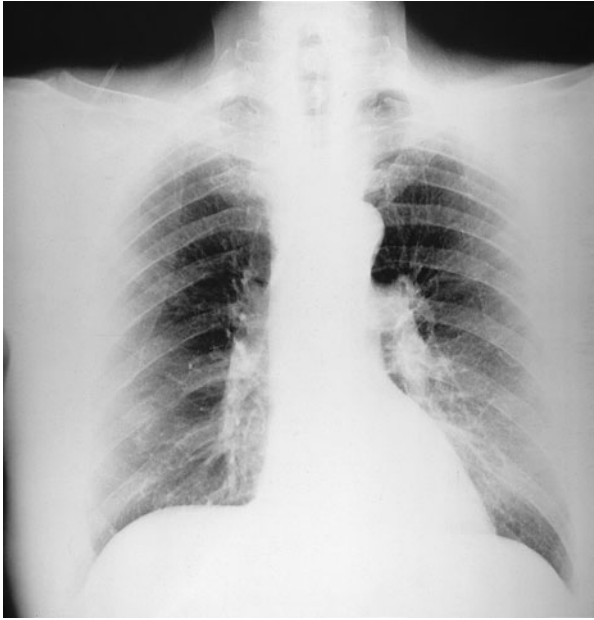
Figure 13–3. *High contrast* as a result of insufficient *kV.* (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
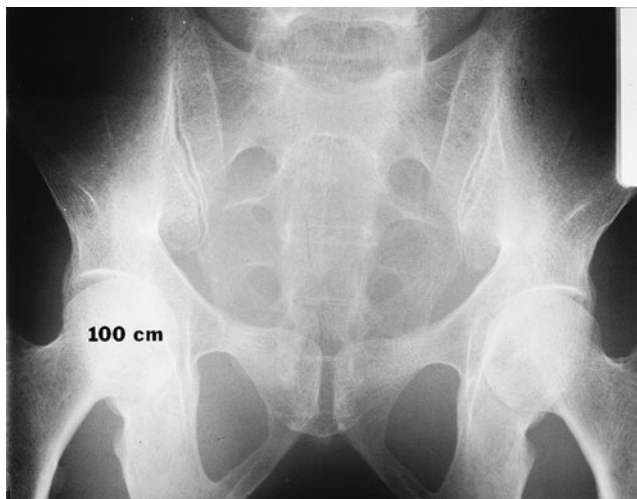
A
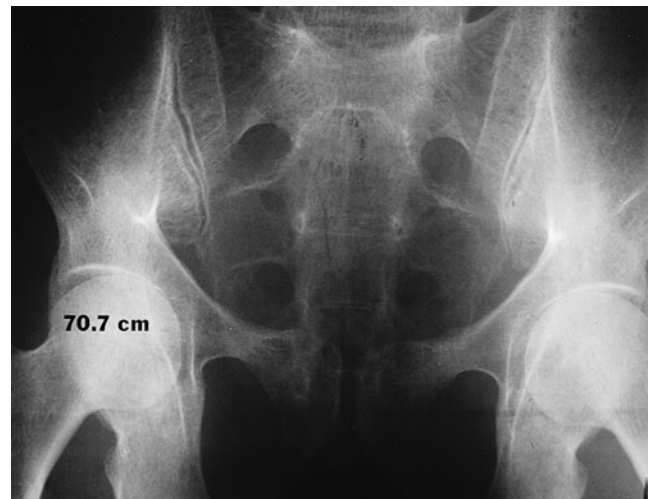
B

Figure 13–4. **(A)** X-ray beam intensity at a given point is dependent on the distance from its source. **(B)** Optical *density increases* as a result of *decreased SID.* (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–5. Noisy CR image as a result of quantum mottle. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003.)

B. EQUIPMENT USE AND POSITIONING

See Figures 13–6 through 13–17.
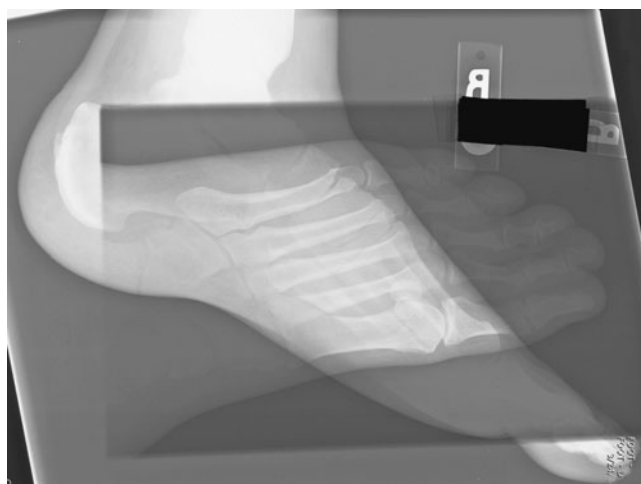
Figure 13–6. Double exposure. Care must be taken to keep exposed IPs separate from unexposed. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 13–7. Incomplete erasure of PSP. CR reader failed to completely erase previous image. Faint image of ribs can be seen. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 13–8. Double exposure. Note how CR will "correct" the exposure values—image does not appear overexposed, but second abdomen image is visible. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 13–9. Motion is the greatest enemy of image detail. (Courtesy of Stamford Hospital, Department of Radiology.)

Figure 13–10. CR cassette inadvertently used upside down. Artifacts from CR cassette rear panel are superimposed on anatomic part.
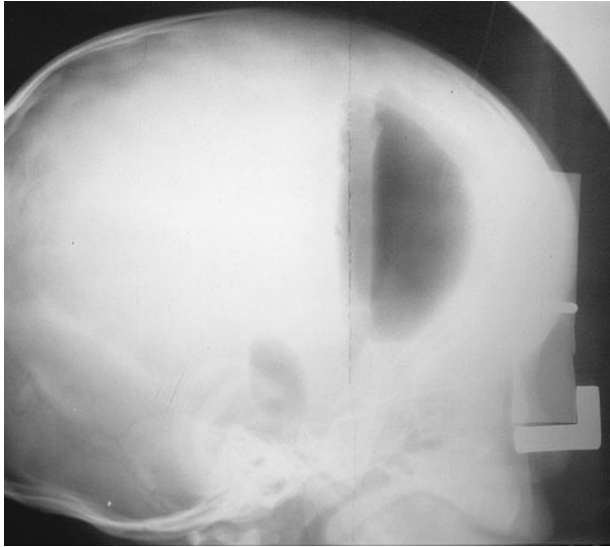
Figure 13–11. A *defective grid*; probably a wafer grid or grid cassette. Lead strips in grids are exceedingly thin and fragile. If grids are handled carelessly, lead strips can become damaged and/or misaligned and can create uneven bands of density. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–12. *Inverted focused grid.* If a focused grid is placed upside down, the divergent x-ray beam will be absorbed by the grid's lead strips (everywhere but the grid's central portion, where grid lines are vertical). See density versus grids section of Chapter 12. (Courtesy of Stamford Hospital, Department of Radiology.)
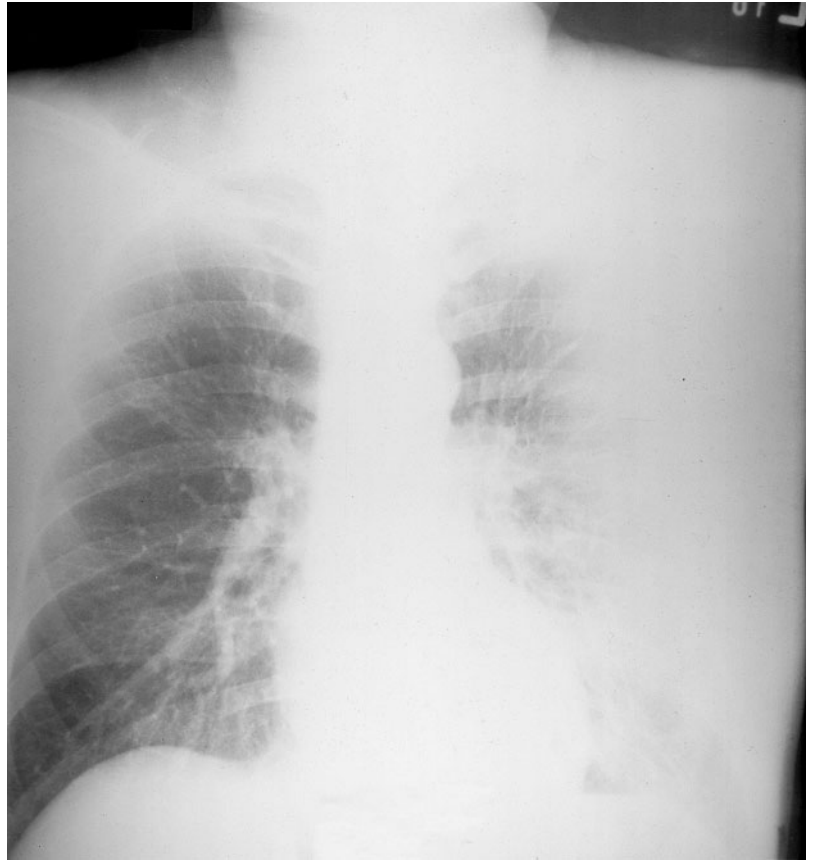
Figure 13–13. *Off-focus and lateral decentering* errors. Notice the asymmetric cutoff from right to left (see density vs. grids section of Chapter 12). (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–14. *Moiré effect.* This is a classic example of the effect of *superimposing two linear grids*, that is, a grid cassette placed in a Bucky tray. When the lead strips are aligned in the same direction, yet not exactly superimposed, this unmistakable moiré pattern occurs. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–15. *Magnification* image performed using *large focal spot.* Magnification studies can yield useful information about tiny details *only* if a *fractional* (0.3 mm or smaller) focal spot is used. Use of a larger focal-spot size causes loss of recorded detail as a result of increased visualization of penumbra blur. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–16. *Tomographic streaking.* Longitudinal streaking can be very pronounced in *linear tomography* when the dominant anatomic lines parallel tube motion. Placing the x-ray tube motion and dominant lines at right angles to each other, or using an appropriate tube motion (with pluridirectional tomographic equipment), can remedy the situation. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–17. The "partition pattern recognition process" in CR will determine if the image is divided and, if so, how it is divided. In the CR image above, one image was not recognized. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003.)

C. PATIENT VARIABLES

See Figures 13–18 through 13–23.

Figure 13–18. *Involuntary motion* on right (ureter) caused by *peristalsis.* Use of the shortest possible exposure time is the best way to avoid loss of detail caused by involuntary motion. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
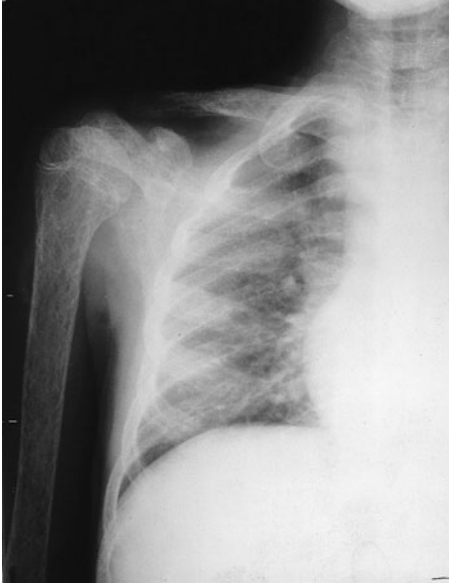
Figure 13–19. *Osteoporotic* bone as a result of thalassemia (Cooley or Mediterranean anemia) requires *reduction of technical factors.* (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–20. *Paget disease* (osteitis deformans) is characterized by bone thickening and therefore requires an increase in technical factors. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

A
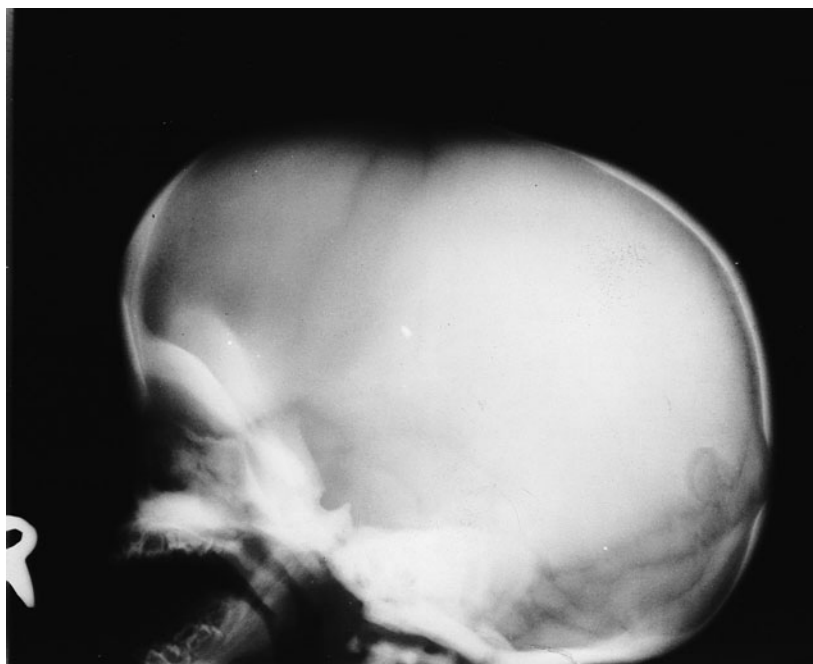
B

Figure 13–21. *Osteopetrosis* (Albers–Schönberg, or marble-bone, disease) is characterized by *increased bone density*, requiring an appropriate *increase in technical factors*. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–22. Pathology such as *increased amounts of air* can require decrease in technical factors. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–23. A change in *body position* from recumbent to erect will require an increase in technical factors. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

D. IDENTIFICATION OF ARTIFACTS

See Figures 13–24 through 13–37.

Many *artifacts* are produced by misuse of imaging equipment, as discussed in Section B. Artifacts can be classified as *exposure* artifacts (ring on finger, hair braids, etc.), *handling* artifacts (crinkle or crescent marks, fingerprints, etc.), or *processor* artifacts (guide-shoe marks, pi lines, etc.).

Figure 13–24. CR reader processing artifact seen vertically through shoulder joint. (Courtesy of Stamford Hospital, Department of Radiology.)

A

B
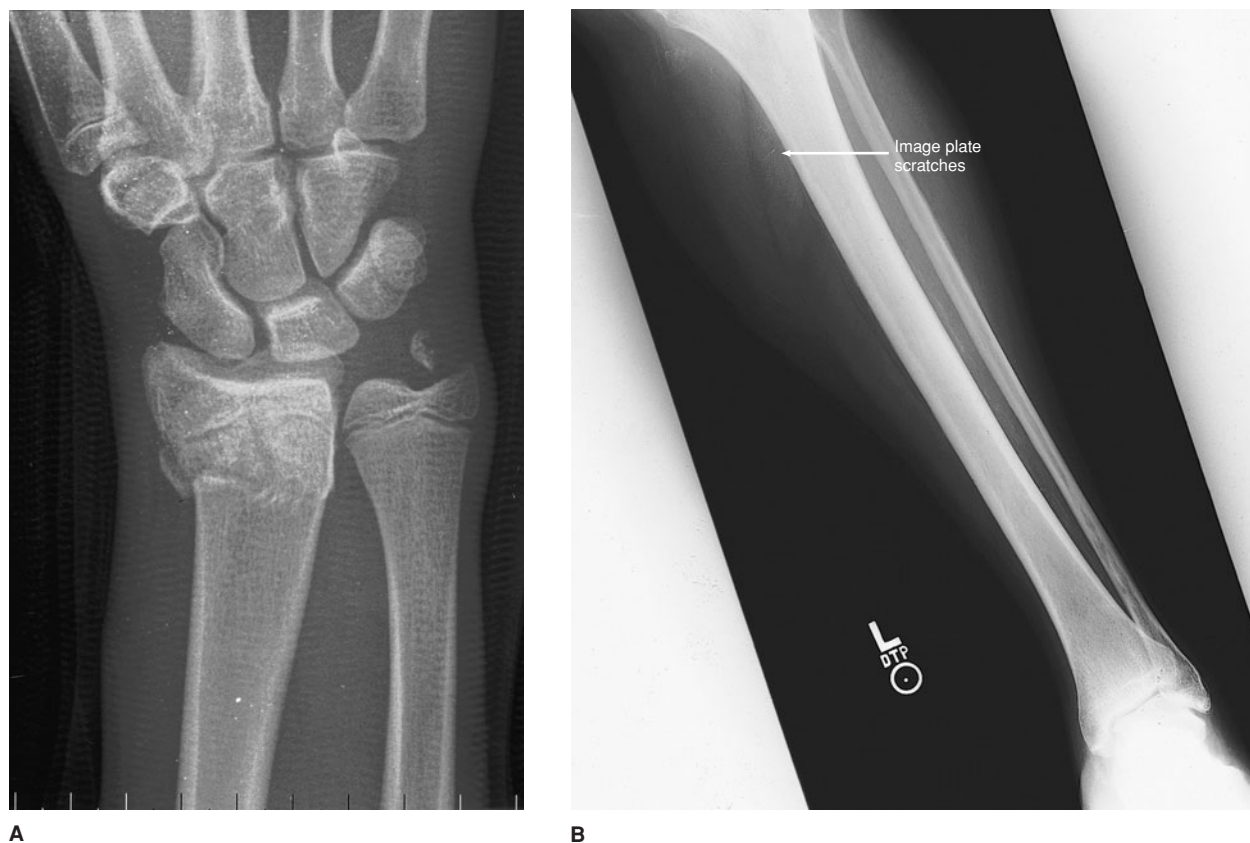
Figure 13–25. Dust/dirt on the CR image plate creates artifacts similar to those caused by dust on traditional intensifying screens. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003.)
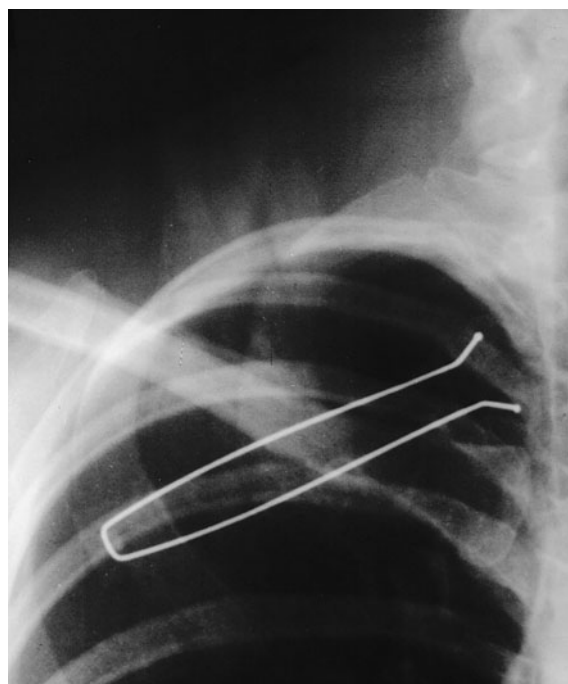
Figure 13–26. Hairpin and braid artifacts. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–27. The suspicious *coin lesion* seen in the mid–left-lung field was discovered to be a *wad of chewing gum* placed there for safekeeping during this radiographic examination!! (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
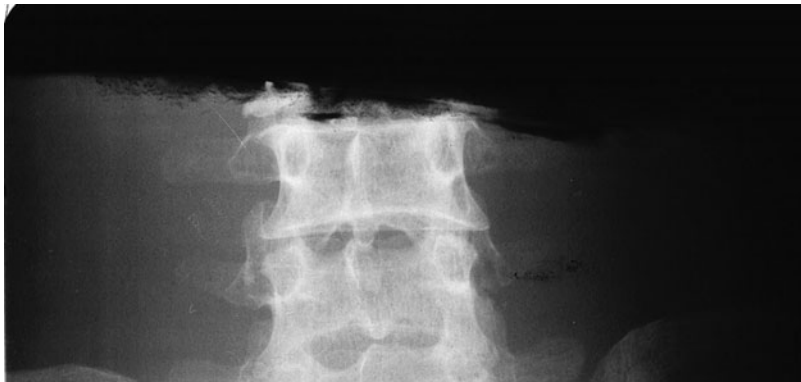
Figure 13–28. *Light leak.* Fogging from *exposure to white light*, such as film bin exposure resulted in exposed upper edge of film. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
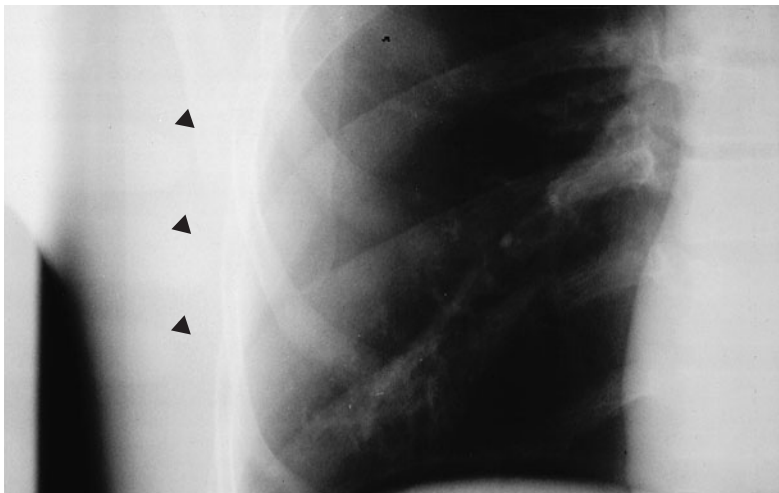
Figure 13–29. *Safelight fog.* Notice the fingers imaged in the soft tissues of the right thorax. This was probably caused by an unsafe safelight over the processor feed tray. The safelight wattage may be too great, or the safelight may be positioned too close to the feed tray. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–30. *Fingerprints.* Notice that the fingerprints are black (mid-right edge of film). If developer solution is on fingers while handling film, silver grains will be *overdeveloped* (black). If oils from the skin are deposited on the film during handling, developer will be prevented from reaching the silver grains and the fingerprints will be white (*undeveloped*). (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

A

B
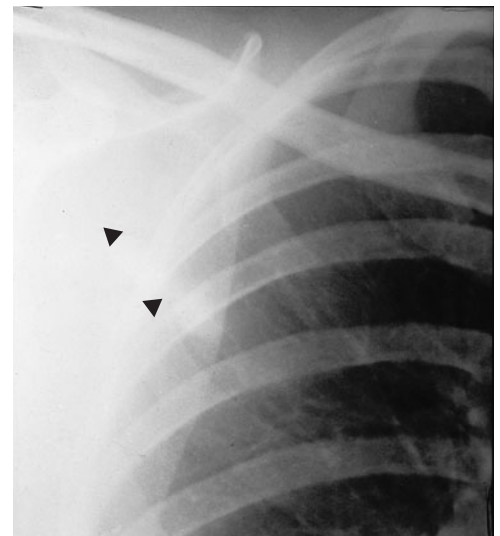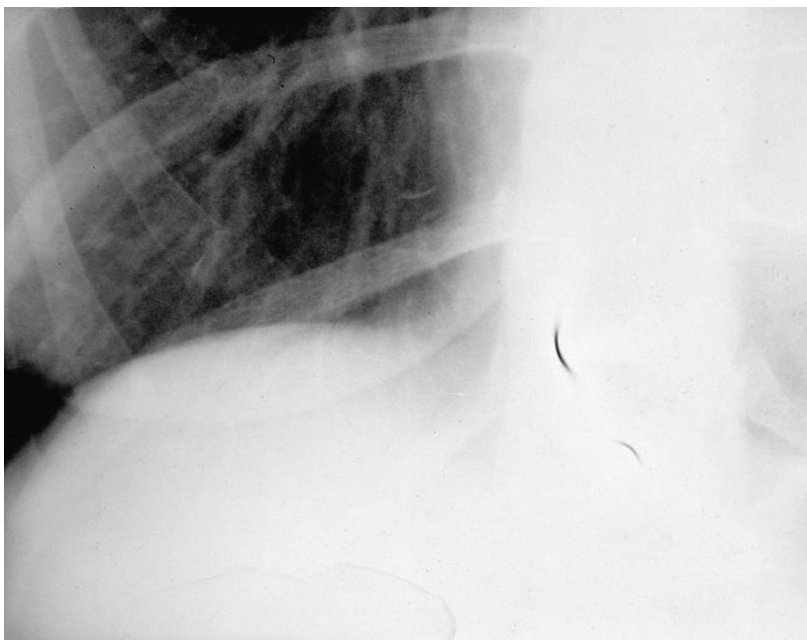
Figure 13–31. *Sensitized and desensitized marks.* **(A)** Typical, obvious *sensitized* (plus density) crescent (kink) mark caused by bending the film sharply *after* exposure. **(B)** Less-obvious *desensitized diffuse* (minus density) area (near the axillary border of fourth and fifth ribs) is caused by bending the film *before* exposure. Both of these artifacts are caused by *pressure on the film emulsion.* (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–32. *Scratches.* Notice that the scratches are varied and irregular, unlike processor scratches, which are usually uniform and regularly spaced. These scratches were probably made by *sliding one film from a box of tightly packed films.* (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
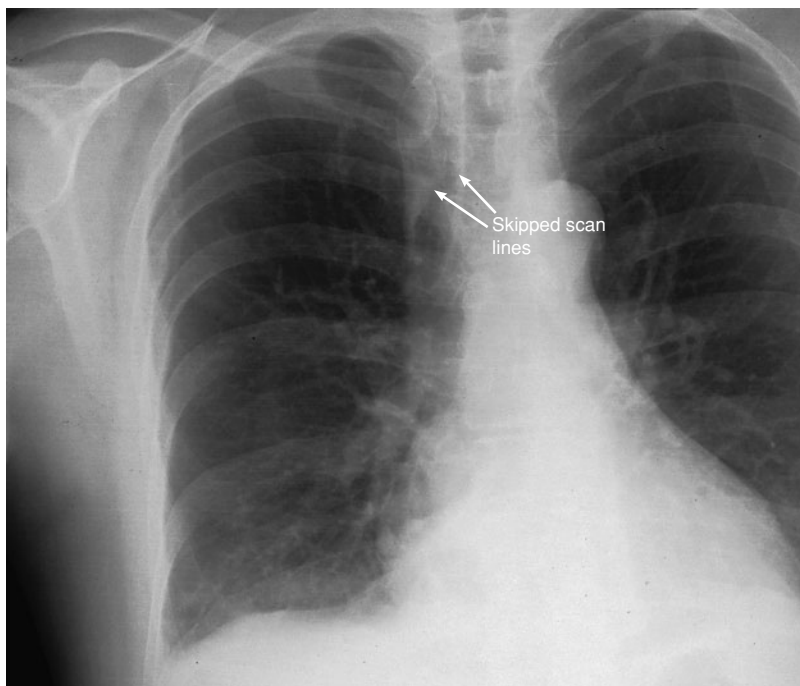
Figure 13–33. CR image demonstrating scratches on the image plate. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003.)
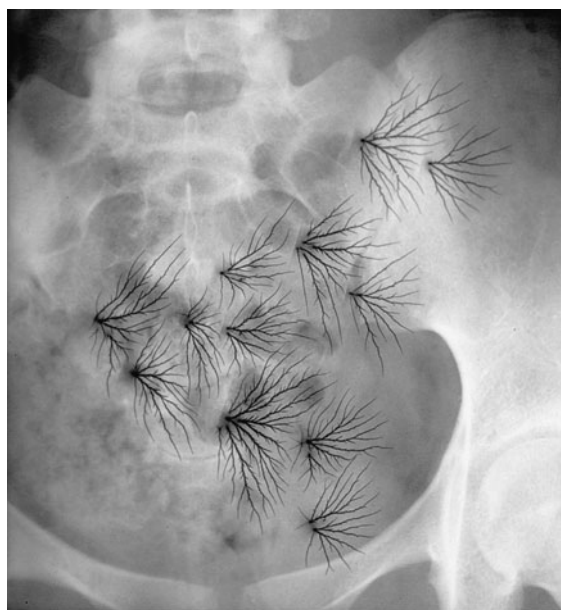
A

B

C

Figure 13–34. *Static electrical discharge*. **(A)** *Tree* static. **(B)** *Crown* static. **(C)** *Smudge* static. Static electricity artifacts are caused by *low humidity and improper handling* of films and can obscure diagnostic information. Darkroom personnel should avoid clothing made of *synthetic materials* and screens should be cleaned with special antistatic screen cleaner. Most importantly, because *friction between film and screen* causes static buildup, it is essential not to slide film in and out of cassettes. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
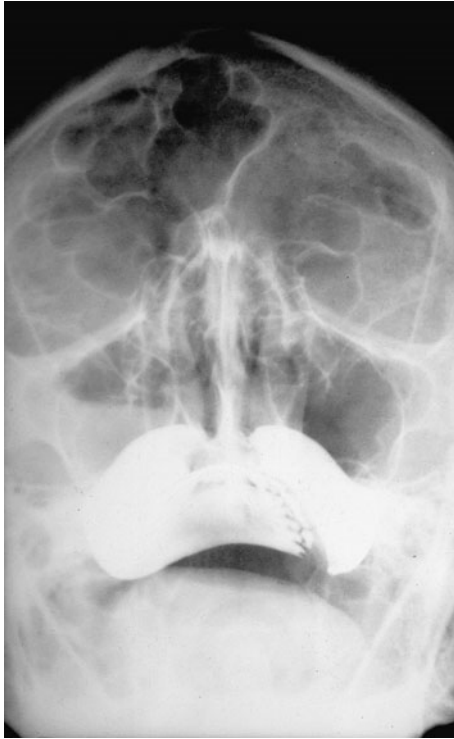
Figure 13–35. *Dentures artifact.* (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
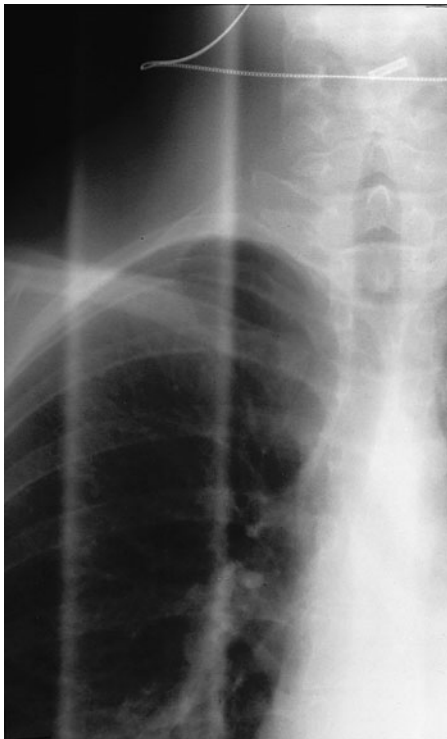
Figure 13–36. Neck chain held in patient's mouth, but (magnified) *IV pole* left between patient and x-ray tube!! (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–37. *Tape* used for immobilization is often imaged and can obscure bony detail. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

E. PROCESSING ERRORS AND MALFUNCTION

See Figures 13–38 through 13–43.
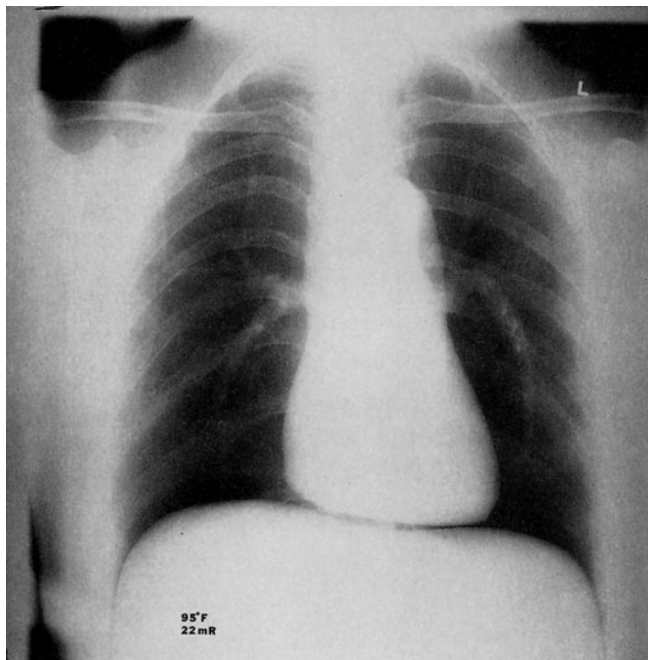
A
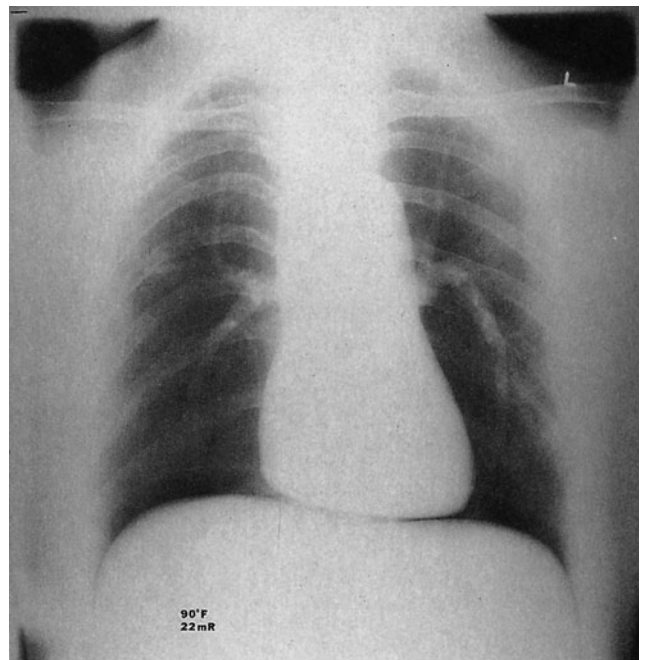
B

Figure 13–38. **(A)** Film received adequate development at 95°F and exhibits satisfactory density. **(B)** Film received insufficient development at 90°F and exhibits inadequate density caused by *underdevelopment.* Developer *activity is retarded by too low a temperature.* (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

A

B
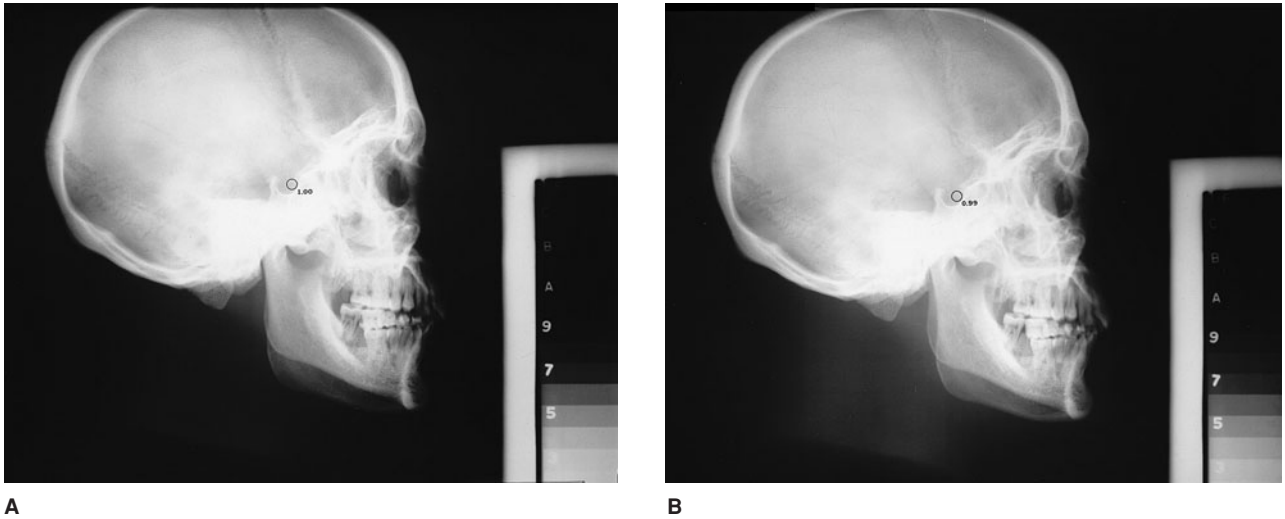
Figure 13–39. *Underreplenishment.* The only differences between films *A* and *B* are re-plenishment rate and mAs. *Notice the difference in exposure factors required to reproduce identical density:* film *A* at 37 mAs, film *B* at 50 mAs. While film *A* replenishment rate was 150 cc per 14 × 17-inch film, film *B* replenishment rate was 30 cc per 14 × 17-inch film. Underreplenishment leading to underdevelopment (and a "light" film) was *compensated for by an increase in mAs.* This problem was common before automatic processing. Today's quality control measures make this an unlikely occurrence. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–40. *Minus-density artifacts* (scratches), running in the direction of film travel, caused by *misaligned guide shoes.*

Figure 13–41. *Dirty-roller artifact.* Notice that the artifact is most apparent on the leading edge of the film (anterior chest) and diminishes with the film travel (as the film "cleans" the roller). (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)
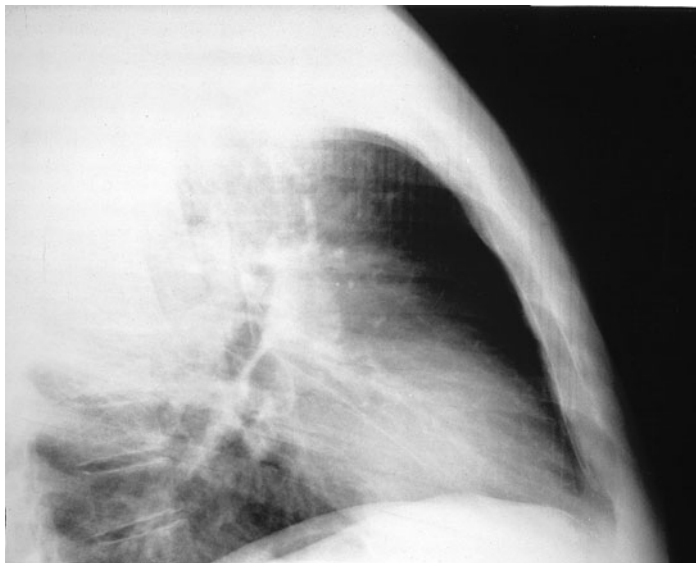
Figure 13–42. A *pi line* is a plus-density artifact occurring 3.14 inches from the film edge. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Figure 13–43. Artifact was caused by partially *crystallized fixer* on the edge of the developer–fixer crossover roller. (From the American College of Radiology Learning File. Courtesy of the American College of Radiology.)

Chapter Exercises

⭐ ***Congratulations!*** *You have completed this chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have mastered this section.*

1. Evaluate radiographs, assessing them for:
    A. recorded detail and distortion *(pp. 421–422).*
    B. radiographic density and contrast, including structural considerations *(p. 422, 424).*
    C. film and screen combinations *(pp. 422–423).*
    D. grid selection and use *(p. 423, 429).*
    E. film identification *(p. 423).*
    F. beam restriction *(pp. 423–424).*
    G. patient shielding *(p. 423).*
    H. proper use of AEC *(p. 423).*
    I. positioning accuracy, including structural considerations *(p. 423).*
    J. evidence of artifacts *(p. 424).*
    K. processing malfunctions or errors *(pp. 437–440,442–444).*

2. Determine the cause(s) of any problem(s) your evaluation has uncovered and discuss recommendations for corrective action.

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V

Equipment Operation and Quality Control

Chapter 15
Standards of Performance and
Equipment Evaluation
  I. **Equipment Calibration**
      A. kV
      B. mA
      C. Timer
      D. Reproducibility
      E. Half-Value Layer
      F. Focal Spot Size

 II. **Radiographic and Fluoroscopic**
     Accessories
      A. Cassettes
      B. Intensifying Screens
      C. Illumination
      D. Lead Aprons and Gloves
III. **Digital Imaging Considerations**

Chapter 16
Practice Test

Radiographic and Fluoroscopic Equipment

I. PRINCIPLES OF RADIATION PHYSICS

A. X-RAY PRODUCTION

Diagnostic x-rays are produced within the x-ray tube as high-speed *electrons* are rapidly decelerated by the tungsten target. The *source of electrons* is the heated cathode filament; they are driven across to the anode focal spot when thousands of volts (kV) are applied. When the high-speed electrons are suddenly stopped at the focal spot, their kinetic energy is converted to x-ray photon energy. This happens in two ways:

1. *Bremsstrahlung* ("Brems") or "braking" *radiation*: A high-speed electron, passing near or through a tungsten atom, is attracted and "braked" (i.e., slowed down) by the positively charged nucleus and deflected from its course with a loss of energy. *This energy loss is given up in the form of an x-ray photon* (Fig. 14–1). The electron might not give up all its kinetic energy in one interaction; it can go on to have several more interactions deeper in the anode, each time giving up an x-ray photon having less and less energy. This is one reason the x-ray beam has a heterogeneous *spectrum of energies*. Brems radiation *comprises 70% to 90%* of the x-ray beam.

2. *Characteristic radiation:* In the case of characteristic radiation, a high-speed electron encounters a tungsten atom within the anode and *ejects* a K shell electron (Fig. 14–2) leaving a vacancy in the K shell. An electron from the adjacent L shell fills the vacancy, and in doing so *emits a K characteristic ray*. The *energy* of the characteristic ray is equal to the *difference in energy between the K and L shell*.

B. X-RAY BEAM

1. Frequency and Wavelength. All *electromagnetic radiations*, including x-rays, can be described as wavelike fluctuations of electric
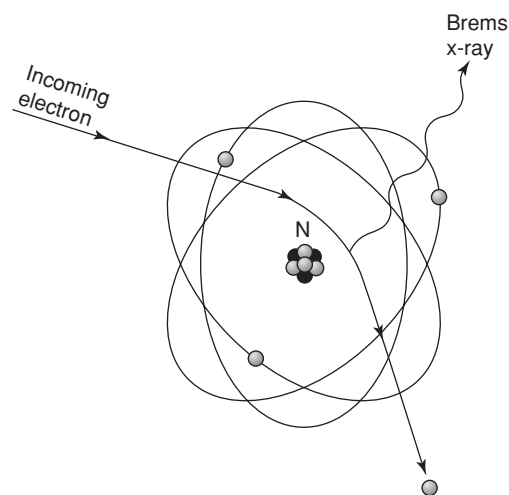
Figure 14–1. Production of bremsstrahlung (Brems) radiation. A high-speed electron is deflected from its path, and the loss of kinetic energy is emitted in the form of an x-ray photon.

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A Incoming electron strikes K shell tungsten electron.

B Both electrons leave the shell.

C The K vacancy is filled by an L shell electron. The difference in energy levels is represented by a K characteristic ray.
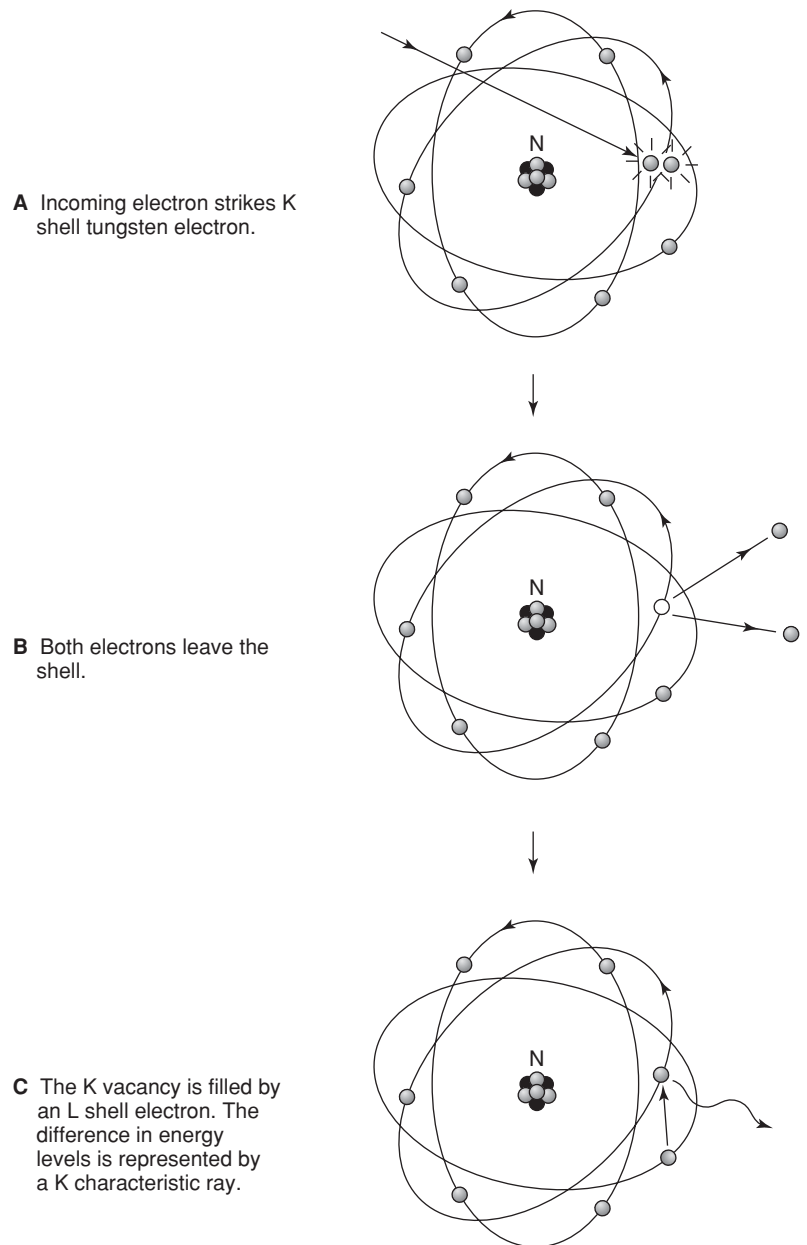
Figure 14–2. Production of characteristic radiation. A high-speed electron **(A)** ejects a tungsten K-shell electron, leaving a K-shell vacancy **(B)**. An electron from the L shell fills the vacancy and emits a K characteristic ray **(C)**.

and magnetic fields (Fig. 14–3). The figure illustrates that visible light, microwaves, and radio waves, as well as x-ray and gamma rays, are all part of the *electromagnetic spectrum*. All electromagnetic radiation has the same *velocity*, 186,000 miles per second (3×10^8 m/s); however, they differ greatly in *wavelength*.

Wavelength refers to the distance between two consecutive wave crests (Fig. 14–4). *Frequency* refers to the number of cycles per
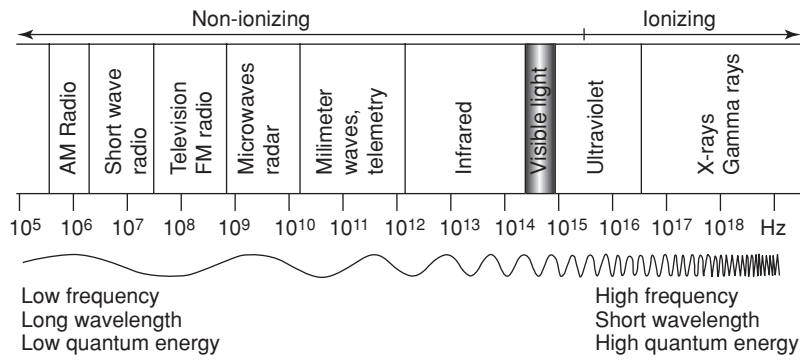
Figure 14–3. The electromagnetic spectrum. Frequency and photon energy are *directly* related; frequency and photon energy are *inversely* related to wavelength.

second (cps); its unit of measurement is the *hertz* (Hz), which is equal to 1 cps. Frequency and wavelength are closely associated with the relative *energy* of electromagnetic radiations. More energetic radiations have shorter wavelength and higher frequency. The relationship among frequency, wavelength, and energy is graphically illustrated by the electromagnetic spectrum.

2. Beam Characteristics. Some radiations, like x-rays, are energetic enough to rearrange atoms in materials through which they pass, and they can therefore be hazardous to living tissue. These radiations are called *ionizing* radiation because they have the energetic potential to break apart electrically neutral atoms, resulting in the production of negative and/or positive *ions*.

Figure 14–4. Wavelength versus frequency. *Wavelength* is described as the distance between successive crests. The shorter the wavelength, the more crests or cycles per unit of time (e.g., per second). Therefore, the shorter the wavelength the greater the *frequency* (number of cycles/second). Wavelength and frequency are *inversely* related.

X-rays are infinitesimal bundles of energy called *photons* that deposit some of their energy into matter as they travel through it. This deposition of energy and subsequent *ionization* has the potential to cause chemical and biologic damage. Several of the outstanding properties of x-ray photons are listed in the *summary box*.

The possibility of tissue damage as a result of exposure to x-ray photons depends partly on the *quantity* and *quality* of the x-ray beam and the exposure factors that contribute to these factors. The *primary beam* of x-rays refers to the x-ray beam that emerges from the x-ray tube focal spot, before it strikes anything. Many of these photons then encounter the part to be radiographed. X-ray photons emerging from the part are referred to as the *remnant or exit beam* and help contribute to forming the image. The principal factor affecting beam *quantity* is mAs; the principal factor affecting beam *quality* is kV. Another x-ray beam characteristic is described by the *inverse square law* of radiation. The inverse square law is particularly important in radiation protection considerations and in selection of exposure factors. These factors and many others are thoroughly discussed in Part III *Radiation Protection* and in Part IV *Image Production and Evaluation*.

C. PHOTON INTERACTIONS WITH MATTER

The gradual decrease in exposure rate as radiation passes through tissues is called *attenuation*. Attenuation is principally attributable to the two major types of interactions that occur between x-ray photons and tissue in the diagnostic x-ray range of energies.

1. Photoelectric Effect. In the *photoelectric effect*, a relatively *low*-energy (low-kV) x-ray photon uses all its energy (true/total absorption) to eject an *inner shell* electron, leaving an orbital vacancy. An electron from the shell above drops down to fill the vacancy and, in doing so, gives up energy in the form of a *characteristic ray* (Fig. 14–5).

Properties of X-Ray Photons

- X-rays are not perceptible by the senses.
- X-rays travel in straight lines.
- X-rays travel at the speed of light.
- X-rays are electrically neutral.
- X-rays have a penetrating effect on all matter.
- X-rays have a physiological effect on living tissue.
- X-rays have an ionizing effect on air.
- X-rays have a photographic effect on film emulsion.
- X-rays produce fluorescence in certain phosphors.
- X-rays cannot be focused.
- X-rays have a spectrum of energies.

Figure 14–5. In the photoelectric effect, all of the incoming (low-energy) photon's energy is absorbed as it ejects an inner shell electron from orbit.
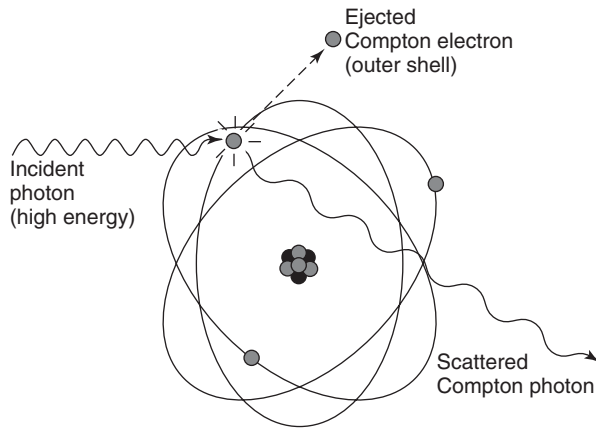
Figure 14–6. In Compton scatter, the incoming (high-energy) photon uses *part* of its energy to eject an outer shell electron; in doing so, the photon changes direction (scatters) but retains much of its original energy.

The photoelectric effect is more likely to occur in absorbers having *high atomic number* (e.g., bone, positive contrast media) and contributes significantly to patient dose, as all the photon energy is absorbed by the patient (and, therefore, is responsible for the production of short-scale contrast).

2. Compton Scatter. In *Compton scatter*, a fairly *high*-energy (high-kV) x-ray photon ejects an *outer shell* electron (Fig. 14–6). Though the x-ray photon is deflected with somewhat reduced energy (modified scatter), it retains most of its original energy and exits the body as an energetic scattered photon.

Because the scattered photon exits the body, it poses little radiation hazard to the patient. Some internal scatter, however, can contribute to patient dose. Compton scatter contributes to *image fog* and poses a *radiation hazard to personnel* (as in fluoroscopic procedures).

3. Coherent (Classical) Scatter. The process of *coherent* scatter is also known as *classical*, *unmodified*, or Rayleigh scatter. This interaction between x-rays and matter occurs with very low-energy x-ray photons—energies rarely used in diagnostic radiology. As a very low-energy x-ray photon interacts with an atom of matter, the photon "disappears" as it is absorbed by the atom, leaving the atom in an excited state. As the atom returns to its normal state, it releases an x-ray photon of *identical* wavelength, but traveling in a different direction than the incident photon (i.e., a *scattered photon*). It is important to note that this is the only interaction between x-ray photons and matter in which *no ionization occurs*.

4. Tissue Attenuation. The radiologic image is obtained as a result of the attenuation processes occurring in the body. Tissues that are very dense will allow little or no passage of x-rays—those tissues appear white or light on the image. Other tissues are easy for x-ray photons

to penetrate—those tissues appear darker. Sometimes we use contrast agents to better demonstrate certain parts; depending on the nature of the contrast agent, these parts will look lighter or darker. Some body parts are smaller while others are larger. Various pathologic conditions can alter the nature of the tissues they affect; this can also impact how light or dark the image will be. All this means that the *thickness* or size of body parts, as well as the *atomic number* of the tissue (e.g., bone vs. soft tissue), has a significant influence on photon interactions and, therefore, attenuation of the x-ray beam by various tissues.

■ *SUMMARY*

- **The radiations of the electromagnetic spectrum all travel at the same velocity, 186,000 miles per second, but differ in wavelength.**
- **Wavelength is the distance between two consecutive wave crests.**
- **The number of cycles and crests per second is frequency; its unit of measure is Hz.**
- **Wavelength and frequency are inversely related.**
- **Ionization is caused by high-energy, short-wavelength electromagnetic radiations that break apart electrically neutral atoms.**
- **Two types of x-radiation are produced at the anode through energy conversion processes: Brems radiation and characteristic radiation; Brems radiation predominates.**
- **X-rays can interact with tissue cells and cause ionization; interactions between x-rays and tissue cells are the photoelectric effect, Compton scatter and coherent (classical) scatter.**
- **Characteristics of photoelectric effect**
  - **Low-energy x-ray photon gives up all its energy ejecting an inner shell electron**
  - **Produces a characteristic ray (secondary radiation)**
  - **Major contributor to patient dose**
  - **Occurs in absorbers having high atomic number and mass density**
  - **Produces short-scale contrast**
- **Characteristics of Compton scatter**
  - **Predominates in the diagnostic x-ray range**
  - **High-energy x-ray photon uses a portion of its energy to eject an outer shell electron**
  - **Responsible for scattered radiation fog to the image**
  - **Radiation hazard to personnel and to patient as internal scatter**
- **Characteristics of coherent scatter**
  - **Very low-energy x-ray photon interacts with the atom, disappears, sets the atom into an excited state**
  - **As the atom returns to a normal state, an identical photon is emitted, but in a different direction**
  - **This is the only interaction that does not cause ionization**

■ **Exposure dose depends on beam attenuation and on which type of interaction occurs between x-ray photons and tissue. Exposure dose is, therefore, affected by radiation quality (kV) and the subject being irradiated (i.e., thickness and nature of part; atomic number of part).**

II. TYPES OF EQUIPMENT

The various kinds of x-ray machines are generally named according to the x-ray energy they produce or the specific purpose(s) for which they are designed, for example, mammographic unit, tomographic equipment, mobile unit, 150 kV (kilovolts) chest unit, 1200 mA (milliampere) general diagnostic unit, digital fluoroscopy (DF), digital R/F (radiography and fluoroscopy), or computed radiography (CR).

A. FIXED

Most x-ray equipment is *fixed*, or stationary, that is, it is installed in a particular place and cannot be moved. Most general radiographic and fluoroscopic equipment in the radiology department is fixed.

B. MOBILE

Mobile x-ray equipment is designed to be taken to patients who are unable to travel to the radiology department, for example, the very ill, incapacitated patients, and patients in surgery. Mobile equipment is available for radiographic and/or fluoroscopic x-ray procedures.

C. DEDICATED

X-ray equipment that is designed for a specific purpose or type of examination is referred to as *dedicated equipment*. Examples of dedicated equipment are head units, mammography equipment, chest units, tomographic equipment, bone densitometry, and dental units.

D. DIGITAL/ELECTRONIC

Computed radiography and digital fluoroscopy units are examples of equipment whose images can be manipulated and stored for transfer via electronic means and/or printed as hard copies. Detailed discussion of CR/DR is given in Chapters 11 and 12, and later in this chapter.

III. ELECTRICITY, X-RAY TRANSFORMERS, AND RECTIFIERS

Fundamental to the study of x-ray equipment is a basic understanding of magnetism and electricity. The relationship between magnetism and electricity is central to the operation of many x-ray circuit components; therefore, it is important to review these concepts prior to reviewing x-ray circuit components.

Generators function to change mechanical energy to electrical energy (whereas *motors* convert electrical energy to mechanical energy).
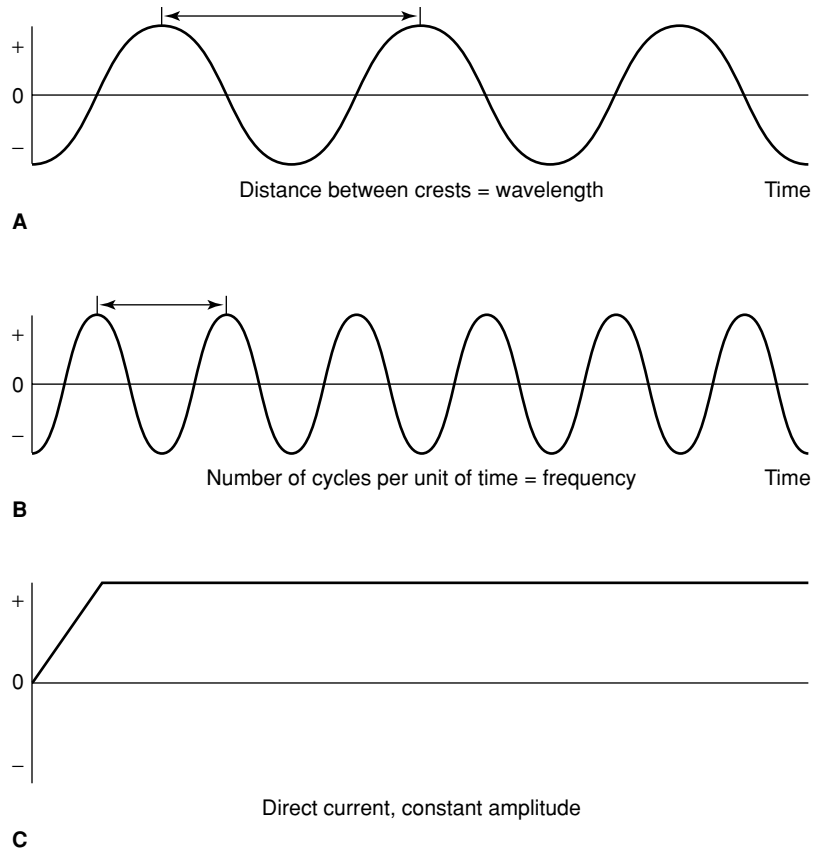
Figure 14–7. Alternating and direct current waveforms. **(A)** Alternating current (AC), low frequency. **(B)** High frequency AC. Compare the distance between crests and troughs in **(B)** with those in **(A)**. **(C)** Direct current, like that supplied by a battery, is characterized by constant amplitude (peak potential).

Alternating Current

- **Amplitude** and **polarity** vary periodically
- **Wavelength:** Distance between 2 consecutive crests; one positive and one negative half cycle
- **Crest:** Positive half cycle peak
- **Trough:** Negative half cycle peak
- **Amplitude:** Maximum height of the wave
- **Frequency:** Number of cycles per second
- **Hertz:** Unit of frequency

Electrical current flowing through a conductor in only one direction and with constant magnitude is called *direct current* (DC). A familiar source of direct current is the *battery*.

Electricity is more efficiently transported over long distances at low-current and high-voltage values to avoid excessive power loss (according to the power, or heat, loss formula: $P = I^2 R$). Most applications of electricity require the use of *alternating current* (AC), in which the amplitude and polarity of the current vary periodically with time (Fig. 14–7). AC consists of sinusoidal waves. One *wavelength* consists of two half cycles: a *positive half cycle* and a *negative half cycle*. A *wavelength* is defined as the distance between two consecutive *crests*. A crest is the positive half cycle peak and a *trough* is the negative half cycle peak. The maximum height of the wave/impulse is referred to as its *amplitude* and represents electrical potential, or voltage. *AC is therefore characterized by varying amplitude and periodic reversal of polarity.* The number of cycles per unit of time (e.g., second) is called *frequency* (Fig. 14–7), and its unit of measurement is the *hertz* (Hz). In the United States, AC is generated at 60 Hz or cps, that is, 60 cycles

(60 positive half cycles and 60 negative half cycles) occur each second. One half second, therefore, would include 30 cycles ($1/2 \times 60 = 30$); consequently, 4 cycles represent a 4/60 or 1/15 second time interval.

X-rays are produced when high-speed electrons are suddenly decelerated upon encountering the tungsten atoms of the anode. To produce x-rays of diagnostic value, high voltage must be available. To produce high-quality images, a selection of x-ray energy levels (kV) must be available. The use of alternating current and electromagnetic principles are fundamental to the operation of the high-voltage transformer and the autotransformer. These are the x-ray circuit devices responsible, respectively, for producing the required high voltage and permitting a selection of kilovoltages.

It has long been known that there is an important relationship between magnetism and electricity. Famous scientists, including Volta, Oersted, Lenz, and Faraday, performed various experiments demonstrating the relationship, making important observations, and formulating principles that explain the operation of electromagnetic devices.

Faraday's observation that a *magnetic field* will induce an electric current in a conductor if there is motion of either the magnetic field or the conductor (Fig. 14–8) is the fundamental principle of operation of the high-voltage *transformer*. If a coiled conductor is supplied with an AC, a magnetic field expands and collapses around the coil, accompanying the peaks and valleys of the AC waveform. If a second coiled conductor is placed near, but not touching, the first (primary) coil, the moving magnetic field will interact similarly with the second coil and an electric current will be induced in it. Thus, the moving magnetic field from the primary coil can be used to induce a current in another circuit with whom it has no physical connection; this is called *mutual induction*. An alternating current, producing a continuously moving magnetic field, is necessary for mutual induction to occur.

A conductive wire shaped into a coil is called a *helix*, a helix supplied with a current is a *solenoid*. If an iron core is inserted within the coil, a simple *electromagnet* is formed and the magnetic lines of force
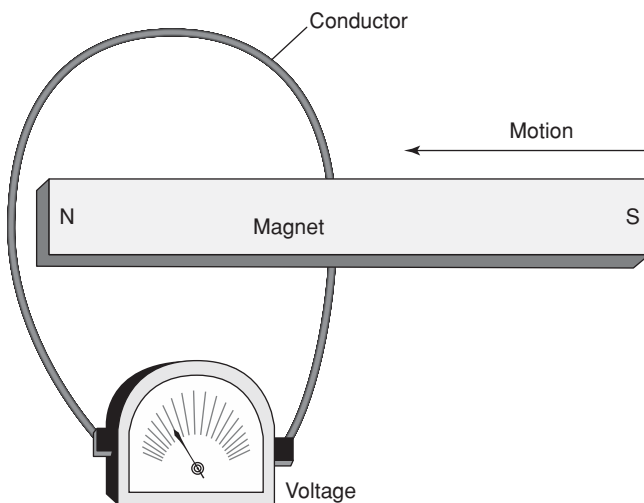
Figure 14–8. Electromagnetic induction. An electric current will be induced in a conductor whenever there is relative motion between a conductor and magnetic field; that is, if a conductor moves through a magnetic field, if a magnetic field moves across a conductor, or if the magnetic field is constantly changing (as in AC).

are intensified. Thus, a transformer's conductor is frequently coiled around an iron core to increase its efficiency.

■ *SUMMARY*

- ■ **X-ray equipment may be described as either fixed or mobile.**
- ■ **X-ray equipment designed for a particular purpose (e.g., mammographic, head, chest units) is termed *dedicated*.**
- ■ **A generator converts mechanical to electrical energy; a motor converts electrical to mechanical energy.**
- ■ **Electricity is transported over long distances at high-voltage and low-current values to minimize energy loss, according to the heat loss formula: $P = I^2 R$.**
- ■ **Alternating current is characterized by constantly changing polarity and amplitude.**
- ■ **A coil of wire is a helix; supplied with current it is a solenoid; with an iron core, it is the simplest type of electromagnet.**
- ■ **X-ray transformers operate on the principle of mutual induction.**

A. *HIGH-VOLTAGE TRANSFORMERS*

X-ray transformers are used to increase the incoming voltage to the more useful *kilovoltage* required for x-ray production. Transformers that increase voltage are called *step-up transformers* or high-voltage transformers. The degree to which transformers increase voltage is determined by their *turns ratio*, that is, the number of turns in the secondary (high-voltage) coil compared to the number of turns in the primary (low-voltage) coil; the higher the ratio, the greater the voltage increase. As voltage increases, however, current decreases proportionally according to the (*transformer law*) equations that follow:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \frac{N_s}{N_p} = \frac{I_p}{I_s}.$$

Notice that the relationship between the turns ratio and the *voltage* is a *direct one*, while there is an *inverse* relationship between the turns ratio and *current*. So, as voltage increases, current decreases proportionally.

For example, if a particular x-ray transformer has a turns ratio of 500 to 1 and is supplied with 50 A and 220 V, *what is its kV and mA output?*

$$\frac{x}{220} = \frac{500}{1} \qquad\qquad \frac{500}{1} = \frac{50}{x}$$
$$x = (500)(220) \qquad\qquad 500x = 50$$
$$x = 110,000 \text{ V} = 110 \text{ kV} \qquad x = 0.1 \text{ A} = 100 \text{ mA}.$$

Transformers can also be the *step-down* type, like that found in the x-ray filament circuit.

Although transformers operate at approximately 95% efficiency, energy loss varies according to transformer design. An *open-core* transformer consists of two parallel iron cores with conductive windings; however, a loss or leaking away of magnetic flux occurs at the ends

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Types of Energy Loss Inherent in All Transformers

- *Copper losses* are caused by the resistance to current flow that is characteristic of all conductors and are reduced by using larger *diameter* conductive wire.
- *Hysteresis losses* are a result of the continually changing magnetic domains of the core material (as a result of changing polarity of AC) and can be reduced by using core material of greater *permeability* (e.g., silicon).
- *Eddy current* losses are a result of small currents (eddy currents) built up in the core material as a result of the continually changing magnetic fields. Eddy current losses are reduced by *laminating* the core material; any currents generated can travel only the small distance between laminations and, therefore, represent a smaller energy loss.
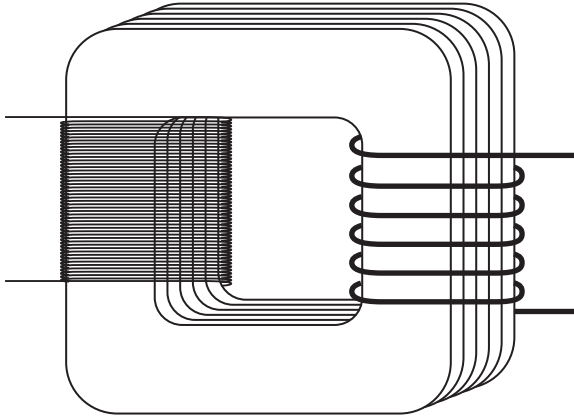
Figure 14–9. The *closed-core* transformer reduces loss of magnetic flux. Note the *laminated* silicon steel that serves to reduce *eddy-current* losses.

of the iron cores. A *closed-core* transformer (Fig. 14–9) consists of a ring-shaped core of iron that serves to reduce leakage flux energy loss. A *shell*-type transformer has a central partition, effectively dividing it into two halves. The transformer primary and secondary coil are wound around the center bar (but not touching each other) and this arrangement serves to reduce energy loss still further.

B. AUTOTRANSFORMERS

The x-ray circuit transformer is a *fixed*-ratio transformer, that is, the turns relationship is constant. How, then, are we able to have a selection of kilovoltages from which to choose? It is through the use of an *autotransformer*, which sends the correct amount of *voltage* to the primary of the high-voltage transformer to be stepped up to the required *kilovoltage* level.

The autotransformer consists of an iron core with a single coil wrapped around it (that serves as its primary and secondary winding) and operates on the principle of *self-induction*. Each coil turn has a contact or tap. A movable contact (corresponding to the kV selector dial on the control panel) makes connection with the appropriate tap on the autotransformer. The voltage sent to the primary coil of the high-voltage transformer depends on the number of coils "tapped." For example, a particular autotransformer has 2000 windings and is supplied with 220 V. If 500 windings are tapped, *what voltage is sent to the primary of the step-up transformer?* The solution can be determined by using the *autotransformer law* (which is the same as the transformer law):

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$\frac{x}{220} = \frac{500}{2000}$$

$$2000x = (500)(220)$$

$$2000x = 110,000$$

$$x = 55 \text{ V sent to primary coil of step-up transformer.}$$

■ *SUMMARY*

- **High-voltage (step-up) transformers function to provide the necessary kilovoltage for x-ray production.**
- **As the high-voltage transformer steps up voltage to kilovoltage, it proportionally steps down current according to the primary to secondary turns ratio and the transformer law.**
- **The transformer and autotransformer laws are expressed by the following equations:**

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

- **Step-down transformers are also called filament transformers; they function on the same principles as step-up transformers, and are placed in the filament circuit.**
- **Transformers can be designed as open core, closed core, or shell type.**
- **Transformers are approximately 95% efficient.**
- **Types of transformer losses include copper losses, eddy current losses, and hysteresis losses.**
- **The autotransformer, operating on the principle of self-induction, functions to provide a selection of kilovoltages.**
- **Both the transformer and autotransformer require AC for operation.**

C. Rectification

Some x-ray circuit devices, such as the transformer and autotransformer, will operate only on AC. The efficient operation of the x-ray tube, however, requires the use of unidirectional current, so current must be *rectified* before it gets to the x-ray tube. The process of full-wave *rectification* changes the negative half cycle to a useful positive half cycle.

An x-ray circuit rectification system is located between the secondary coil of the high-voltage transformer and the x-ray tube. Rectifiers are solid-state diodes made of *semiconductive materials* such as silicon, selenium, or germanium that conduct electricity *in only one direction*. Thus, a series of rectifiers placed between the transformer and x-ray tube function to change alternating current to a more useful unidirectional current.

Although rectification remedies the changing polarity problem of single-phase AC, the problem of constantly varying amplitude remains. The continually changing voltage from zero to maximum potential and back to zero produces a pulsating beam of x-rays having a wide range of energies. *Three-phase rectification* superimposes three AC waveforms, each separated from the other two by 120 degrees and resulting in a nearly constant potential waveform. While *single-phase rectification* produces a waveform having 100% "ripple" (i.e., 100% drop in potential between pulses), the three-phase waveform exhibits only a slight drop between pulses (Fig. 14–10).

Three-phase/6-pulse rectification presents a 13% ripple; 3-phase/12-pulse presents only a 4% ripple. The average beam energy therefore

Figure 14–10. **(A)** Single-phase, full-wave rectified waveform. Note the 100% voltage ripple as each pulse starts at 0 potential, makes its way to 100%, and returns to 0 potential. **(B)** The three-phase/six-pulse waveform exhibits a 13% voltage drop between peak potentials. **(C)** Three-phase/12-pulse has only a 4% voltage drop between peak potentials. **(D)** High-frequency generators are most efficient and produce less than 1% voltage ripple.

Figure 14–11. A simplified diagram of the secondary (high-voltage) side of a 3φ 6p rectified x-ray circuit. 3φ equipment requires the use of three autotransformers (not shown) and one transformer having three windings arranged in *delta* and *star* (or wye) configuration.

increases. For example,

1φ 2p − 100 kV − approximately 70 keV (kilo-electron volt) beam

3φ 6p − 100 kV − approximately 95 keV beam

3φ 12p − 100 kV − approximately 98 keV beam.

Three-phase rectification requires the use of *three autotransformers* (one for each incoming current) and *one transformer* having three windings. A transformer winding can be arranged in either *star* (wye) or *delta* configuration (Fig. 14–11).

Remember that a change in technical factors is required when changing among Sφ to 3φ 6p to 3φ 12p rectified equipment.

Comparison of Technical Factors Required		
Single φ	3φ 6p	3φ 12p
mAs	2/3 *x* mAs	1/2 *x* mAs

■ *SUMMARY*

- ■ **The x-ray tube operates most efficiently on unidirectional (pulsating) current.**
- ■ **The rectification system changes AC to unidirectional current and is located between the secondary coil of the high-voltage transformer and the x-ray tube.**
- ■ **Rectifiers are solid-state diodes made of semiconductive materials such as silicon, selenium, or germanium that permit the flow of electricity in only one direction.**
- ■ **3φ rectification uses three alternating currents out of phase with each other by 120 degrees.**
- ■ **In 3φ rectification, only the peak values of the waveform are used, thus creating a nearly constant potential current.**
- ■ **3φ rectification may be 6 pulse (13% ripple) or 12 pulse (4% ripple), depending on the number of rectifiers employed.**
- ■ **3φ rectified equipment requires three autotransformers and one high-voltage transformer.**
- ■ **3φ high-voltage transformer windings are arranged in either star (wye) or delta formation.**

IV. THE X-RAY TUBE

X-rays are produced when high-speed electrons emitted from the cathode filament are suddenly decelerated as they encounter tungsten atoms of the x-ray tube anode or target. This can happen in two ways; a review of the two processes follows:

1. *Bremsstrahlung* ("Brems") or "braking" *Radiation*. A high-speed electron, passing through a tungsten atom, is attracted and "braked" (i.e., slowed down) by the positively charged nucleus, and therefore is deflected from its course with a resulting loss of energy. *This energy loss is given up in the form of an x-ray photon* (Fig. 14–1). The electron may not give up all its kinetic energy in one such interaction; it may go on to have several more interactions deeper in the target, each time giving up an x-ray photon having less and less energy. This is one reason the x-ray beam is heterogeneous (i.e., has a spectrum of energies). Brems radiation comprises 70% to 90% of the x-ray beam.
2. *Characteristic Radiation*. In this case, a high-speed electron encounters the tungsten atom and ejects a K shell electron, leaving a vacancy in the K shell. An electron from the adjacent shell (i.e., the L shell) fills the vacancy and in doing so *emits a K characteristic ray* (see Fig. 14–2). The energy of the characteristic ray is equal to the difference in energy between the K and L shells.

A. *COMPONENT PARTS*

X-ray tubes are used for both radiographic and fluoroscopic purposes. Their basic components are the *anode* (positive electrode) and *cathode* assembly (negative electrode), enclosed within an evacuated *glass envelope* (Fig. 14–12).
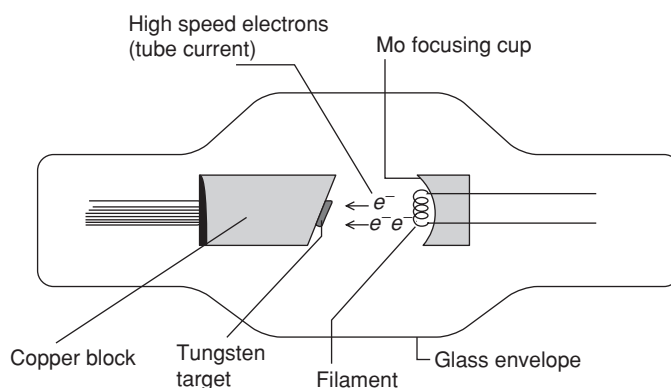
Figure 14–12. A simplified illustration of a *stationary* anode x-ray tube. The tungsten target is embedded in a solid block of copper that serves to conduct heat away from the tungsten and into the oil coolant that surrounds the glass envelope. Most x-ray tubes today use *rotating* anodes as a means of more even heat distribution.

The *glass envelope* enclosure creates a *diode* (two electrodes) tube somewhat reminiscent of early radio and television tubes. The x-ray tube glass enclosure, however, is made of glass that is extremely heat resistant to maintain the necessary *vacuum* for the production of x-rays. Should the vacuum begin to deteriorate, air molecules within the tube would collide with, and decelerate, the high-speed electrons traveling to the anode, thus diminishing the production of x-rays. Air within the glass envelope is referred to as a "gassy tube" and will eventually cause oxidation and burnout of the cathode filament.

The cathode assembly consists of one or more *filaments*, their supporting wires, and a *focusing cup*. The filament is a fine (approximately 0.2-mm diameter), 1- to 2-cm coil of tungsten wire that, when heated to incandescence by approximately 4 A of current, boils off (i.e., liberates) outer shell tungsten electrons. This event is called *thermionic emission*. Most x-ray tubes actually have two or more filaments and are called *double-focus tubes*. The typical x-ray tube has two filaments, one small and one large, to direct electrons to either the small or large anode focal spot. Each filament is closely embraced by a negatively charged molybdenum focusing cup that serves to direct the electrons toward the anode.

As the filament boils off electrons, small quantities of tungsten can be vaporized and deposited on the inner surface of the glass envelope. If tungsten is deposited on the port window, it acts as a filter and reduces the intensity of the x-ray beam; it can also affect the tube vacuum and ultimately leads to tube failure.

The filament is heated with the required 3 to 5 A and 10 to 12 V by the *filament circuit*. The filament current is kept at a standby quantity until the rotor is activated; at that time, the *filament booster circuit* brings it up to the level required for exposure. The rotor switch should not be activated for extended periods because the filament current is at maximum potential and tungsten vaporization can increase. Extended activation can also result in bearing damage and decreased tube life.

The anode is a 2- to 5-inch diameter molybdenum or graphite disk with a beveled edge. The beveled surface has a *focal track* of tungsten and rhenium alloy. The anode rotates at approximately 3600 rpm (high-speed anode rotation is approximately 10,000 rpm), so that heat generated during x-ray production is evenly distributed over the entire track. *Rotating anodes* can withstand delivery of a greater amount of heat for a longer period of time than *stationary anodes*.

The anode is made to rotate through the use of an *induction motor*. An induction motor has two main parts, a *stator* and a *rotor*. The stator is the part located outside the glass envelope and consists of a series of electromagnets occupying positions around the stem of the anode. The stator's electromagnets are supplied with current and the associated magnetic fields function to exert a drag or pull on the rotor within (Fig. 14–13).

Tungsten (W) is usually chosen as target material because of its *high atomic number* ($Z = 74$), *high melting point* (3410°C), and *thermal conductivity* (equal to that of copper). The high atomic number serves to increase the efficiency of x-ray production; its high melting point makes it resistant to pitting and cracking; its thermal conductivity helps it dissipate the heat produced during x-ray production. Rhenium is added to further resist anode pitting at high temperatures (Fig. 14–14).

Characteristics of Tungsten (W) As Target Material

- High atomic number (74) increases x-ray production
- High melting point (3410°C) to resist pitting and cracking
- Thermal conductivity for heat dissipation
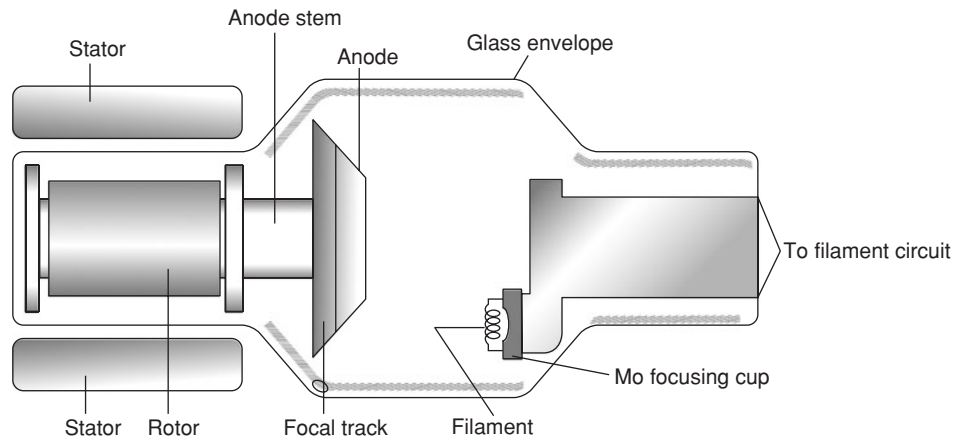
Figure 14–13. The component parts of a rotating anode x-ray tube. Note the position of the stator and rotor. Note the beveled edge of the anode, forming the focal track, and the position of the filament directly across from the rotating focal track.
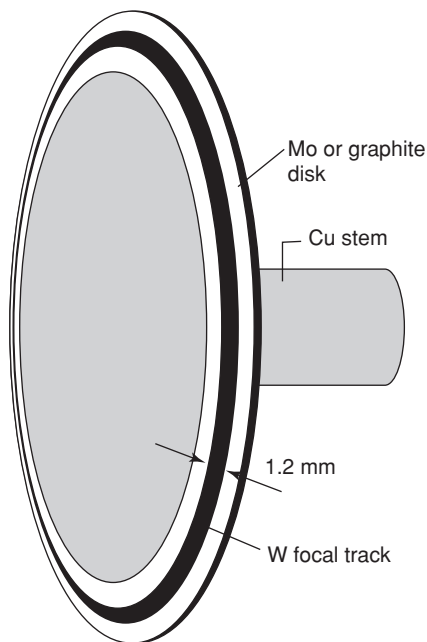
Figure 14–14. A typical rotating anode. The anode disk is usually made of molybdenum and has a beveled edge containing a "band" of tungsten/rhenium alloy that forms the focal track.

■ *SUMMARY*

- **X-rays (Brems and characteristic) are produced by the abrupt deceleration of high-speed electrons by tungsten atoms within the target (anode).**
- **The x-ray tube is a diode, that is, it has a negative electrode (cathode) and a positive electrode (anode).**
- **The x-ray tube's electrodes are enclosed within a vacuum glass envelope; a "gassy" tube produces x-rays less efficiently and results in filament oxidation or burnout.**
- **The cathode assembly consists of tungsten filament(s) with supporting wires and a (negatively charged) molybdenum focusing cup.**
- **Most x-ray tubes have at least two filaments, one for each focal spot.**
- **Heating of the filament to incandescence (with 3–5 A, 10–12 V) and subsequent "boiling off" of electrons is called thermionic emission.**
- **The anode is a 2- to 5-inch molybdenum or graphite disk with a peripheral focal track of tungsten and rhenium alloy.**
- **Tungsten is the target material of choice because of its high atomic number, high melting point, and thermal conductivity; rhenium helps prevent pitting.**
- **An induction motor, consisting of stator and rotor, rotates the anode 3600 to 10,000 rpm.**

The production of x-rays involves the generation of significant amounts of heat; *only 0.2% of the kinetic energy of the electron stream is converted to x-rays*, and the rest of the energy is converted to *heat*. Because heat can be very damaging to the x-ray tube and its efficient operation, several features are incorporated to expedite its dissipation.
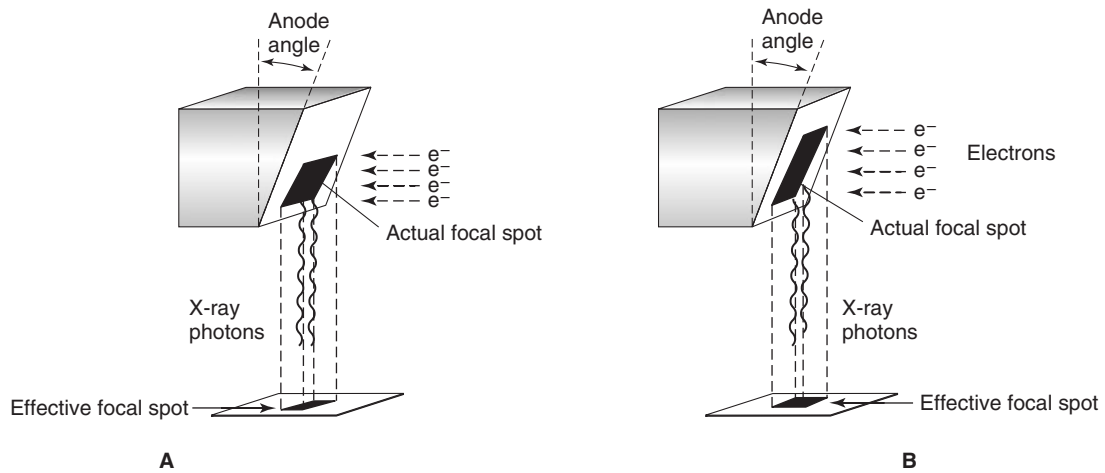
Figure 14–15. Line focus principle. Note how foreshortening of the actual focal spot impacts the effective (projected or apparent) focal spot. **(A)** A square actual focal spot produces a rectangular effective focal spot. **(B)** An elongated actual focal spot produces a square effective focal spot. As the anode *angle* is made smaller, the actual focal spot may be made larger while a small effective focal spot is still maintained.

The *thermal conductivity* of tungsten is one feature; however, most cooling is a result of heat diffusion to the oil that surrounds the x-ray tube. If large quantities of heat were continually directed to a single stationary small spot, that spot would be subjected to all the heat generated and would suffer more abuse and subsequent damage. The focal track of the rotating anode serves to spread generated heat over a large area. The width of the focal track on the anode's beveled edge is approximately 6 mm. Rotating anodes having a diameter of 2 to 5 inches will, therefore, provide significant surface area for the production and dissipation of heat.

The width of the beveled focal track is referred to as the *actual* focal spot size. A distinction is made between the actual focal spot and the *effective*, projected, or apparent focal spot. The actual focal spot size is the width of the finite area on the tungsten target that is actually bombarded by electrons from the filament. The effective, projected, or apparent focal spot is the *foreshortened* size of the focus as it is projected down toward the image receptor, that is, as it would be seen looking up into the x-ray tube (Fig. 14–15). This is called line focusing or the *line focus principle*. The effective focal spot size is also affected by the degree of focal track bevel, or anode angle. Anode angles are usually 5 to 20 degrees. Anode angle also has a significant effect on the severity of the heel effect. The line focus principle and the *anode heel effect*, and their effects on radiographic quality, are discussed more fully in Part IV. When specifying focal spot size, it is the effective focal spot size that is quoted. We often speak of "double focus" x-ray tubes, meaning that a small (e.g., 0.6 mm) and a large (1.2 mm) focal spot are available to choose from. These x-ray tubes actually have only one focal track, a portion of it is used for the small focus setting. It is more accurate to say that these are *double filament* tubes, for there are two filaments: the smaller one is activated when the small focal spot is selected, and the large one is activated for the large focal spot.

The amount of heat produced at the target is expressed in terms of *heat units* (HU). Exposure factor selection has a significant effect on the production of heat as expressed in the following equation.

$$HU = mA \times s \times kV \text{ (single phase)}$$

For example,

300 mA, 0.4 second, 80 kV = 9600 HU

300 mA, 0.2 second, 92 kV = 5520 HU

Thus, a greater number of heat units are produced with higher mAs and lower kV exposure factors. A *correction factor* is added to the equation when using three-phase equipment.

$$HU = mA \times s \times kV \times 1.35 \, (3\varphi \, 6p)$$

$$HU = mA \times s \times kV \times 1.41 \, (3\varphi \, 12p)$$

For example,

300 mA, 0.4 second, 80 kV (3φ 6p) = 12,960 HU

300 mA, 0.4 second, 80 kV (3φ 12p) = 13,536 HU

B. OPERATION

Each x-ray tube has its own *tube rating chart* and *anode cooling curve* that illustrate safe tube *heat limits* and the particular *cooling characteristics* of the anode. It is essential that the radiographer know how to use these charts in order to use the x-ray tube properly and safely and to prolong its useful life (Fig. 14–16).

For example, what is the maximum safe kV that may be used with each of the three x-ray tubes using 200 mA and 0.2-second exposure?

Do this for each of the x-ray tubes illustrated: Find the exposure time on the horizontal axis, follow it up until it meets the 200 mA line, and then follow that across to the vertical axis and read the kV.

A = approximately 147 kV; B = greater than 150 kV (off the chart); C = approximately 57 kV.

Comparing these answers with the information provided in the legend for Figure 14–16, it can be seen that the *size of the focal spot* and the *type of rectification* significantly impact heat loading characteristics of an x-ray tube.

Next, refer to the anode-cooling curve. For example, if the x-ray tube were saturated with 1,300,000 HU, it would take 30 minutes to cool down to 300,000 HU. How long would it take to cool from 700,000 HU to 450,000 HU? (Answer: Approximately 10 minutes.)

C. CARE

Careless treatment or abuse of the x-ray tube, as well as normal wear and tear, will lead to its ultimate demise.

1. Some Causes of X-Ray Tube Failure

Vaporized Tungsten—As a result of thermionic emission, quantities of tungsten can be vaporized and deposited on the inner surface of the glass envelope. When deposited on the port
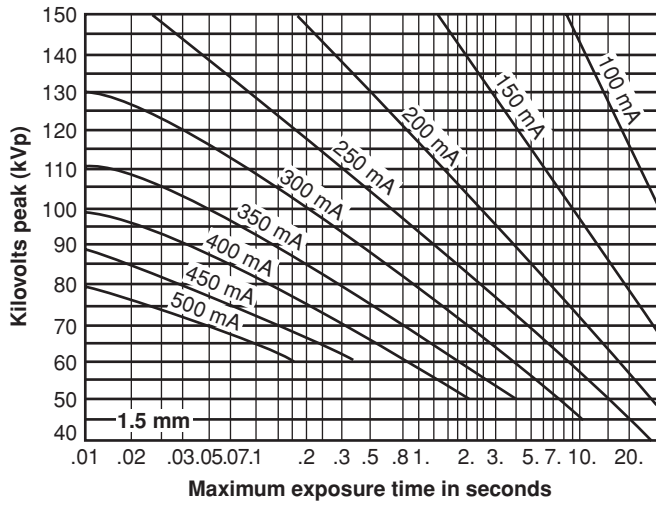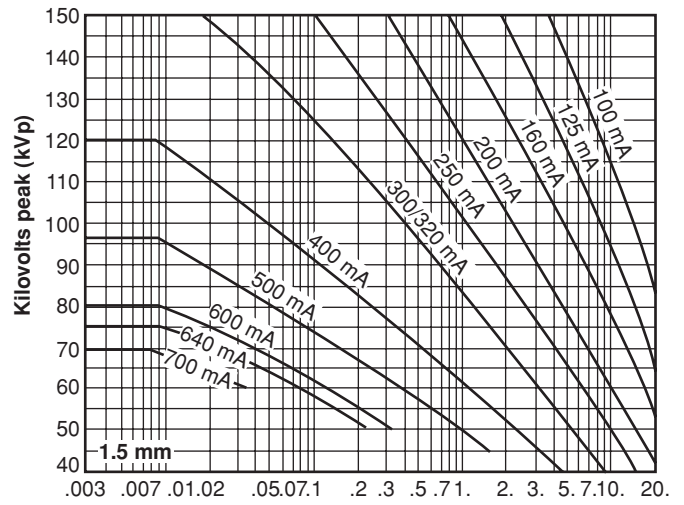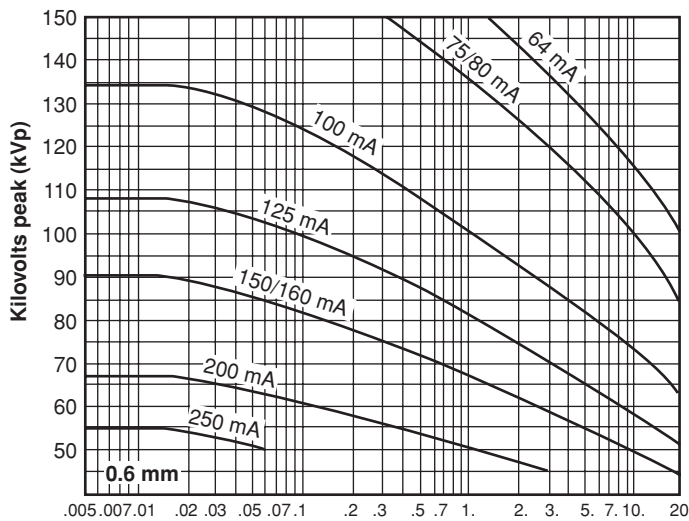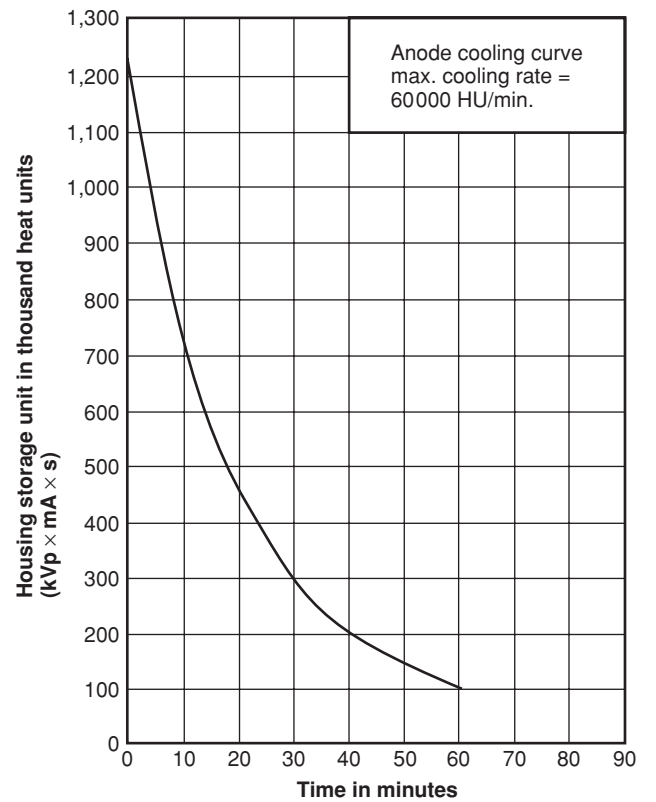
Figure 14–16. Three radiographic tube rating charts. **(A)** A Sφ 60-Hz tube with 1.5-mm focal spot. **(B)** A 3φ 60-Hz tube with 1.5-mm focal spot. **(C)** A 3φ 60-Hz tube with 0.6-mm focal spot. **(D)** An anode-cooling curve illustrates the cooling characteristics of the x-ray tube. (Reproduced, with permission, from General Electric Company.)

window, tungsten acts as a filter and reduces the intensity of the beam; it can also alter the tube vacuum and finally leads to tube failure.

Pitted Anode—Exposures made exceeding the tube rating create enough excessive heat to produce many small melts, or pits, over the surface of the focal track. X-ray photons are absorbed by these surface irregularities and, consequently, x-ray intensity is reduced. Extensive *pitting* also results in *vaporized* tungsten deposited on the inner surface of the tube window that acts as an additional filter and further reduces beam intensity. Arcing can occur between the filament and tungsten deposit, resulting in a cracked glass envelope.

Cracked Anode—A single, large, excessive exposure to a cold anode can be severe enough to crack the anode: the large dose of heat creates sudden expansion of the cold anode. It is therefore advisable to practice tube *warm-up procedures*, as suggested by the manufacturer, prior to starting the day's examinations or after the tube has not been used for several hours. Typical warm-up procedure consists of two exposures made using 100 mA, 2-second exposure, and 70 kV. The long 2-second exposures distribute heat over the entire surface of the anode and promote uniform thermal expansion of the anode.

Gassy Tube—If the tube vacuum begins to deteriorate, air molecules collide with and decelerate the high-speed electrons, thus decreasing the efficiency of x-ray production. The condition is referred to as a "gassy tube" and eventually causes oxidation and burnout of the cathode filament.

■ *SUMMARY*

- **Most of the energy used to produce x-rays is converted to heat; only 0.2% is converted to x-rays.**
- **Heat is damaging to x-ray tubes; x-ray tubes are surrounded with oil to carry heat away from the anode (also for insulating purposes).**
- **The width of the focal track is identified as the actual focal spot; its bevel (angle) projects a smaller, effective focal spot to the image receptor according to the line-focus principle.**
- **The degree of anode bevel (angle) influences the degree of heel effect; the smaller the angle, the more pronounced the heel effect.**
- **Heat units (HU) are used to express the degree of accumulation of anode heat and determined by mA × time × kV; the correction factor for 3φ 6p is 1.35 and for 3φ 12p, it is 1.41.**
- **Excessive heat loading will cause accelerated tube aging and failure as a result of conditions such as pitted or cracked anode, gassy tube, or vaporized tungsten.**
- **Tube rating charts and anode cooling curves must be used to determine safe exposures and heat loading.**

V. THE RADIOGRAPHIC CIRCUIT

The x-ray circuit can be divided into three portions:

1. The low-voltage, or primary, circuit contains most of the devices found on the control console.
2. The *filament circuit* varies the current sent to the filament to provide the required mA value.
3. The *high-voltage*, or *secondary*, *circuit* includes the high-voltage transformer, rectification system, and x-ray tube.

A. PRIMARY CIRCUIT COMPONENTS

1. Primary or Low-Voltage Circuit Devices

Main Switch and Circuit Breakers—These are usually located on a wall in or near the x-ray room (Fig. 14–17). Circuit breaker switches must be closed to energize the equipment.

Autotransformer—The autotransformer is a variable transformer that operates on AC and enables the radiographer to select kilovoltage. The function and operation of the autotransformer was discussed earlier in this section.

kV Selector—This is used by the radiographer to choose the kilovoltage, often as kV major (in increments of 10) and kV minor (in increments of 2). In doing so, the appropriate number of coils

1 = Auto transformer
2 = Primary coil, high voltage transformer
3 = Secondary coil, high voltage transformer
4 = mA meter
5 = Rectifiers
6 = Filament circuit
7 = X-ray tube
A = Primary/low voltage circuit
B = Secondary/high voltage circuit

Figure 14–17. Simplified x-ray circuit. High-voltage current from the secondary transformer coil is rectified before it reaches the x-ray tube.

(representing V) on the autotransformer are selected by the movable contact.

Line-Voltage Compensator—This functions to automatically adjust for any fluctuations in incoming voltage supply. A uniformly consistent and accurate voltage supply is required for predictable radiographic results. A small variation in voltage entering the primary transformer coil voltage represents a much larger variation as it leaves the secondary coil. The control consoles of some older x-ray units were equipped with line-voltage compensators that were adjustable by the radiographer, but in equipment manufactured today, the process takes place automatically within the machine.

Timer—_Timers_ function to regulate the length of x-ray exposure. Very simple timers such as the mechanical, synchronous, and impulse timers are rarely used in x-ray equipment manufactured today because they do not permit very fast, accurate exposures. _Mechanical timers_ are capable of exposures only as short as $1/4$ second; _synchronous timers_ as short as 1/60 second. _Impulse timers_ are more accurate and capable of exposures as short as 1/120 second.

Types of X-Ray Timers

- Mechanical
- Synchronous
- Impulse
- Electronic
- mAs
- AEC (phototimer or ionization chamber)

The _electronic timer_ used in x-ray equipment manufactured today is somewhat complex and based on a capacitor–resistor circuit. Electronic timers are very accurate and capable of rapid exposures as short as 1 millisecond (i.e., 1/1000 or 0.001 second).

The _milliampere-second timer_ (mAs timer) monitors the product of mA and time and terminates the exposure when the desired mAs has been reached. mAs timers are found on some mobile x-ray units. They are also found on some older fixed x-ray units and display the mAs exposure value when exposure time is too short to permit the actual mA to register on the mA meter.

Another type of timer is the automatic exposure device (AED), or _automatic exposure control_ (AEC), which functions to produce consistent radiographic results (Fig. 14–18). AECs have sensors that signal to terminate the exposure once a predetermined, known correct, exposure has been reached.

One type of AEC, the _ionization chamber_, is located just beneath the tabletop, above the x-ray cassette. The part being imaged is centered to the sensor and exposed. When the predetermined quantity of air ionization has occurred within the chamber, as measured and determined by an electrometer, the exposure is automatically terminated.

Another type of AEC is the _phototimer_, located behind the cassette. The phototimer consists of a special fluorescent screen that, when activated by x-ray, produces light and charges a photomultiplier tube. When the correct charge has been reached, as determined by the electrometer, the exposure is automatically terminated. Special cassettes, having very little foil backing, are often used with phototimers.

A _backup timer_ (the manual timer) is used to protect the patient from excessive exposure and x-ray tube from damage should the AEC fail to operate properly. Additional discussion of AECs can be found in Part IV.

X-ray timer malfunction can cause undesirable fluctuation in radiographic density. If the timer terminates the exposure too soon, the

Figure 14–18. Two types of automatic exposure controls. The AEC on the _top_ consists of an _ionization chamber_ located _under the x-ray tabletop._ The electrometer measures the number of ionizations and terminates the exposure once a predetermined quantity has been reached. The AEC on the _bottom_, the phototimer, consists of a _photomultiplier_ tube located _under the cassette._ Note that a backup timer is in place to terminate the exposure, should the AEC fail to do so.

Figure 14–19. The spinning-top test was made using 1/20 second (50 ms) exposure and correctly produced 6 dots.

image will be underexposed; if the exposure is delayed in terminating, the image will be overexposed. The radiographer should be able to perform a *spinning-top test* to evaluate timer accuracy (Figs. 14–19 and 14–20).

A simple spinning top consists of a circular steel or lead disk with a small hole in its periphery. The disk is mounted on a base that allows the disk to revolve freely. The device is placed on a cassette, the spinning top is set in motion, and an exposure made using the exposure time station to be evaluated.

Recall that with single-phase equipment there are 120 useful x-ray impulses per second using *single-phase full-wave rectified* current. If the x-ray timer is set to use some portion of the impulses, for example,
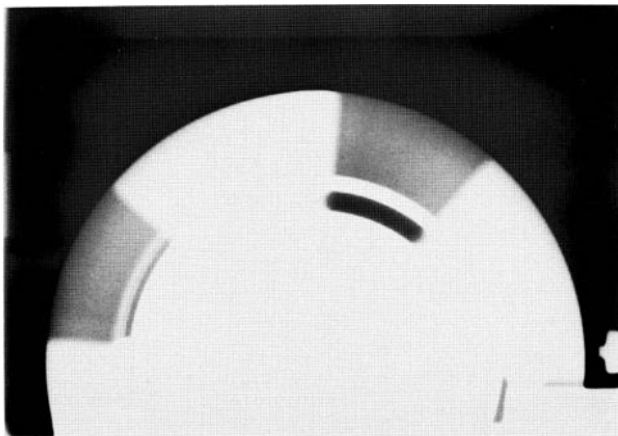
Figure 14–20. Synchronous spinning-top test. An exposure was made using 1/12 second (83 ms). The resulting image correctly demonstrates a 30-degree arc.

$\frac{1}{4}$ second, then one-fourth of the 120 impulses should be recorded on film if that time station is accurate. Thus, the film should show 30 dots. A minor discrepancy usually indicates a *timer malfunction;* exactly one-half of the correct number of dots indicates a *rectifier problem.* If an exposure of 1/10 second is made, 12 dots should be recorded, and so on. Simply multiply the number of impulses per second (120 in the case of Sφ full-wave rectified equipment) by the exposure time. In the unlikely event that *half-wave rectified* equipment is being tested, the exposure time is multiplied by 60 (useful impulses/second).

Because most x-ray equipments manufactured today are three phase, a slightly different approach must be taken when evaluating these timers. Because *three-phase full-wave rectified* equipment produces a *ripple wave*, that is, almost constant potential, the standard spinning-top test does not demonstrate impulses; rather, a *solid arc* is recorded. The use of a *synchronous* (motorized) *spinning top* (or oscilloscope) is required. The exposure is made at the time station to be evaluated, and the resulting image demonstrates a solid arc. If the exposure time made was 1 second, an entire circle (360 degrees) should be demonstrated. For exposure times less than 1 second, the corresponding portion of a circle should be recorded. For example, an exposure made at $\frac{1}{4}$ second should record a 90-degree arc (i.e., 1/4 of a 360-degree circle); at an exposure of 1/10 second, a 36-degree arc should be recorded.

Primary Coil of the High-Voltage Transformer—*The primary coil of the high-voltage transformer* is the final component of the primary, or low-voltage, circuit. The low voltage entering the primary coil is stepped up to high kilovoltage in the secondary coil by means of mutual induction.

Exposure Switch—*The exposure switch* is a remote control switch that functions to start the x-ray exposure (the timer terminates the exposure).

B. FILAMENT CIRCUIT COMPONENTS

The filament circuit is responsible for supplying low-voltage current (3–5 A, 10–12V) to the filament of the x-ray tube. Because the incoming voltage (110–220 V) is greater than that required, a *step-down transformer* is placed in the filament circuit to make the required voltage adjustment. A *rheostat*, or other type of *variable resistor*, is placed in the filament circuit to adjust amperage and corresponds to the *mA selector* on the control console.

C. SECONDARY CIRCUIT COMPONENTS

1. Secondary or High-Voltage Circuit Devices

Secondary Coil of High-Voltage Transformer—This carries the required high voltage for x-ray production (and proportionally smaller current value).

mA Meter—This is located at the midpoint of the secondary transformer coil. Because it is grounded, it can be safely placed in the operator's console. The mA meter displays the tube current value.

Rectifiers—The *rectification* system of diodes is located between the secondary coil of the high-voltage transformer and the x-ray tube. Recall from earlier discussion that it functions to change alternating current to unidirectional pulsating current. Current pulsations decrease with solid-state three-phase rectification (3φ 6p rectification has a 13% ripple; 3φ 12p has a 4% ripple).

X-ray Tube—The x-ray tube is the final device in the secondary circuit. The filament of its negative electrode, the cathode, is heated by its own circuit to produce *thermionic emission*. As high voltage is applied, the thermionic electron cloud is driven to the anode target. The rapid deceleration of electrons, and their interaction with tungsten atoms of the target, results in an energy conversion to heat and x-rays (99.8% heat, 0.2% x-rays).

D. CIRCUITRY OVERVIEW OF A SINGLE EXPOSURE

1. X-ray machine is turned on. This activates the filament circuit and heats the x-ray tube filament (10–12 V, 3–5 A).
2. If the machine has been off overnight, warm-up exposures are made to warm the anode throughout (anode cracking can occur when surface heat is applied to a cold anode).
3. Appropriate exposure factors are chosen on the control panel (machines having a line-voltage compensator on the control panel should be adjusted to compensate for any incoming voltage fluctuation).
4. The rotor/exposure switch is often a two-stage exposure button that should be depressed completely in one motion; the first click heard after partial depression is the induction motor bringing anode rotation up to speed. At this time, the filament is heated to maximum (thermionic emission) and produces an electron cloud.
5. Upon complete depression of the rotor/exposure switch, the exposure is made. The moment the exposure button is depressed, the voltage selected by the autotransformer is sent to the step-up transformer where it is converted to the high voltage (kV) and low amperage (mA) required. This high-voltage current then passes through the rectification system that changes AC to pulsating DC.
6. The applied high voltage (potential difference) propels the electron cloud to the anode where interactions between the high-speed electrons and tungsten target atoms convert electron kinetic energy to (99.8%) heat energy and (0.2%) x-ray photon energy (see *x-ray production* details in Chapter 8).

E. ELECTRONIC (DIGITAL) IMAGING

1. Computer Fundamentals. The following is an overview of how we use computers to represent data, and the factors that influence image characteristics.

Computer System. The computer system consists of the *hardware*, which is any physical component of the computer, and the *software*, which is a set of instructions or program to operate the computer.

The hardware consists of input and output devices. These devices allow information to be put into a computer and allow information to be directed outside the computer. The *central processing unit* (CPU) is the primary control center for the computer consisting of a control unit, arithmetic unit, and memory. The speed is measured in "millions of instructions per second." Most desktop computer speeds are given in MHz. The *memory* is solid state. It is used by the computer during execution of a program. There are two types of memory. The first is *RAM*, or random access memory. This memory is volatile and will lose all information when the computer is turned off unless previously saved. Read-only memory, or *ROM*, is memory that is hardwired into the computer, which means it stays in the computer even when the computer is turned off. ROM usually contains the booting instructions.

The *software* is a set of instructions the computer uses to function effectively, known as a *program*. Computer programmer languages include, but are not limited to

- Fortran: Formula translation. Used mainly in science and engineering applications.
- Basic: A beginner's all-purpose language with symbolic instructions and code.
- Cobol: Common business-oriented language.
- Pascal: High-level mathematics.

Binary Numbers. The computer hardware interprets all information as a simple "yes" or "no" decision. Current "on" implies "yes" and current "off" implies "no." This is symbolically represented with digits 1 and 0. A *bit* in computer terminology refers to an individual one or zero and is a single bit of information.

Image Storage. Image storage is located in a *pixel* (Fig. 14–21), which is a two-dimensional "picture element." Pixels are measured in the "XY" direction.

The third dimension in the matrix of pixels is the depth that, together with the pixel, is referred to as the *voxel* (Fig. 14–22). The
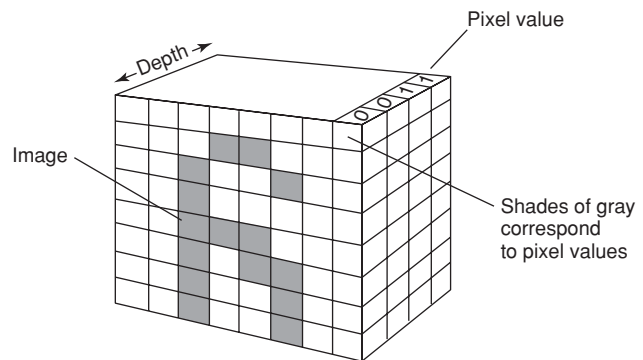
Figure 14–21. A digital image may be likened to a three-dimensional object made up of many small cubes, each containing a binary digit or bit. The image is seen on one surface of the block, whose depth is the number of bits required to describe each pixel's gray level.
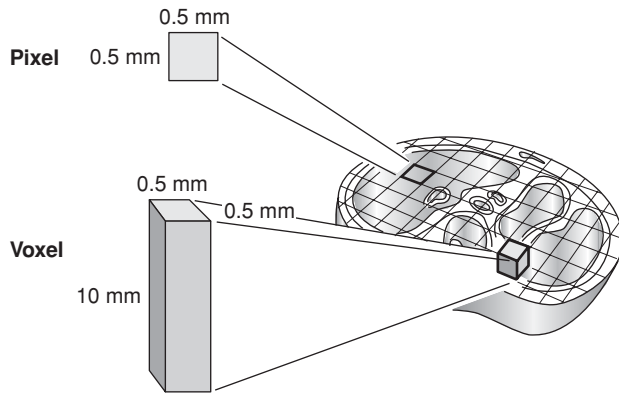
Figure 14–22. The third dimension in the matrix of pixels is the depth, which together with the pixel is referred to as the voxel (volume element).

voxels are measured in the "Z" direction. The depth of the block is the number of bits required to describe the gray level that each pixel can take on. This is known as the *bit depth*.

The *matrix* is the number of pixels in the XY direction. *The larger the matrix size, the better the image resolution* (Fig. 14–23).

A digital image is formed by a *matrix* of *pixels* in rows and columns. A matrix having 512 pixels in each row and column is a 512×512 matrix. The term *field of view* is used to describe how much of the patient (e.g., 150-mm diameter) is included in the matrix. The matrix or field of view can be changed without affecting the other, but changes in either will change pixel size. As matrix size is increased, there are more and smaller pixels in the matrix therefore improved spatial resolution; *spatial resolution* is measured in line pairs per mm (*lp/mm*). Fewer and larger pixels result in a poor-resolution "pixelly" image, that is, one in which you can actually see the individual pixel boxes (Fig. 14–23).

One of the most important factors to consider in computed radiography is the ability to transmit images over distances, known as *teleradiography*. The amount of information transferred per unit time is known as the baud rate and is in units of bits per second.

Example: A network is capable of transmitting data at a rate of 9600 baud. If each pixel has a bit depth of 8 bits, how long will it take to transmit a 512×512 image?

Typical Image Matrix Sizes Used in Radiography Are

• Nuclear medicine	128×128
• Digital subtraction angiography (DSA) (Fig. 14–24)	1024×1024
• CT	512×512
• Chest radiography	2048×2048

| 16×16 | 32×32 | 64×64 | 128×128 | 256×256 |
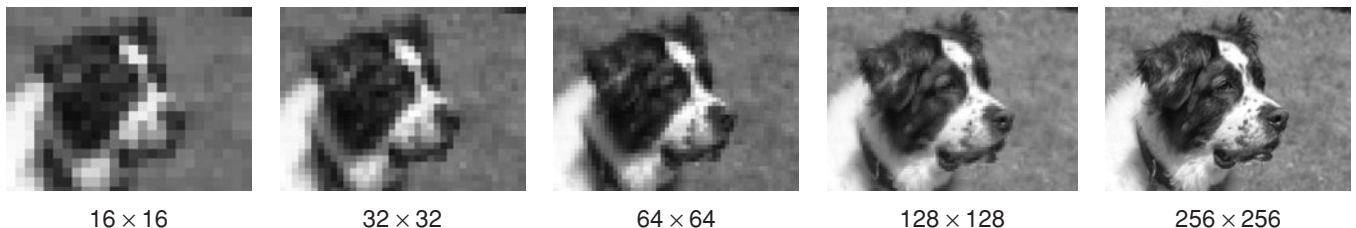
Figure 14–23. The matrix is the number of pixels in the XY direction. The larger the matrix size, the better the image resolution.

Bones and vessels   minus   Bones (mask)   equals   Vessels

After injection of contrast medium   Before injection of contrast medium
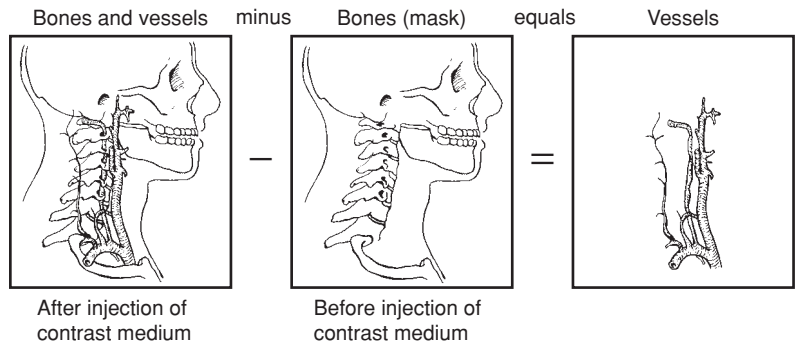
Figure 14–24. Digital subtraction angiography (DSA). Image details not required for diagnosis can be subtracted from an image. Only vessels containing contrast medium are visualized in the final image.

Solution:

$$(512 \times 512 \text{ pixels})(8 \text{ bits/pixel})/9600 \text{ bits/s} = 128 \text{ s}.$$

There are three possible means of image transmission. *Telephone* wires offer low transmission speed while using a modem. *Coaxial cable* will transmit at approximately 100 MBaud. Finally, there are *fiberoptic cables* that are unaffected by electrical fields and therefore have less error than cables or wires with electrical signals.

2. Computed Radiography.

Computed radiography is also referred to as *filmless radiography* because *a photostimulable storage phosphor* (*PSP*) within the *image plate* (*IP*) is used as the image receptor. The IP looks very similar to a traditional radiographic cassette (Fig. 14–25), is used in the same way, and is available in similar sizes. Instead of the traditional intensifying screens and film, the computed radiography IP contains a europium-doped barium fluorohalide coated screen. When the PSP receives image-forming useful x-ray photons, the x-ray energy interacts with the crystals. As a result of this interaction, a small amount of visible light is emitted, but most of the x-ray energy is stored (hence the term *storage plate*). This stored energy represents the latent image. The IP is placed in the CR reader. Here a helium–neon, or

Figure 14–25. An image plate (IP) is very similar in appearance to a conventional screen–film cassette. The IP holds a PSP (the image receptor) between its front and rear panels. There is no film or intensifying screens. (Reproduced, with permission, from Shephard CT. *Radiographic Image Production and Manipulation.* New York: McGraw-Hill, 2003.)

solid-state, laser beam scans the PSP and the stored energy is released as blue-violet light (phosphostimulated luminescence [PSL]). This light signal (representing the latent image) is transferred to an *analog-to-digital converter* (*ADC*), which converts the signal to a digital (electrical) one. The resulting digital information can now be displayed on a monitor, electronically transmitted, manipulated, and stored efficiently (archived). After the reading process has been completed, any remaining information on the PSP is *erased* by exposing the PSP screen to high-intensity light and the IP is ready for reuse. Figure 14–26 illustrates this imaging cycle.

Another advantage of CR is the ability to *manipulate the image after exposure*. Image manipulation postprocessing can be used for *contrast modification, image subtraction* (Fig. 14–24), and *windowing*. Image subtraction is used primarily in angiography to remove superimposed bone structures from contrast-filled vessels.

The digital images' *scale of contrast*, or *contrast resolution*, can be changed electronically through leveling and windowing of the image. *Windowing* is a process of changing the contrast and density setting on the monitor image. The window *width* controls the *number* of shades of gray in the image, while the window *level* corresponds to the *density* (Fig. 14–27). Narrower windows result in higher (shorter-scale) contrast. Pixel values *below* the window range will be displayed as *black*, whereas pixel values *above* the window range will be displayed as *white*. Pixel values between the two limits are spread over the full scale of gray.

Applications for computed imaging include the following:

- Radiography
- Computed tomography
- Nuclear medicine
- Magnetic resonance
- Ultrasonography
- DSA

3. Spatial Resolution. As mentioned earlier, spatial resolution of digital images is partly determined by the *pixel size* in the monitor matrix. The greater the number of pixels, the smaller their size and the better
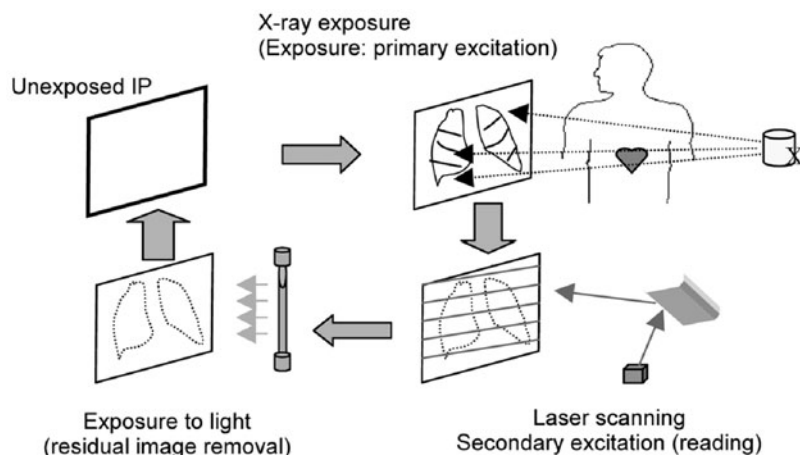
Figure 14–26. The *recording, reading,* and *erasure* cycle of a CR image plate. The IP is exposed to x-ray photons, scanned/read, and then erased for reuse. (Courtesy of FUJIFILM Medical Systems USA, Inc.)

Figure 14–27. Changes in *window width* and *window level.* Image **A** (*center*) has a window width of 1810 and window level of 761. In image **B** the window width is increased to 4174, and in image **C** the window width is decreased to 732, leaving window level unchanged. The changes in image *contrast* are evident. Next, images D and E are compared to A. In image **D** the window level is increased to 1497, and in image **E** it is decreased to 325. This time the changes in image *density* are obvious.

the resolution. Hence, a 2000 × 2000 (2 K) monitor will demonstrate better spatial resolution than a 1000 × 1000 (1 K) monitor. Another way to describe monitor resolution that is gaining favor is simply in terms of *megapixels.*

Other factors contributing to image resolution are the *size of the laser beam* and the *size of the* barium fluorohalide *phosphors.* Smaller phosphor size improves resolution in ways similar to that of intensifying screens—anything that causes an increase in light diffusion will result in a decrease in resolution. Smaller phosphors in the PSP screen allow less light diffusion. Additionally, the scanning laser light must be the correct intensity and size. A narrow laser beam is required for optimum resolution.

4. Contrast Resolution.

The terms *dynamic range* and *contrast resolution* are commonly used to describe the range of grays a particular digital system is capable of resolving/demonstrating. The *higher* the contrast resolution, the better the ability to see similar adjacent gray shades. As mentioned earlier, the greater the number of bits per pixel, the greater the capability of displaying many shades of gray.

CR Resolution Is Determined By

- Size of barium fluorohalide phosphor
- Width of laser beam
- Monitor matrix

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5. Noise.

Noise is an electronic term for anything that interferes with visualization of the image we wish to see. We see noise in traditional radiography as a result of fast imaging systems. CR images are even more subject to noise; as in traditional radiography, it appears as *graininess* referred to as *quantum mottle.* Insufficient mAs can cause image noise, and it cannot be removed in postprocessing. Intelligent selection of exposure factors is still required and radiographers must be even more vigilant in minimizing patient exposure. In digital/electronic imaging, high signal and low noise are desired, i.e., a high SNR (signal-to-noise ratio).

6. Direct Digital Radiography.

Computed radiography (CR) and direct digital radiography (DR) are similar in that computers are required for each. The difference between them is the way in which the useful beam is captured. In DR, images are produced *instantly* in pixel form (as in CT and MR) on the monitor. Remember, this does not happen in CR. In CR, images first require processing; that is why there is a short delay before the CR image is displayed on the monitor.

DR uses *charge-coupled device* (CCD) *detectors* or *direct/indirect conversion flat panel detectors* to convert the useful/exit x-ray energy to electrical energy. This electrical energy is then carried to the computer for processing and display.

■ *SUMMARY*

- **The x-ray circuit has three major portions: the primary, or low-voltage, side; the filament circuit; and the secondary, or high-voltage, side.**

- Primary circuit devices include the main switch and circuit breaker; the autotransformer and kV selector; line-voltage compensator; timer; primary coil of the high-voltage transformer; and exposure switch; most of the control console devices are in the primary circuit.
- The line-voltage compensator automatically adjusts for any fluctuations in the incoming electrical supply.
- The timer regulates the length of the x-ray exposure; types of timers include mechanical, impulse, synchronous, mAs timer, electronic timer, and AEC.
- There are two types of AECs: the phototimer, located behind the IR, and the ionization chamber, located above the IR.
- A backup timer terminates the exposure should the AEC fail, thereby functioning to protect the patient from excessive exposure, and prolong the life of the x-ray tube.
- Timer accuracy can be tested with a spinning-top test: a simple *spinning top* for single-phase equipment and a *synchronous* spinning top for three-phase equipment.
- Single-phase spinning-top tests show a series of *dots*, each representing an x-ray impulse; three-phase spinning-top tests show a *solid-arc* exposure in a portion of a circle (measured in degrees) representative of a portion of a second.
- A step-down transformer and rheostat are placed in the filament circuit to supply the x-ray tube with low-voltage current.
- Secondary circuit devices include the secondary coil of the high-voltage transformer, mA meter, rectifiers, and x-ray tube.
- The grounded mA meter displays the tube current value on the control console.
- Rectifiers are located between the transformer's secondary coil and the x-ray tube; they function to change AC to unidirectional current.
- There are two types of computer memory: RAM and ROM.
- A two-dimensional picture element is a pixel; a three-dimensional picture element is a voxel.
- Computed radiography enables image manipulation after exposure ("postprocessing").
- CR uses special detector plates called a photostimulable phosphor (PSP).
- "Windowing" changes image contrast and/or density; window *width* controls the number of grays, while window *level* controls density.
- CR resolution is determined by size of PSP phosphor, laser beam, monitor matrix.
- The terms *dynamic range* and *contrast resolution* are used to describe the range of grays a digital system is capable of resolving.
- Insufficiency of mAs can cause digital image noise (decreased SNR).
- DR images are produced instantly on the monitor; CR images are somewhat delayed.

VI. THE FLUOROSCOPIC SYSTEM

Fluoroscopic x-ray examinations are performed to study the dynamics of various parts in *motion*. Fluoroscopy was performed almost exclusively in the very early days of radiology because of the lack of dependable x-ray tubes and image-recording systems (Fig. 14–28). In the late 1940s and early 1950s, image intensification was developed and served to provide much brighter images at lower exposures. *Image intensifiers* (II) brighten (intensify) the conventional, or "dark," fluoroscopic image 5000 to 20,000 times. Today's fluoroscopic procedures are much safer (lower exposure/mA) and brighter; the fluoroscopic image can be photographed still or moving (cine or videotape), or viewed with a television camera and projected onto a nearby or remote television monitor.

A fluoroscope has two principal components, an x-ray tube and a fluorescent screen, attached at opposite ends of a *C-shaped arm* (Figs. 14–29, 14–30A). The fluoroscopic *table* accommodates the patient and must be able to move to an upright position (90 degrees) and to a Trendelenburg position (up to approximately 40 degrees). Therefore, a 90/30 fluoroscopic table refers to one that will move upright (90 degrees) and angle Trendelenburg up to 30 degrees.

Fluoroscopic x-ray tubes are standard rotating anode tubes, usually installed under the x-ray table, but operated at much lower tube currents than radiographic tubes. Over-the-table fluoroscopic x-ray tubes result in higher radiation exposure to personnel than under-the-table x-ray tubes. Instead of the 50 to 1200 mA used in radiography, fluoroscopic tubes are operated at currents that range from 0.5 to 5.0 mA (averaging 1–3 mA).

Patient dose is much higher in fluoroscopic than radiographic procedures because of the considerably shorter source-to-object distance (SOD) used in fluoroscopy. Fluoroscopic *entrance exposure* is significantly greater than exit exposure as a result of attenuation processes within the patient. The typical entrance skin exposure rate is 2 R/min; a "*boost*" mode is often available for special situations—employing
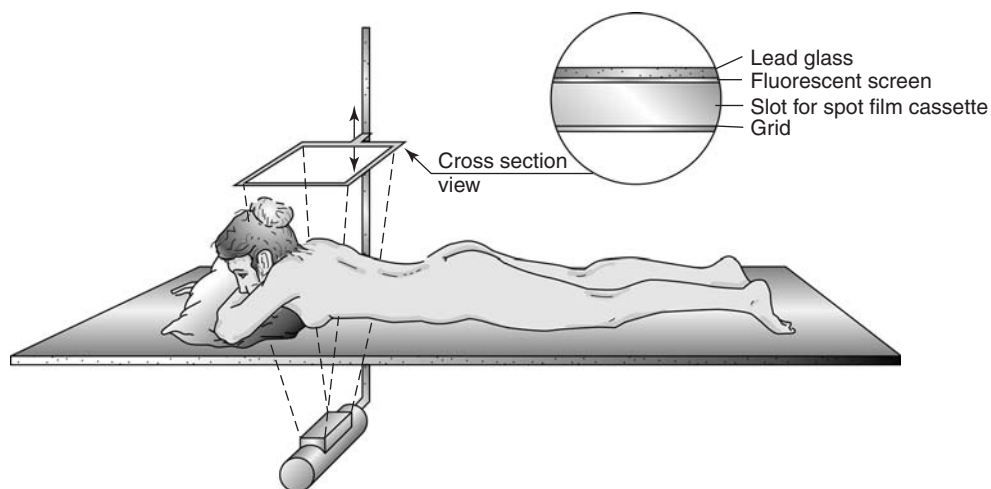
Figure 14–28. Basic early fluoroscope.

Figure 14–29. Conceptualization of relationship and function of an image intensifier input screen, photocathode, and output screen. For every one x-ray photon interacting with the input screen, 5000 fluorescent light photons are emitted. Note the close (but not touching) relationship between the input screen and photocathode for maintenance of resolution. The light photons interact with the photocathode and approximately 150 electrons are emitted by the photoemissive metal. The photoelectrons then interact with the output screen, and 2000 fluorescent light photons are emitted for every electron.
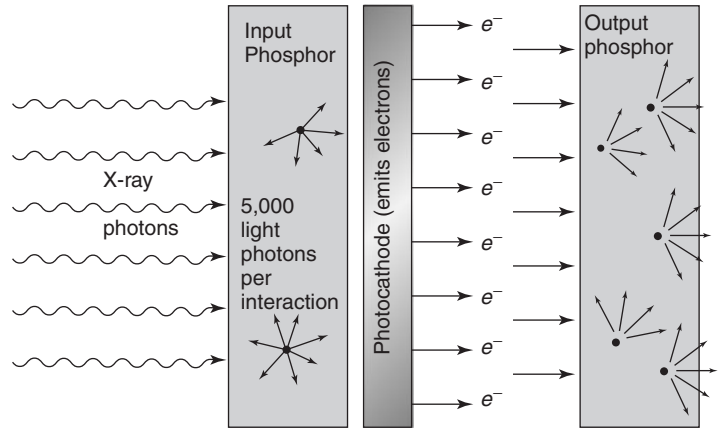
exposure rates of *up to 20 R/min*. Use of the "boost" mode is permitted for only short periods of time and an *audible signal* is activated during its use.

For radiation protection purposes, the fluoroscopic tabletop exposure rate must not exceed 10 *R/min* and all fluoroscopic equipment must provide *at least* 12 *inches* (30 cm), and preferably 15 inches (38 cm), between the x-ray source (focal spot) and the x-ray tabletop. Positioning the image intensifier *closer* to the patient *decreases the SID*

A   Fixed R/F unit   Angiographic unit
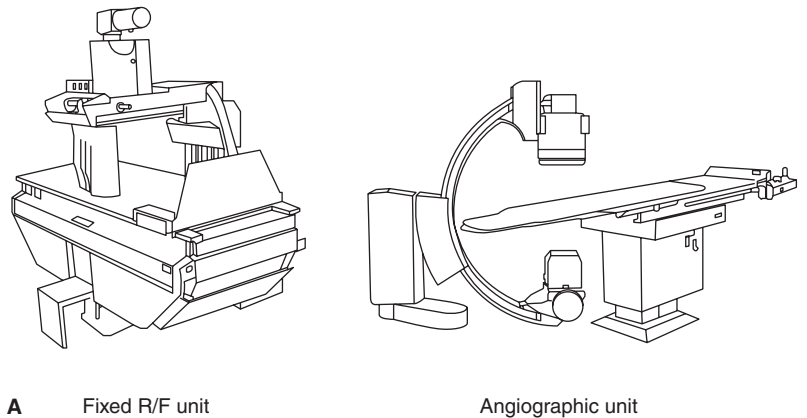
Figure 14–30. **(A)** *C-arm:* A fluoroscope has two principal components, an x-ray tube and a fluorescent screen, attached at opposite ends of a C-shaped arm. **(B)** Transition of x-ray photons emerging from x-ray tube, through part under study, into image intensifier, to human eye.
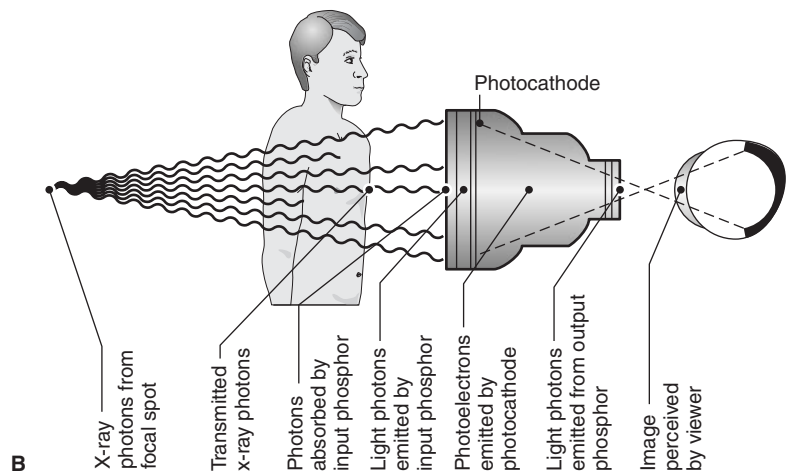
and *decreases patient dose*. Patient dose decreases because as the SID is *decreased* the number of x-ray photons at the input phosphor *increases;* this results in the automatic brightness control *decreasing the mA* to compensate for the increase in x-ray photons.

A *5-minute timer* is used to measure accumulated fluoroscopic examination time and make an audible sound or interrupt exposure after 5 minutes of fluoroscopy. X-ray production is usually activated by a foot switch (*dead-man switch*), thus leaving the fluoroscopist's hands free to handle the carriage and position and palpate the patient. The fluoroscopic tube is usually equipped with electrically driven collimating *shutters*. Leaded glass provides shielding from radiation passing through the intensifying screen, and the image intensifier is lead lined. A *Bucky slot cover* and *protective curtain* also help reduce exposure to the fluoroscopist.

Older fluoroscopes are often equipped with a *spot film* device to record fluoroscopic images. To expose a spot film, a motor is activated that brings a cassette from a lead-lined compartment within the carriage over into the fluoroscopic field between the intensifying screen and grid (Fig. 14–30A). The fluoroscopic x-ray tube current then automatically increases to a conventional radiographic level of approximately 300 mA or more for the cassette exposure. The lead shutters usually adjust automatically, but may be operated manually.

Some Radiation Safety Features of Fluoroscopic Equipment

- Maximum of 5 mA
- 12 inches minimum between focal spot and tabletop
- 10 R/min maximum tabletop exposure
- 5-minute cumulative timer
- "Dead man" switch
- Automatic collimation
- Bucky slot cover
- Protective curtain

■ *SUMMARY*

- **Fluoroscopes are used to examine moving parts and are often equipped with a device to take cassette-loaded spot films.**
- **A fluoroscope has two major parts: an x-ray tube and a fluorescent screen, attached at opposite ends of a C-shaped arm.**
- **The fluoroscopic tube is usually located (at least 12 inches) under the x-ray table and usually operated at 1 to 3 mA (upto a maximum of 5 mA); mA automatically increases for cassette-loaded spot films.**
- **Fluoroscopic patient dose depends on exposure rate, tissue thickness or density, and length of exposure.**
- **Fluoroscopic patient dose decreases as the image intensifier is moved closer to the patient.**
- **Fluoroscopic "boost" mode can deliver up to 20 R/min.**
- **Many guidelines regulate the operation of fluoroscopic equipment because of the unavoidably high patient dose inherent in fluoroscopic procedures (because of the short focus-to-patient distance).**
- **Image intensifiers brighten the conventional, dark fluoroscopic image 5000 to 20,000 times.**

A. The Image Intensifier

The fluorescent layer of early conventional (or "dark") fluoroscopic screens was made of *zinc cadmium sulfide* (Patterson B-2 screen). The *input screen* of today's image intensifier tube is made of a thin layer of *cesium iodide*, is 5 to 12 inches in diameter, and slightly convex in shape.
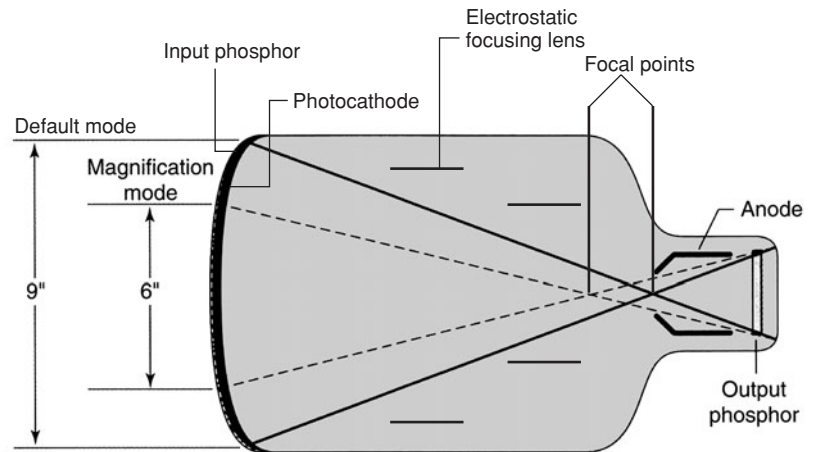
Figure 14–31. As field of view (patient area/normal vs. magnification mode) decreases, magnification of the output screen image increases and contrast and resolution improve. Note that the focal point on the 6-inch field, or mode, is further away from the output phosphor; therefore, the output image appears magnified. Because less minification takes place in this instance, the image is not as bright. Exposure factors are automatically increased to compensate for the loss in brightness.

Cesium iodide is much more efficient than zinc cadmium sulfide because it absorbs, and converts to fluorescent light, a greater number of the x-ray photons striking it. For each absorbed x-ray photon, approximately 5000 light photons are emitted (Fig. 14–29). This fluorescent light strikes a *photocathode* made of a photoemissive metal. A number of electrons are subsequently released from the photocathode and focused toward the output side of the image tube. Although this step actually represents a *deamplification*, it has very little effect on the end result. A thin (0.2-mm) layer of glass or other transparent material is placed between the input screen and photocathode to prevent chemical reaction between the two; otherwise, the two must be as close as possible for maximum transfer of accurate information.

The electrons emitted from the photocathode are focused toward the output end of the tube by negatively charged *electrostatic focusing lenses*. They then pass through the neck of the tube where they are accelerated through a potential difference of 25,000 to 35,000 V and strike the small (0.5–1 inch) fluorescent *output screen* that is mounted on a flat glass support (Figs. 14–30 and 14–31).

The entire assembly is enclosed within a 2- to 4-mm-thick vacuum glass envelope. The glass is then coated to prevent the entry of light. The glass tube is enclosed within a metal housing that functions to attenuate magnetic fields from outside the tube that would distort the electron paths within.

For there to be undistorted focusing of electrons onto the output screen, each electron must travel the same distance, thus the slight curvature of the input screen.

There are several occasions of information transfer within the image intensifier: from x-ray beam to input screen, from input screen to photocathode, from photocathode to electron beam, from electron beam to output screen, and from output screen to the human eye

(Fig. 14–30). Thus, an electrical image is transformed to a light image, then back to an electron image, and finally back to a light image.

Electrons from the photocathode are accelerated as they travel toward the output screen. The gain in brightness achieved by the image intensifier is the result of this *electron acceleration (flux gain)* and *image minification. Flux gain* is defined as the ratio of light photons at the output phosphor to the number at the input phosphor. A typical image intensifier has a flux gain of approximately 50.

The image produced on the input screen of the image intensifier is reproduced as a minified image on the output screen. Because the output screen is much smaller than the input screen, the amount of fluorescent light emitted from it per unit area is significantly greater than the quantity of light emitted from the input screen. This process is referred to as *minification gain*, and is equal to the ratio of the diameters of the input and output screens squared:

$$\text{Minification gain} = \left(\frac{\text{Input screen diameter}}{\text{Output screen diameter}} \right)^2.$$

For example, the minification gain for an image intensifier with an input screen of 11 inches and output screen of 1 inch is 121:

$$\text{Minification gain} = \left(\frac{11''}{1''} \right)^2$$

$$\text{Minification gain} = 121.$$

The total *brightness gain* of an image intensifier is the product of flux gain and minification gain:

$$\text{Total brightness gain} = \text{flux gain} \times \text{minification gain}.$$

For example, the total brightness gain for an image intensifier with a flux gain of 50 and minification gain of 121 is 6050:

$$\text{Total brightness gain} = 50(121)$$

$$\text{Total brightness gain} = 6050.$$

The brightness, resolution, and contrast of an intensified image are greatest in the center of the image. Because the exposure rate is reduced at the periphery of the input screen, and because there is less-than-exact peripheral electron focusing from the photocathode, brightness, resolution, and contrast are reduced (up to 25%) toward the periphery; this characteristic of image intensifiers is called *vignetting*.

Input screen diameters of 5 to 12 inches are available. Although smaller-diameter input screens improve resolution, they do not permit viewing of large patient areas.

A type of image distortion, called *pincushion distortion*, is common to intensified images and is caused by the curvature of the input screen and diminished electron focusing precision at the image periphery.

There will always be some degree of magnification in image intensification (just as in radiography); the degree depends on the distance of the image intensifier from the patient.

Dual- and triple-field image intensifiers are available that permit magnified viewing of fluoroscopic images. Magnified images are reduced in brightness unless the mA is automatically increased when

the image intensifier is switched to the magnification mode (Fig. 14–31). Entrance skin exposure (ESE) can increase dramatically as the FOV decreases (i.e., as magnification increases).

Fluoroscopy units are frequently equipped with a last-view freeze-frame feature. This permits the fluoroscopist a longer view of on-screen anatomy without the need for continuous x-ray exposure.

Comparisons Between Large and Small Fields of View and Modes

Larger Field of View
- Focal point closer to output screen
- Less magnification of perceived image
- Brighter image; less exposure required

Smaller Field of View
- Focal point farther from output screen
- Magnified image
- Less brightness; more exposure required

■ *SUMMARY*

- **The basic parts of the image intensifier are the input screen, photocathode, electrostatic focusing lenses, accelerating anode, and output screen, within a vacuum glass envelope.**
- **The process of energy conversion within the image intensifier is from electrical to light, to electrical, and back to light.**
- **Cesium iodide is the preferred phosphor for the image intensifier's input screen; for each x-ray photon it absorbs, it emits approximately 5000 light photons.**
- **Light photons strike the photocathode, which releases a number of electrons that are directed toward the neck of the image intensifier by the negatively charged focusing lenses.**
- **The input screen and photocathode are slightly curved so that each electron travels the same distance to the output phosphor, to prevent distortion.**
- **Electrons are accelerated by the anode's 25 to 30 kV potential, thus making the output image brighter (*flux* gain); the electrons strike the output screen and are converted to a much brighter, smaller (minification gain), and inverted fluorescent image.**
- ***Minification* gain is determined by dividing the input screen diameter by the output screen diameter and squaring the result; *total brightness* gain is equal to the product of flux gain and minification gain.**
- **Diminished resolution and contrast at the image periphery is called vignetting.**
- **Magnification results in some loss of brightness; mA is automatically increased to compensate.**
- **Last-view freeze-frame feature can significantly decrease patient dose.**

B. VIEWING SYSTEMS

The optical system of the image intensifier can transfer the output screen image to a mirror viewing apparatus. Mirror viewing offers good resolution, but its disadvantages include limited viewing by one person at a time and limited fluoroscopist movement. In comparison, *closed-circuit television fluoroscopy* is far more convenient, allows the fluoroscopist freedom of movement, and permits simultaneous viewing by a number of people.

As body areas of different thicknesses and density are scanned with the image intensifier, image brightness and contrast require adjustment. The *automatic brightness control* functions to maintain constant brightness and contrast of the output screen image, correcting for

fluctuations in x-ray beam attenuation with adjustments in kV and/or mA. There are also brightness and contrast controls on the monitor that the radiographer can regulate. Positioning the image intensifier *closer* to the patient *decreases the SID* and *decreases patient dose*. Patient dose decreases because as the SID is *decreased* the number of x-ray photons at the input phosphor *increases;* as a result, the automatic brightness control *decreases the mA* to compensate for the increase in x-ray photons.

The image on the output screen can be transferred via a television camera to a display *monitor*. The image intensifier output screen image is *coupled* via a *television camera* (in analog fluoroscopy) or a *charge-coupled device/*CCD (in digital fluoroscopy) for viewing on a display monitor. This is an example of closed-circuit TV. The *Vidicon* and *Plumbicon* are currently the most frequently used analog television cameras. They are approximately 6 inches in length and 1 inch in diameter.

C. RECORDING AND STORAGE SYSTEMS

In addition to being transmitted to nearby or remote monitors, traditional images can be recorded on *videotape* or *cine* film. Television monitors do not offer the very good image resolution obtained from the image intensifier, so film recording systems such as spot film cameras and cine cameras can be used to record better resolution images directly from the image intensifier (Fig. 14–32).

Digital images can be stored on *magnetic tape and disks, digital videotape*, and *optical disks and tape*.

1. Cinefluorography.
The fluorescent image on the image intensifier's output screen can be photographed with a 16- or 35-mm movie camera. Approximately 85% to 95% of the light from the image intensifier's output screen is transmitted to the cine camera when it is in use. The rest of the light is used for television monitor viewing. During cinefluorography, x-ray exposure is on only when the film is in proper
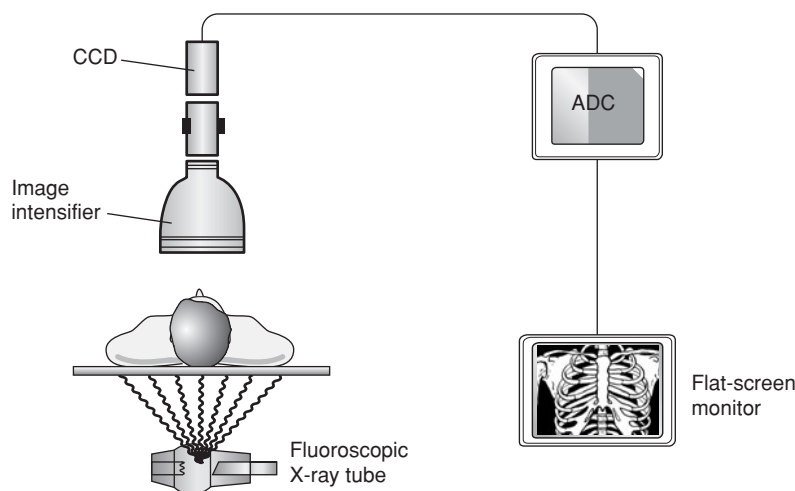
Figure 14–32. Image-intensified fluoroscopic unit with ancillary imaging devices.

position for exposure (i.e., no exposure during film movement between frames). Grid-controlled x-ray tubes are used to synchronize x-ray exposure with proper film position. Cine "flickering" is noticeable only with frame rates below 30 frames per second.

Film used in cine cameras must be sensitive to the fluorescent light emitted by the output screen. *Panchromatic* film is sensitive to all wavelengths (i.e., colors) of visible light; *orthochromatic* film is sensitive to all but red light. These are the two film types most often used in cine cameras. Higher-quality images are obtained with 35-mm film (rather than 16 mm) because the film size is four times greater than 16-mm frames; however, for that same reason, 35-mm film requires greater patient exposure and is more expensive. Another reason patient dose is significantly greater in cinefluorography than in routine image-intensified fluoroscopy is that the output screen image must be bright enough to expose the cine film (hence, increased mA). Typical doses measured at the image intensifier input phosphor are approximately 10 μR/frame.

2. Spot Films. Spot films in 70-mm, 90-mm, and 105-mm sizes can be made from the image on the output screen of the image intensifier. This method of recording static (still) images gained acceptance over the cassette-loaded spot filming procedures (taken from the input screen of the image intensifier). The film used for spot-film cameras is less expensive and easier to store, can be exposed in rapid succession, and requires less patient exposure. Typical doses measured at the image intensifier input phosphor are approximately 50 to 100 μR/spot film. Image quality is slightly less than that of cassette-loaded spot films (939-inch cassette), whose typical doses measured at the image intensifier input phosphor are approximately 300 to 400 μR/film.

3. Video Recording. Fluoroscopic procedures can also be recorded on videotape. The most significant advantage of videotape recordings is that it allows immediate playback of dynamic (motion) images (eliminating film processing). Other advantages include the availability of sound and capabilities of playing at slower speeds and viewing single frames. Its biggest disadvantage is loss of some resolution with regular VHS equipment. High-resolution systems (VHS-S) require the use of high-resolution accessories such as high-resolution cameras and monitors, and thus provide a superior image quality. New video disk recorders are similar to videotape machines, sharing all their advantages and having the added advantage of improved image quality (resolution).

4. Digital Fluoroscopy. In digital fluoroscopy, the image intensifier output screen image is *coupled* via a *charge-coupled device/*CCD for viewing on a display monitor. A CCD converts visible light to an electrical charge, which is then sent to the ADC for processing. When output screen light strikes the CCD cathode, a proportional number of electrons are released by the cathode and *stored as digital values* by the CCD. The CCD's rapid discharge time virtually eliminates image lag and is particularly useful in high-speed imaging procedures such as cardiac catheterizations. CCD cameras have replaced analog cameras (like the Vidicon and Plumbicon) in new fluoroscopic equipment. CCDs are more sensitive to the light emitted by the output phosphor

(than the analog cameras) and are associated with less "noise"; The CCD SNR is approximately 1000:1; the camera SNR is approximately 200:1.

DF offers significantly lower patient dose—its x-ray beam is "pulsed," rather than continuous. Most DF static images can also be made with a lower mA because of the greater sensitivity of the CDD (over film emulsion). It is important to take advantage of these patient dose reduction features—they can be nullified by taking excessive digital spot images.

DF eliminates the need for cassette-loaded spot films and/or 100-mm spot films. DF photospot images, which are simply still-frame images, need no chemical processing, require less patient dose (unless more than necessary are taken), and offer postprocessing capability. DF also offers "road-mapping" capability. "Road-mapping" is a technique useful in procedures involving guidewire/catheter placement. During the fluoroscopic examination, the most recent fluoroscopic image is stored on the monitor, thereby reducing the need for continuous x-ray exposure. This technique can offer significant reduction in patient and personnel exposure.

5. Information Storage. The quantity of patient information and diagnostic image data stored by hospitals is ever-increasing. It is essential that this information be stored, managed, and utilized efficiently. There are radiology information systems (RIS) that centrally process and store image data within a hospital, enabling image retrieval from the server by any department over the hospital network, and image display at the requesting department site. This eliminates the cumbersome task of sorting, conveying, and storing films. Hospital information system's (HIS) networks allow the archiving and distribution of vast amounts of image information from all modalities, managing it all with a single system. Using multiple connections over a network (e.g., PACS), image data can also be shared by multiple hospitals.

Advantages of DF Photospots

- No chemical processing needed
- Decreased patient dose
- Postprocessing capability
- "Road-mapping" capability

■ *SUMMARY*

- **The optical system transfers the output screen image to either mirror viewing or television monitor (via Plumbicon or Vidicon camera).**
- **Television monitor viewing is more practical and convenient, although it involves some loss of image quality.**
- **Automatic brightness control automatically adjusts kV or mA; brightness and contrast controls are also available for adjustment on the TV monitor.**
- **The output screen image is usually coupled to the television camera via a series of complex and precisely adjusted lenses and mirror.**
- **When used in conjunction with cine and spot-film cameras, the largest portion of the output screen light is diverted to the spot film or cine camera; the remainder goes to the television monitor.**

- **Cineradiographic film is either 16-mm or 35-mm panchromatic or orthochromatic film; better quality images are obtained with 35 mm, but patient exposure dose is greater.**
- **Spot-film cameras use 70-mm, 90-mm, or 105-mm film, and are preferable to cassette-loaded spot films because the film is more economical and easier to store and requires less patient exposure.**
- **Videotape recordings, permitting immediate playback, may be made during the fluoroscopic procedure, although there is some loss of image resolution.**
- **In digital fluoroscopy, the II output screen image is coupled via a CCD for viewing on a display monitor.**
- **Advantages of DF include no chemical processing, higher SNR, less patient dose, postprocessing capability, and "roadmapping."**

Chapter Exercises

★ ***Congratulations!*** *You have completed your review of the entire chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You can refer back to the indicated pages to check your answers and/or review the subject matter.*

1. Define and give examples of dedicated x-ray equipment *(p. 455).*

2. Distinguish between an AC and DC waveform *(p. 456).*

3. Discuss the following characteristics of AC: amplitude, polarity, wavelength, and frequency *(p. 0).*

4. Define helix, solenoid, electromagnet *(p. 456).*

5. Describe the function of the transformer, and identify the principle on which it operates *(p. 457).*

6. Using the transformer law, determine the voltage and current delivered to the x-ray tube *(p. 458).*

7. Identify four types of x-ray transformer construction *(pp. 458–459).*

8. Describe three types of transformer energy losses and methods by which they can be reduced *(p. 458).*

9. Describe the function of the autotransformer, and identify the principle on which it operates *(p. 459).*

10. Using the autotransformer law, determine the voltage sent to the transformer primary *(p. 459).*

11. Identify the type of current required for operation of the transformer and autotransformer *(p. 457).*

12. Define the function of the generator; motor *(p. 455).*

13. Describe the rectification process *(p. 460).*

14. Identify and give examples of the type of material of which solid-state diodes are made *(p. 0).*

15. Differentiate among single-phase, 3-phase/6-pulse, and 3-phase/12-pulse waveforms *(p. 460).*

16. Identify the pulse ripple for single-phase, 3-phase/6-pulse, and 3-phase/12-pulse rectification *(p. 460).*

17. Identify the number of autotransformers and transformers required for three-phase rectification *(p. 461).*

18. Identify the two types of transformer winding configurations *(p. 461).*

19. List the three basic component parts of the x-ray tube *(p. 462).*

20. Discuss the importance of the evacuated glass envelope *(pp. 462–463).*

21. Identify the component parts of the cathode assembly *(p. 463).*

22. Describe thermionic emission *(p. 463).*

23. Describe how a double or dual focus tube differs from a single focus tube *(p. 463).*

24. Explain why x-ray tube inherent filtration increases as the x-ray tube ages *(p. 463).*

25. Identify the current and voltage required by the filament circuit *(p. 463).*

26. Discuss why prolonged periods of rotor activation should be avoided *(p. 463).*

27. Describe the construction of the anode *(p. 463).*

28. Discuss the composition and function of the anode focal track *(p. 463).*

29. Discuss the value of anode rotation (vs. stationary anode) *(p. 463).*

30. Identify the device responsible for anode rotation and its two major parts *(p. 463).*

31. Identify two characteristics of tungsten that make it a desirable target material *(p. 463).*

32. Describe the line focus principle; distinguish between actual and effective focal spot *(p. 465).*

33. Describe the anode heel effect; relate it to focal track bevel (anode angle) *(p. 465).*

34. Discuss why heat removal mechanisms are important in x-ray tube construction; give examples of heat reduction features *(p. 464, 465).*

35. Determine heat units for Sφ, 3φ 6p, and 3φ 12p x-ray equipment *(p. 466).*

36. Determine safe exposure limits using tube rating charts and anode cooling curves *(p. 467)*.

37. Discuss at least three causes of x-ray tube failure *(p. 468)*.

38. Identify the three portions of the x-ray circuit *(p. 469)*.

39. Identify the components of the primary, or low-voltage, circuit *(pp. 469–470)*.

40. Describe the various types of x-ray timers and identify their accuracy *(p. 470)*.

41. Describe the two types of AECs and identify the location of each *(p. 470)*.

42. Discuss the importance of a backup timer *(p. 470)*.

43. Describe the tests used to evaluate $S\varphi$ and 3φ timers *(pp. 471–472)*.

44. Evaluate $S\varphi$ and 3φ timer tests for accuracy *(pp. 471–472)*.

45. Identify the function of the rheostat and transformer in the filament circuit *(p. 472)*.

46. Identify and describe the components of the secondary, or high-voltage, circuit *(pp. 472–473)*.

47. What is the primary control center for the computer consisting of a control unit, arithmetic unit, and memory *(p. 473, 474)?*

48. What are the two types of computer memory *(p. 474)?*

49. What term is used to describe how much of the patient is included in the matrix *(p. 475)?*

50. How does matrix size influence resolution *(p. 475)?*

51. What is the computed radiography PSP *(p. 476)?*

52. Describe how the image on the PSP is converted to the image seen on the monitor *(pp. 476–477)*.

53. What is the value of postprocessing *(p. 477)?*

54. Describe how *windowing* (width and level) affects the contrast and density of the diagnostic image *(p. 477)*.

55. What term is commonly used to describe the range of grays a particular digital system is capable of resolving *(p. 477)?*

56. List three things that determine CR resolution *(p. 477, 479)*.

57. Define *noise;* explain how it might be encountered in CR *(p. 0)*.

58. Explain the function of fluoroscopy *(p. 481).*

59. Identify the usual location of the fluoroscopy tube *(p. 481).*

60. Identify the fluoroscopic mA range of operation; what is "boost mode"? *(pp. 481–482).*

61. List at least six fluoroscopic equipment features designed to reduce patient and personnel exposure *(pp. 482–483).*

62. Explain why fluoroscopic exposure dose is greater than radiographic dose *(p. 482).*

63. Identify, with respect to the image intensifier (II), the: *(pp. 483–485)?*
    A. composition of the input screen, and its characteristics and advantages
    B. action of the photocathode
    C. function of the electrostatic focusing lenses
    D. function and potential difference of the accelerating anode
    E. function and size of the output screen
    F. two components of total brightness gain

64. Determine minification gain *(p. 485).*

65. Define vignetting *(p. 485).*

66. Discuss advantages and disadvantages of magnified images *(pp. 485–486).*

67. Identify ways in which the fluoroscopic image can be recorded *(pp. 483, 487–488).*

68. Identify by what means the image intensifier compensates for varying body thicknesses *(p. 487).*

69. Define what is meant by coupling *(p. 487).*

70. Identify the fluoroscopic monitor controls regulatable by the radiographer *(p. 487).*

71. Compare television monitor resolution with that of spot films *(p. 484, 485, 490).*

72. Identify the sizes of cine film available and compare each with regard to patient dose and image quality *(p. 487).*

73. Differentiate between panchromatic and orthochromatic film *(p. 488).*

74. Identify the spot film sizes available and relate each to patient dose and image quality *(p. 488).*

75. Describe the advantages and disadvantages of videotape image recording *(p. 488).*

76. What device couples the II and TV monitor in DF *(p. 488)?*

77. Describe the operation of CCDs. *(pp. 488–489).*

78. Compare the SNR of cameras such as Plumbicon and vidicon to the SNR of CCDs. *(pp. 488–489).*

79. List four advantages of DF over analog fluoroscopy *(pp. 488–489).*

80. Explain how/why DF can offer considerably less patient dose. *(p. 489).*

81. What is the advantage of "last image hold"? What is "road-mapping" technique *(p. 489)?*

Chapter Review Questions

1. Advantages of digital radiography (computed radiography) include all of the following, *except* the ability to:
   (A) compensate for exposure factors
   (B) make changes in contrast characteristics
   (C) improve geometric detail
   (D) store images in binary form

2. A three-phase timer can be tested for accuracy using a synchronous spinning top. The resulting image looks like a:
   (A) series of dots or dashes, each representative of a radiation pulse
   (B) solid arc, the angle (in degrees) representative of the exposure time
   (C) series of gray tones, from white to black
   (D) multitude of small mesh-like squares of uniform sharpness

3. In the production of Bremsstrahlung radiation, the incident electron:
   (A) ejects an inner shell tungsten electron
   (B) ejects an outer shell tungsten electron
   (C) is deflected with resulting energy loss
   (D) is deflected with resulting energy increase

4. Which of the following will occur as a result of decreasing the anode target angle?
   1. anode heel effect will be less pronounced
   2. effective focal spot size will decrease
   3. greater photon intensity toward the cathode side of the x-ray tube
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

5. Which of the following image matrix sizes will result in the best resolution?
   (A) 128×128
   (B) 512×512
   (C) 1089×1089
   (D) 2048×2048

6. The device used to ensure reproducible images, regardless of tissue density variations, is the:
   (A) phototimer
   (B) penetrometer
   (C) grid
   (D) rare earth screen

7. Changes in window width in digital imaging result in changes in:
   (A) contrast
   (B) density
   (C) resolution
   (D) distortion

8. If the primary coil of the high-voltage transformer is supplied by 220 V and has 150 turns, and the secondary coil has 75,000 turns; what is the voltage induced in the secondary coil?
   (A) 75 kV
   (B) 110 kV
   (C) 75 V
   (D) 110 V

9. Which of the following circuit devices operate(s) on the principle of self-induction?
   1. autotransformer
   2. choke coil
   3. high-voltage transformer
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

10. Which of the following statement(s) regarding transformer laws is (are) correct?
    1. the voltage and current values are increased with a step-up transformer
    2. the voltage is directly related to the number of turns in the two coils
    3. the product of voltage and current in the two circuits must be equal
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

Answers and Explanations

1. (C) All other factors can be changed in the computer to manipulate the image. Geometric detail is controlled only by source-to-image-receptor distance (SID), object-to-image-receptor distance (OID), and focal spot size. These factors are fixed during the x-ray exposure.

2. (B) When a spinning top is used to test the efficiency of a single-phase timer, the result is a *series of dots* or dashes, with each dot or dash representing a pulse of radiation. With

full-wave rectified current, and a possible 1/20 dots (pulses) available per second, one should visualize 12 dots at 1/10 second, 24 dots at 1/5 second, 6 dots at 1/20 second, and so on. But because three-phase equipment is almost constant potential, a synchronous spinning top must be used, and the result is a *solid arc* (rather than dots). The number of degrees formed by the arc is measured and equated to a particular exposure time. A multitude of small mesh-like squares describes a screen contact test. An aluminum step-wedge (penetrometer) may be used to demonstrate the effect of kV on contrast (demonstrating a series of gray tones from white to black), with a greater number of grays demonstrated at higher kV levels.

3. (C) Bremsstrahlung (or Brems) radiation is one of the two kinds of x-rays produced at the tungsten target of the x-ray tube. The incident high-speed electron, passing through a tungsten atom, is attracted by the positively charged nucleus; therefore, it is *deflected from its course with a resulting loss of energy*. This energy loss is given up in the form of an x-ray photon.

4. (C) Target angle has a pronounced geometric effect on the effective, or projected, focal spot size. As target angle *decreases* (i.e., gets steeper or smaller), the effective (projected) focal spot becomes smaller. This is advantageous because it will improve radiographic detail without creating a heat-loading crisis at the anode (as would be the case if the actual focal spot size were reduced to produce a similar detail improvement). There are disadvantages, however. With a smaller target angle the anode heel effect increases; photons are more noticeably absorbed by the "heel" of the anode, resulting in a smaller percentage of x-ray photons at the anode end of the x-ray beam and a concentration of x-ray photons at the cathode end of the image.

5. (D) A digital image is formed by a *matrix* of *pixels* in rows and columns. A matrix having 512 pixels in each row and column is a 512×512 matrix. As in traditional radiography, *spatial resolution* is measured in line pairs per mm (*lp/mm*). As matrix size is increased, there are more and smaller pixels in the matrix, which means improved resolution. Fewer and larger pixels result in a poor resolution "pixelly" image, that is, one that you can actually see the individual pixel boxes (Fig. 14–23).

6. (A) Radiographic reproducibility is an important concept in producing high-quality diagnostic films. Radiographic results should be consistent and predictable, not only in positioning accuracy but with respect to exposure factors as well. Automatic exposure devices (phototimers and ionization chambers) automatically terminate the x-ray exposure once a predetermined quantity of x-ray has penetrated the patient, thus ensuring consistent results.

7. (A) One advantage of computed radiography is the ability to *manipulate* the image after exposure ("postprocessing"). Image manipulation postprocessing can be used for *windowing, contrast and/or density modification*, or *image subtraction.*
   Windowing is a process of changing the contrast and density setting on the finished image. The window *width* controls the *number of shades of gray* in the image (contrast), while the window *level* corresponds to the image *density.*

8. (B) The high-voltage, or step-up, transformer functions to *increase voltage* to the necessary kilovoltage. It *decreases the amperage* to milliamperage. The amount of increase or decrease *depends on the transformer ratio*, that is, the number of turns in the primary coil to the number of turns in the secondary coil. The transformer law is as follows:

To Determine Secondary V

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

To Determine Secondary I

$$\frac{I_s}{I_p} = \frac{V_p}{V_s}$$

Substituting known values,

$$\frac{x}{220} = \frac{75000}{150}$$

$$150x = 16\,500\,000$$

$$x = 110\,000 \text{ V} (= 110 \text{ kV})$$

9. (B) The principle of self-induction is an example of the second law of electromagnetics (Lenz's law), which states that an induced current within a conductive coil will oppose the direction of the current that induced it. It is important to note that self-induction is a characteristic of AC *only*. The fact that AC constantly changes direction accounts for opposing currents set up in the coil. Two x-ray circuit devices operate on the principle of self-induction: The *autotransformer* operates on the principle of self-induction and enables the radiographer to vary the kilovoltage. The *choke coil* also operates on the principle of self-induction; it is a type of variable resistor that may be used to regulate filament current. The high-voltage transformer operates on the principle of mutual induction.

10. (C) Transformers are used in the x-ray circuit to change the value of the supplied voltage to a value appropriate for the production of x-rays. Although the incoming voltage supply may be 220 V, thousands of volts are required for the production of x-rays. A step-up transformer consists of two coils, a primary and a secondary, in close proximity to each other (e.g., side by side). As the primary coil is supplied with AC, a magnetic field rises up around the coil and proceeds to "cut" the secondary coil. Because the current supply is AC, the magnetic field is constantly expanding and contracting (rising and falling) and continuously "cutting" the secondary coil. This interaction between magnetic field and conductive coils induces a current in the secondary coil *proportional to* the number of turns in the secondary coil. As the number of turns in the secondary coil increases, so does the induced voltage. However, because we cannot just create energy, only change its form, *the amperage in the second coil is proportionally less.* For example, if the voltage in the secondary coil increased 10 times, the current would decrease by a factor of 10. Therefore, in keeping with the law of conservation of energy, the product of the voltage and current in one coil must equal the product of voltage and current in the second coil.

Standards of Performance and Equipment Evaluation

15

National Council on Radiation Protection and Measurements (NCRP) Report No. 102 serves as a guide to good medical radiation practices by describing the federal regulations on equipment design, performance, and use. Manufacturers of x-ray equipment must follow guidelines that state maximum x-ray output at specific distances, total quantities of filtration, positive beam limitation, and other guidelines. Radiographers must practice safe *principles of operation*; *preventive maintenance* and *quality control* checks must be performed at specific intervals to ensure continued safe equipment performance.

Radiologic quality control involves monitoring and regulating the variables associated with image production and patient care. Every radiologic facility today must establish quality control (QC) guidelines and conduct QC programs to provide a consistent standard of care. A properly documented, ongoing, and effective QC program is required by hospital accrediting agencies and state departments of health.

The rationale behind QC is that a radiographic imaging system performing in an erratic and undependable manner results in repeat exposures, thus contributing to unnecessary patient dose and uneconomical use of time, equipment, and supplies. *Radiographic QC* is an organized and methodical evaluation of imaging components from the x-ray tube to the automatic film processor, with the purpose of decreasing repeat exposures, thereby decreasing patient radiation exposure and increasing cost-effectiveness. The *frequency of testing* ranges from daily processor checks to quarterly, semiannual, and annual equipment performance testing. Processor QC was discussed in Chapter 12.

The position of QC technologist is an increasingly important one requiring advanced knowledge and skills. In recognition of this, the ARRT has implemented an advanced certification examination in QC.

The QC program requires the combined efforts of the radiographer, QC technologist, service engineers, and medical physicist. The radiographer must be alert to any equipment malfunctions or unusual occurrences and report them to the QC technologist without delay. The QC technologist, service engineer, and medical physicist are responsible for equipment testing, correlation of test results, any necessary

corrections or modifications, and accurate documentation of their activities.

QC in digital/electronic imaging is relatively new. There are some established parameters for consideration, but there is much more to be experienced and learned. Established maintenance procedures will be discussed.

I. EQUIPMENT CALIBRATION

A. κV

Kilovoltage accuracy is essential to achieve the desired radiographic contrast. *Calibration* of kV (kilovolts) was formerly evaluated using a Wisconsin test tool and cassette. The *digital kV test meters* used today are more convenient and simple to use. When various kilovoltages are tested in the normal diagnostic range (40–150 kV), the selected kilovolt and actual kilovolt value should not differ by more than ±4 kV for *general diagnostic* equipment and by 5% of the nominal kV for *mammography* equipment (Fig. 15–1), for example, at 30 kV, a margin of error of 1.5 kV would be within specifications.

B. мА

The accuracy of individual mA (milliampere) stations is related to *patient dose* and is essential for production of expected radiographic *density* levels.

Elements of a Typical Quality Control Program

- Timer accuracy testing
- mA (milliampere) linearity testing
- kV (kilovolts peak) accuracy testing
- HVL (half-value layer) testing
- Exposure reproducibility testing
- Focal spot size test
- X-ray beam/light field/Bucky tray alignment evaluation
- Intensified screen cleaning and testing
- Illuminator cleaning and evaluation
- Automatic processor maintenance and control
- X-ray evaluation of lead aprons and gloves

Figure 15–1. A mammographic phantom contains mylar fibers, simulated masses, and specks of simulated calcifications. American College of Radiology accreditation criteria states that a minimum of 10 objects (4 fibers, 3 specks, and 3 masses) must be visualized on test films. (Courtesy of Gammex Inc.)

An *aluminum step-wedge* (penetrometer) can be used to evaluate each mA station. A series of exposures is made at a particular kV *using the same mAs (milliampere-seconds) value at each mA station*, with exposure time adjusted to maintain a constant mAs. The resulting step-wedge images should be identical. Performance of this test on properly calibrated equipment is a good illustration of the *reciprocity law*. *Linearity* of mA is frequently evaluated using a digital dosimeter (ionization chamber). Exposures are made at a particular mAs with various combinations of mA and time; x-ray output is measured in mR/mAs and should be accurate to within 10%.

C. TIMER

Timer accuracy is related to patient dose and the production of expected radiographic density, and should be tested at least on an annual basis. *Spinning-top tests*, for determination of timer accuracy, were described in Chapter 14. The use of the digital dosimeter, however, is favored by many as a more simple and accurate measure of timer accuracy. The selected exposure time should be within 5% of the actual exposure time. Similar tests are used to evaluate the accuracy of automatic exposure devices.

D. REPRODUCIBILITY

This test should be performed annually to evaluate *consistency* of x-ray tube output. A particular group of technical factors is selected and a series of consecutive exposures (at least five) is made. The factors are changed between exposures and then changed back to the original technique. The digital radiation meter should register radiation output that does not vary more than 5%. If a radiographer notices an exposure fluctuation while using a particular group of technical factors, the *reproducibility* test is performed using those factors, but alternately changing to other technical factors between exposures.

E. HALF-VALUE LAYER

Half-value layer (HVL) testing provides beam-quality information that is different from that obtained from kV testing. HVL is defined as the thickness of any absorber that will reduce x-ray beam intensity to one-half its original value. HVL is determined by measuring the beam intensity without an absorber, then recording the intensity as successive millimeters of aluminum are added to the radiation field. HVL is influenced by the type of rectification, total filtration, and kV. An x-ray tube HVL should remain almost constant. If HVL decreases, it is an indication of a decrease in the actual kV. If the HVL increases, it indicates the deposition of vaporized tungsten on the inner surface of the glass envelope (as a result of tube aging) or an increase in the actual kV.

F. FOCAL SPOT SIZE

Focal spot size accuracy is related to the degree of *geometric blur*, that is, edge gradient or penumbra. Manufacturer tolerance for new focal spots is a surprisingly large, 50%; that is, a 0.3-mm focal spot may actually be 0.45 mm (that can significantly impact magnification radiography). Additionally, the focal spot can increase in size as the

x-ray tube ages; hence, the importance of *testing* newly arrived focal spots and periodic testing to monitor focal spot changes.

Focal spot size can be measured with a *pinhole camera, slit camera*, or *star-pattern*–type *resolution device*. The pinhole camera is rather difficult to use accurately and requires the use of excessive tube (heat) loading. With a *slit camera*, two exposures are made; one measures the length of the focal spot, and the other measures the width. The *star pattern*, or similar resolution device, can measure focal spot size *as a function of geometric blur* and is readily adaptable in a QC program to monitor focal spot changes over a period of time. It is recommended that focal spot size be checked on installation of a new x-ray tube and annually thereafter.

II. RADIOGRAPHIC AND FLUOROSCOPIC ACCESSORIES

A. CASSETTES

The exterior of all cassettes should be checked periodically for damage and signs of wear. Loose latches or hinges, damaged frames, or deteriorated felt or sponge should be repaired or replaced.

B. INTENSIFYING SCREENS

Intensifying screens should first be visually inspected for abrasions, stains, and other signs of wear. Screens need regular periodic cleaning according to the manufacturer's recommendations. In general, a nonabrasive, lint-free cloth is used with a special antistatic screen cleaner. Care must be taken not to use excessive solution and to allow the screens to dry thoroughly before use.

Adequate screen care includes periodic *screen–film contact tests* using the special wire-mesh test device. The cassette to be tested is placed on the x-ray table, the wire-mesh device on top of the cassette, and an exposure made of approximately 5 mAs and 40 kV. The processed film should be viewed at a distance of at least 6 feet. Any blurry areas are indicative of poor screen to film contact and representative of diminished image detail. Cassettes having areas of poor screen and film contact must be repaired or replaced, as poor contact will seriously impair *recorded detail*.

Grid cassettes should be evaluated periodically to identify any damage to the fragile lead strips within. The film-loaded grid cassette is slightly exposed, just enough to make the lead strips visible. The processed radiograph is examined for any areas of uneven density or evidence of damaged, misaligned lead strips.

C. ILLUMINATION

One of the most frequently overlooked components of an adequate QC program is radiographic illumination. Radiographic density and contrast can be significantly misrepresented on illuminators providing different degrees of brightness. A radiographic image viewed by the QC technologist in the processor room can look very different on the radiologist's illuminator. A simple light meter, held at the same

distance from each illuminator (approximately 3 feet), will reveal any differences in illumination.

Illuminator surfaces need to be cleaned periodically to remove buildup of dust and grime. When one bulb in a bank of illuminators requires changing, *all* the bulbs should be changed to guarantee uniform brightness.

D. LEAD APRONS AND GLOVES

Personal fluoroscopic shielding apparel such as lead aprons, gloves, and thyroid shields should be *fluoroscoped annually* to detect any cracks that may have developed in the leaded vinyl.

Proper care is required to help prolong the useful life of lead apparel. If soiled, it can be cleaned with a damp cloth. Lead aprons should not be folded or carelessly dropped to the floor, for that facilitates the development of cracks in the leaded vinyl. Lead aprons and gloves should be hung on appropriate racks when not in use.

III. DIGITAL IMAGING CONSIDERATIONS

Digital/electronic imaging is still relatively new, but a good QC program is essential to consistent, effective operation. There are some established parameters for consideration, but there is much more to be experienced and learned. Established maintenance procedures will be covered here.

A *daily density check* on the printer/processor should be performed according to the manufacturer's recommendations. The air intakes on the *reader* should be cleaned weekly or according to the manufacturer's recommendations.

The *laser* in the CR reader should be checked monthly for evidence of "jitter." Regular *contrast evaluation* is recommended; this confirms the consistency of the x-ray exposure, the CR reader, the workstation display, and the hard copy printer. A *sharpness* test is performed to evaluate the x-ray tube performance, the CR reader optics, the monitor display, and the hard copy printer. The assessment of the exposure index/sensitivity checks the calibration and consistency of the actual x-ray exposures as well as the photomultiplier tube of the CR reader. Other tests include assessment of image *noise*, *artifacts*, *erasure* thoroughness, and *linearity* testing. A special phantom is provided to evaluate all system components/characteristics (Fig. 15–2).

CR image plates should be visually checked on a regular basis for any physical damage. Inserting a damaged IP into the reader can result in mechanical failure and system shutdown. The photostimulable phosphor storage screen (PSP) should be removed before cleaning the IP. Image plates should be cleaned in a manner similar to traditional screen–film cassettes. IPs should be treated in the same way as traditional screen–film cassettes in the presence of blood–body fluids (placed in plastic bag for use). Never place a damp–wet IP into the reader.

The *PSPs* should be cleaned monthly. It is important that *anhydrous ethanol* be used for cleaning most CR PSPs. A small amount of anhydrous ethanol is placed on a lint-free cloth for cleaning and removal of any dust or other particles. Remnant moisture of any kind

Figure 15–2. CR requires a regular QA program, just as other imaging systems and system components. The figure shows a typical CR test phantom—it is used to evaluate the accuracy of several system components/characteristics. (Courtesy FUJIFILM Medical Systems USA, Inc.)

must be avoided—it can cause the phosphors to swell. *Dust* on PSPs has the same effect as dust on intensifying screens—a clear pinhole artifact. PSPs should be checked for physical damage, too. *Scratches* will appear as clear areas on the resulting image.

Appropriate care will ensure a maximum useful life. The life of the typical PSP is approximately 10,000 exposures.

■ *SUMMARY*

- **The function of QC is to provide consistent high-quality radiographs, thus reducing patient dose and increasing cost-effectiveness.**
- **QC programs involve evaluation and documentation of all imaging components from the x-ray tube to automatic processor.**
- **Kilovoltage accuracy can be determined using a Wisconsin test cassette or digital meter, and must be accurate to within 5 kV (plus or minus 10%).**
- **Milliamperage accuracy is determined using an aluminum step-wedge or digital dosimeter, and must be accurate to within 10%.**

- **Timer accuracy is evaluated using a manual spinning top (for Sφ) or synchronous spinning top (for 3φ), and must be accurate to within 5%. Reproducibility refers to tube output consistency and must not vary more than 5%.**
- **HVL is tested periodically to evaluate x-ray beam quality; HVL should remain almost constant.**
- **Focal spot size is tested by using a pinhole camera, slit camera, or star test pattern on installation and every year thereafter.**
- **Cassette exteriors and interiors should be inspected periodically.**
- **Intensifying screens must be cleaned regularly and screen and film contact tests performed periodically.**
- **Grid cassettes should be tested for damaged lead strips.**
- **Illuminators must be cleaned and checked for uniformity.**
- **Lead gloves and aprons must be fluoroscoped annually to detect any cracks; they should be properly hung when not in use.**
- **CR printer/processors should have a daily density check performed.**
- **Reader air intakes should be checked weekly.**
- **IPs and their PSPs should be visually checked and correctly cleaned on a regular basis.**
- **Dust and scratches on CR PSPs create artifacts similar to those created with screen–film cassettes.**

Chapter Exercises

⭐ *Congratulations! You have completed your review of the entire chapter. If you are able to answer the following group of very comprehensive questions, you should feel confident that you have really mastered this section. You are then ready to go on to "Registry-type" questions that follow. For greatest success, do not go to these multiple-choice questions without first completing the short-answer questions below.*

1. Describe the value of a QC program *(p. 499).*

2. Identify the method used for kV calibration and the required degree of accuracy *(p. 500).*

3. Describe the method of evaluating mA calibration using an aluminum step-wedge *(pp. 500–501).*

4. Describe how mA linearity is usually evaluated, and identify the required degree of accuracy *(p. 501).*

5. Describe how Sφ and 3φ timer accuracy is evaluated, identify the appropriate tool for each, give examples of acceptable results, and identify the degree of accuracy required *(p. 501).*

6. Explain what is meant by reproducibility, and identify the degree of accuracy required *(p. 501).*

7. Define HVL and list the three factors that influence it *(p. 501).*

8. Explain how tube aging can result in increased HVL *(p. 501).*

9. Identify when the focal spot size should be checked and the three devices that can be used to determine focal spot size *(pp. 501–502).*

10. Describe the conditions/faults/injuries that cassettes and intensifying screens should be visually checked for *(p. 502).*

11. Explain the need for, and proper method of, periodic screen cleaning *(p. 502).*

12. Describe the purpose and method of screen–film contact testing *(p. 502).*

13. Explain how to check the condition of a grid *(p. 502).*

14. Explain the necessity of QA checks on illumination *(p. 502)*.

15. Describe the proper care, storage, and checking of lead apparel *(p. 503)*.

16. How often should density checks be made on CR printer/processors? How often the air intakes be checked? *(p. 503)*.

17. How should CR cassettes be checked and cleaned *(pp. 503–504)*.

18. If a CR image plate has particles of dust on it, how will that appear on the digital image *(p. 504)*.

19. If a CR image plate is scratched, how will that appear on the digital image *(p. 504)*.

Chapter Review Questions

1. Radiographs from a particular three-phase, full-wave rectified x-ray unit were underexposed, using known correct exposures. A synchronous spinning-top test was performed using 100 mA, 1/20 second, and 70 kV, and a 12-degree arc is observed on the test film. Which of the following is *most* likely the problem?
   (A) the 1/20-second time station is inaccurate
   (B) the 100 mA station is inaccurate
   (C) a rectifier is not functioning
   (D) the processor needs servicing

2. Which of the following refers to a regular program of evaluation that ensures proper functioning of x-ray equipment, thereby protecting both patients and radiation workers?
   (A) sensitometry
   (B) densitometry
   (C) quality assurance
   (D) modulation transfer function

3. Which of the following is used to evaluate focal spot size?
   (A) spinning top
   (B) wire-mesh
   (C) slit camera
   (D) penetrometer

4. Which of the following is usually recommended for cleaning PSPs?
   (A) denatured alcohol
   (B) anhydrous ethanol
   (C) soap and water
   (D) intensifying screen cleaner

5. Proper care of leaded apparel includes:
    1. periodic check for cracks
    2. careful folding following each use
    3. routine laundering with soap and water
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

6. Periodic equipment calibration includes testing of the:
    1. focal spot
    2. mA
    3. kV
    (A) 1 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

7. The spinning-top test can be used to evaluate:
    1. timer accuracy
    2. rectifier failure
    3. effect of kV on contrast
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 1, 2, and 3

8. Which of the following contribute(s) to inherent filtration?
    1. x-ray tube glass envelope
    2. x-ray tube port window
    3. aluminum between tube housing and collimator
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

9. By which of the following can poor screen–film contact be caused?
    1. damaged cassette frame
    2. foreign body in cassette
    3. warped cassette front
    (A) 1 only
    (B) 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

10. A quality assurance program includes checks on which of the following radiographic equipment conditions?
    1. reproducibility
    2. linearity
    3. positive beam limitation
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

Answers and Explanations

1. (A) A synchronous spinning top test is used to test timer accuracy or rectifier function in three-phase equipment. Because three-phase, full-wave rectified current would expose a 360-degree arc per second, a 1/20-second exposure should expose an 18-degree arc. Anything more or less indicates timer inaccuracy. If exactly one-half of the expected arc appears, one should suspect rectifier failure.

2. (C) Sensitometry and densitometry are used in evaluation of the film processor, just one part of a complete quality assurance (QA) program. Modulation transfer function (MTF) is used to express spatial resolution, which is another component of the QA program. A complete QA program includes testing of all components of the imaging system: processors, focal spot, x-ray timers, filters, intensifying screens, beam alignment, and so on.

3. (C) Focal spot size accuracy is directly related to the degree of *geometric blur*, that is, as focal spot size increases, blur increases. Manufacturer tolerance for new focal spots is 50% and focal spot size can increase in size as the x-ray tube ages; hence, the importance of *testing* new focal spots and periodic testing to monitor any focal spot changes. Focal spot size can be measured with a *pinhole camera, slit camera,* or *star-pattern*–type *resolution device.* The pinhole camera and slit camera measure the physical size of the focal spot, while the star pattern measures focal spot size as a function of resolution/geometric blur.

Perfect film–screen contact is essential to recorded detail and is evaluated with a *wire-mesh* test. A *spinning-top* test is used to evaluate timer accuracy and rectifier operation. A *penetrometer* (aluminum step-wedge) is used to illustrate the effect of kV on contrast.

4. (B) CR *PSPs* should be cleaned monthly. It is important that *anhydrous ethanol* be used for cleaning most CR PSPs. A small amount of anhydrous ethanol is placed on a lint-free cloth for cleaning and removal of any dust or other particles. Water and remnant moisture must not be used as it can cause phosphor swelling. *Dust* on PSPs has the same effect as dust on intensifying screens—a clear pinhole artifact. PSPs should also be checked for physical damage. Scratches will appear as clear areas on the resulting image. CR *IPs* should be visually checked for physical damage; inserting a damaged CR IP into the reader can result in mechanical failure and system shutdown.

5. (A) Protective lead aprons and gloves are made of lead impregnated vinyl or leather. They should be checked for cracks radiographically from time to time. Otherwise, minimal care

is required. Lead aprons and gloves should always be hung on appropriate hangers. Glove supports permit air to circulate within the glove. Apron hangers provide convenient storage without folding. If lead aprons are folded (or just left in a heap!), cracks are more likely to form. If lead aprons or gloves become soiled, cleaning with a damp cloth and appropriate solution is all that is required. Excessive moisture should be avoided.

6. (D) Radiographic results should be consistent and predictable not only in positioning accuracy but with respect to exposure factors and image sharpness as well. X-ray equipment should be calibrated periodically as part of an ongoing QA program. The quantity (mAs) and quality (kV) of the primary beam have a big impact on the quality of the finished radiograph. The focal spot should be tested periodically to evaluate its impact on image sharpness.

7. (C) The spinning-top test is used to evaluate *timer accuracy* or *rectifier failure*. With single-phase, full-wave rectified equipment (120 pulses per second) for example, 12 dots should be visualized when using the 1/10-second station. A few more or less indicate timer inaccuracy. If the test demonstrated six dots, one might suspect rectifier failure. With three-phase equipment a special synchronous spinning top (or oscilloscope) is used and a solid black arc is obtained rather than dots. The length of this arc is measured and compared with the known correct arc.

8. (B) Inherent filtration is that which is "built into" the construction of the x-ray tube. Before exiting the x-ray tube, x-ray photons must pass through the tube's glass envelope and port window; the photons are filtered somewhat as they do so. This inherent filtration is usually the equivalent of 0.5 mm Al. Aluminum filtration *placed* between the x-ray tube housing and collimator is added to contribute to the total necessary requirement of 2.5 mm Al equivalent. The collimator itself is considered part of the added filtration (1.0 mm Al equivalent) because of the silver surface of the mirror within. It is important to remember that as aluminum filtration is added to the x-ray tube, the HVL increases.

9. (D) Perfect contact between the intensifying screens and film is essential to maintain image sharpness. Any separation between them allows diffusion of fluorescent light and subsequent blurriness and loss of detail. Screen–film contact can be diminished if the cassette frame is damaged and misshapen, if the front is warped, or if there is a foreign body between the screens elevating them.

10. (D) The accuracy of all three is important to ensure adequate patient protection. *Reproducibility* means that repeated exposures at a given technique must provide consistent intensity. *Linearity* means that a given mAs, using different mA stations with appropriate exposure time adjustments, will provide consistent intensity. *Positive beam limitation (PBL)* is automatic collimation and must be accurate to 2% of the source-to-image-receptor distance (SID). Light-localized collimators must be available and must be accurate to within 2%.

Practice Test

This practice test is intended to simulate the actual certification examination. Set aside special time for this test after your preparations for the actual examination are complete. Try to *simulate the actual examination environment* as much as possible. Choose a quiet place free from distractions and interruptions, gather the necessary materials, and arrange to be uninterrupted for *up to 3 hours*.

Each of the numbered items or incomplete statements in this section is followed by answers or by completions of the statement. Select the lettered answer or completion that is *best* in each case.

1. Required components of a digital fluoroscopy system include:
    1. computer
    2. video monitor
    3. image manipulation console
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

2. What is used to account for the relative radiosensitivity of various tissues and organs?
    1. radiation weighting factors (W_r)
    2. tissue weighting factors (W_t)
    3. absorbed dose
    (A) 1 only
    (B) 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

3. Which of the following statements regarding Figures 16–1A and B is true?
    (A) In Figure 16–1A, the CR and plantar surface form a 30-degree angle
    (B) In Figure 16–1A, the CR and plantar surface form a 60-degree angle
    (C) In Figure 16–1B, the CR and plantar surface form a 30-degree angle
    (D) In Figure 16–1B, the CR and plantar surface form a 60-degree angle

Figure 16–1. **A & B**. Courtesy of Conrad P. Ehrlich, MD.

4. Photostimulable luminescence occurs when the PSL is exposed to:
   (A) monochromatic laser light
   (B) barium fluorohalide
   (C) high-energy x-ray photons
   (D) low-energy x-ray photons

5. Structures located in the LUQ of the average adult include:
      1. ascending colon
      2. spleen
      3. pancreatic tail
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

6. When reviewing patient blood chemistry levels, what is considered the normal creatinine range?
   (A) 0.6–1.5 mg/100 mL
   (B) 4.5–6 mg/100 mL
   (C) 8–25 mg/100 mL
   (D) up to 50 mg/100 mL

7. Symptoms of imminent anaphylactic shock include:
   1. dysphagia
   2. itching of palms and soles
   3. constriction of the throat
   (A) 1 only
   (B) 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

8. Which of the following is/are well demonstrated in the lateral position of the cervical spine?
   1. intervertebral foramina
   2. apophyseal joints
   3. intervertebral joints
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

9. The effects of radiation to biologic material are dependent on several factors. If a quantity of radiation is delivered to a body over a long period of time, the effect:
   (A) will be greater than if it were delivered all at one time
   (B) will be less than if it were delivered all at one time
   (C) has no relation to how it is delivered in time
   (D) is solely dependent on the radiation quality

10. Which ethical principle below is most closely related to truth telling?
    (A) autonomy
    (B) beneficence
    (C) fidelity
    (D) veracity

11. *Somatic effects* of radiation refer to effects that are manifested:
    (A) in the descendants of the exposed individual
    (B) during the life of the exposed individual
    (C) in the exposed individual and their descendants
    (D) in the reproductive cells of the exposed individual

12. The right colic flexure is formed by the junction of the:
    (A) transverse and ascending colon
    (B) descending and transverse colon
    (C) descending and sigmoid colon
    (D) cecum and ascending colon
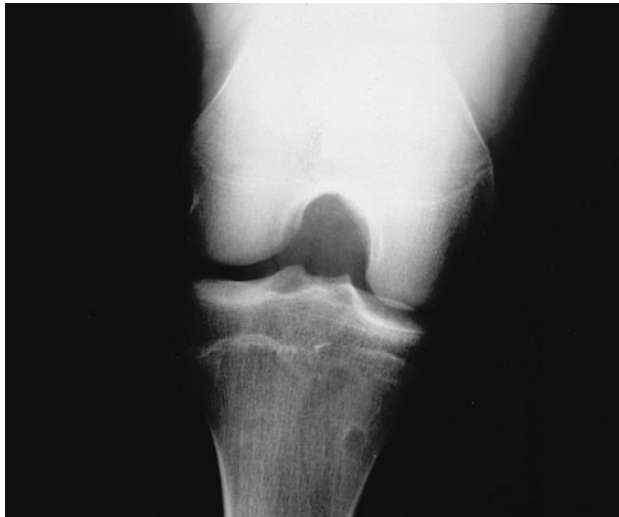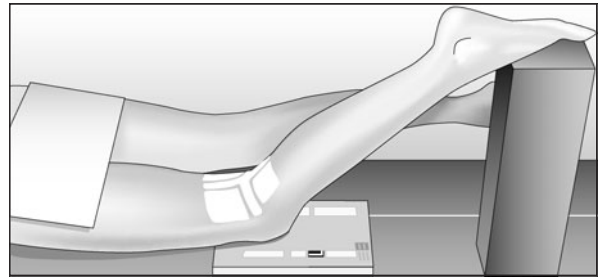
A   B

Figure 16–2.

13. Which of the following imaging procedures do *not* require the use of ionizing radiation to produce an image?
    1. sonography
    2. computerized tomography
    3. magnetic resonance imaging
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

14. An abnormal passage between organs is a/an:
    (A) fistula
    (B) polyp
    (C) diverticulum
    (D) abscess

15. The position seen in Figure 16–2, used to demonstrate the intercondyloid fossa, requires that the CR be directed:
    (A) vertically to the joint space
    (B) parallel to the long axis of the tibia
    (C) perpendicular to the long axis of the tibia
    (D) perpendicular to the joint space

16. Symptoms of shock include:
    1. pallor and weakness
    2. increased pulse rate
    3. fever
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

17. Red blood cells are formed in the:
    (A) liver
    (B) spleen
    (C) bone marrow
    (D) small intestine

18. The term *effective dose* refers to:
    (A) whole-body dose
    (B) localized organ dose
    (C) genetic effects
    (D) somatic and genetic effects
    (E) flexion and extension laterals

19. With the body in the erect position, the diaphragm moves:
    (A) 2–4 inches higher than when recumbent
    (B) 2–4 inches lower than when recumbent
    (C) 2–4 inches superiorly
    (D) very slightly

20. With all other factors constant, as a digital image's matrix size increases:
    1. pixel size decreases
    2. resolution increases
    3. pixel size increases
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 2 and 3 only

21. During a gastrointestinal examination, the AP recumbent projection of a stomach of average shape will usually demonstrate:
    1. barium-filled fundus
    2. double-contrast of distal stomach portions
    3. barium-filled duodenum and pylorus
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

22. An ambulatory patient is one who:
    (A) is able to walk
    (B) is unable to walk
    (C) has difficulty breathing
    (D) arrives by ambulance

23. In which of the following positions was the radiograph seen in Figure 16–3 made?
    (A) AP erect
    (B) PA recumbent
    (C) right lateral decubitus
    (D) left lateral decubitus

Figure 16–3. From the American College of Radiology Learning File. Courtesy of the American College of Radiology.

24. Advantages of moving the image intensifier closer to the patient during fluoroscopy include:
    1. decreased SID
    2. decreased patient dose
    3. improved image quality
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

25. The exposure factors used for a particular nongrid radiograph were 400 mA, 0.02 second, and 90 kV. Another radiograph using an 8:1 grid is requested. Which of the following groups of factors is *most* appropriate?
    (A) 400 mA, 0.02 second, 110 kV
    (B) 200 mA, 0.08 second, 90 kV
    (C) 300 mA, 0.05 second, 100 kV
    (D) 400 mA, 0.08 second, 90 kV

26. Which of the "curves" seen in Figure 16–4 best illustrates the dynamic range of a computed radiography image plate?
    (A) curve A
    (B) curve B
    (C) both represent a CR PSP/IP
    (D) neither represents a CR PSP/IP
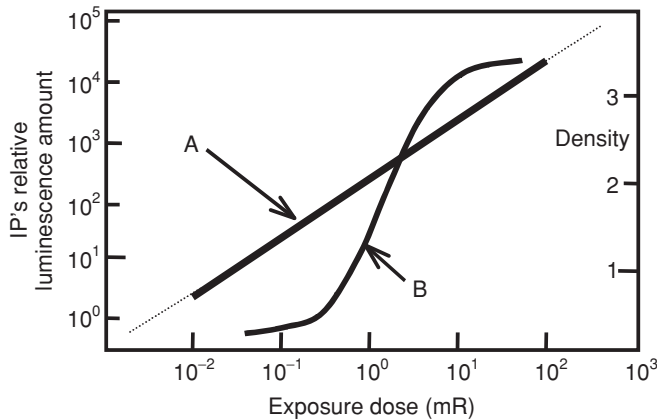
Figure 16–4. Courtesy of FUJIFILM Medical Systems USA, Inc.

27. Which of the following factor(s) is (are) important in determining thickness of protective barriers?
    1. distance between x-ray source and barrier
    2. occupancy factor time
    3. workload (mA-min/wk)
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

28. An autoclave is used for:
    (A) dry heat sterilization
    (B) chemical sterilization
    (C) gas sterilization
    (D) steam sterilization

29. When examining the fourth and fifth fingers in the lateral position, which side of the forearm should be closest to the image receptor?
    (A) anterior
    (B) posterior
    (C) medial
    (D) lateral

30. The input phosphor of the image intensifier tube functions to convert:
    (A) kinetic energy to light
    (B) x-ray to light
    (C) electrons to light
    (D) fluorescent light to electrons

31. Recorded detail can be improved by decreasing:
    1. the SID
    2. the OID
    3. motion unsharpness
    (A) 1 only
    (B) 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

32. Examples of primary radiation barriers include:
    1. x-ray room walls
    2. control booth
    3. lead aprons
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

33. Which of the following formulas would the radiographer use to determine the total number of heat units produced with a given exposure using 3-phase, 12-pulse equipment?
    (A) mA × time × kV
    (B) mA × time × kV × 3.0
    (C) mA × time × kV × 1.35
    (D) mA × time–kV × 1.41

34. Diseases whose mode of transmission is through the air include:
    1. tuberculosis
    2. mumps
    3. rubella
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

35. Which of the following image matrix sizes will provide the best spatial resolution?
    (A) 256 × 256
    (B) 512 × 512
    (C) 1024 × 1024
    (D) 2048 × 2048

36. In which of the following positions was the radiograph seen in Figure 16–5 made?
    (A) AP erect
    (B) PA recumbent
    (C) right lateral decubitus
    (D) dorsal decubitus

37. The photoelectric process is an interaction between an x-ray photon and:
    (A) an inner shell electron
    (B) an outer shell electron
    (C) a nucleus
    (D) another photon

38. What transforms the violet light emitted by the PSP into the image seen on the CRT?
    (A) the photostimulable phosphor
    (B) the scanner/reader
    (C) the ADC
    (D) the helium–neon laser

Figure 16–5. Courtesy of Stamford Hospital, Department of Radiology.

39. When imaging the skull with the OML perpendicular to the image receptor and the CR directed 25-degrees cephalad:
     1. the occipital bone is well demonstrated
     2. the dorsum sella is seen within the foramen magnum
     3. the petrous pyramids fill the orbits
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

40. A profile view of the glenoid fossa can be obtained with the CR directed perpendicular to the glenoid fossa and the patient rotated:
   (A) 20-degree affected side down
   (B) 20-degree affected side up
   (C) 45-degree affected side down
   (D) 45-degree affected side up

41. Characteristics of nonstochastic effects of radiation include:
     1. they have predictability
     2. they have a threshold
     3. severity is directly related to dose
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

42. Chemical substances that are used to kill pathogenic bacteria are called:
    1. antiseptics
    2. germicides
    3. disinfectants
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

43. How is the thickness of the tomographic section related to the tomographic angle?
    (A) the greater the tomographic angle, the thicker the section
    (B) the greater the tomographic angle, the thinner the section
    (C) the lesser the tomographic angle, the thinner the section
    (D) the tomographic angle is unrelated to section thickness

44. In which of the following locations can the pulse be detected only by the use of a stethoscope?
    (A) wrist
    (B) apex of the heart
    (C) groin
    (D) neck

45. Mobile fluoroscopic equipment has all of the following features, *except*:
    (A) an image intensifier
    (B) a spot-film device
    (C) a TV monitor
    (D) a TV camera

46. In which position was the radiograph seen in Figure 16–6B made?
    (A) AP erect
    (B) AP recumbent
    (C) PA erect
    (D) PA recumbent

47. What portion of a CR cassette records the radiologic image?
    (A) the photostimulable phosphor
    (B) the scanner/reader
    (C) the emulsion
    (D) the helium–neon laser

48. The following bones participate in the formation of the knee joint:
    1. femur
    2. tibia
    3. patella
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3
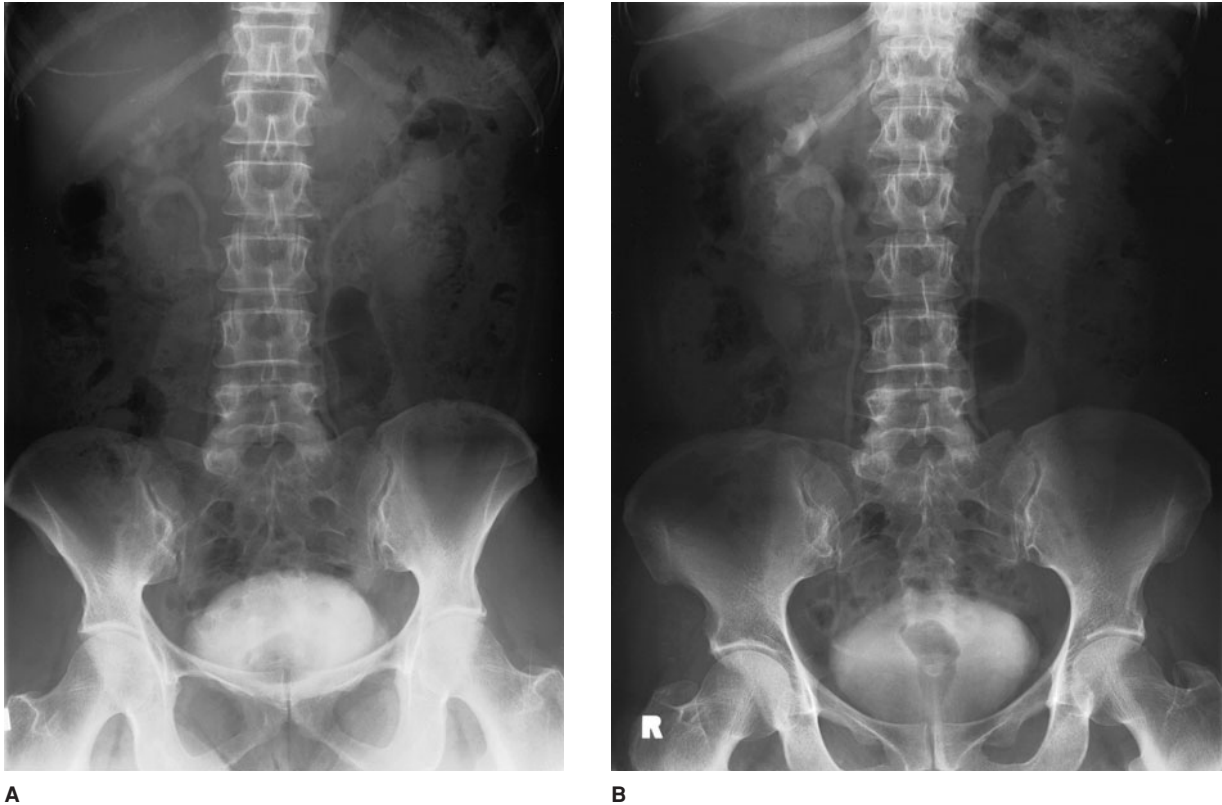
Figure 16–6. Courtesy of Stamford Hospital, Department of Radiology.

49. During GI radiography, the position of the stomach often varies depending on:
    1. respiratory phase
    2. body habitus
    3. patient position
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

50. To better demonstrate ribs below the diaphragm:
    1. suspend respiration at the end of full exhalation
    2. suspend respiration at the end of deep inhalation
    3. perform the examination in the recumbent position
    (A) 1 only
    (B) 2 only
    (C) 1 and 3 only
    (D) 2 and 3 only

51. Any wall that the useful x-ray beam can be directed toward is called a:
    (A) secondary barrier
    (B) primary barrier
    (C) leakage barrier
    (D) scattered barrier

52. In which of the following positions should you place a patient who is experiencing syncope?
    - (A) dorsal recumbent with head elevated
    - (B) dorsal recumbent with feet elevated
    - (C) lateral recumbent
    - (D) seated with feet supported

53. The phenomenon in which the radiographic information recorded on the PSP/IP upon exposure to x-rays decreases with the elapsed time until it is read by the scanner/reader is termed:
    - (A) excitation
    - (B) photostimulable luminescence
    - (C) scatter
    - (D) fading

54. Classify the following tissues in order of *decreasing* radiosensitivity:
    1. liver cells
    2. intestinal crypt cells
    3. muscle cells
    - (A) 1, 3, 2
    - (B) 2, 3, 1
    - (C) 2, 1, 3
    - (D) 3, 1, 2

55. Which of the following can contribute to radiographic image distortion?
    1. tube angle
    2. the position of the organ or structure within the body
    3. radiographic positioning of the part
    - (A) 1 only
    - (B) 1 and 2 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

56. Glenohumeral joint dislocation can be evaluated with which of the following?
    1. inferosuperior axial
    2. transthoracic lateral
    3. scapular Y projection
    - (A) 1 only
    - (B) 1 and 2 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

57. A patient is usually required to drink barium sulfate suspension in order to demonstrate which of the following structure(s)?
    1. pylorus
    2. sigmoid
    3. duodenum
    - (A) 1 and 2 only
    - (B) 1 and 3 only
    - (C) 2 and 3 only
    - (D) 3 only

58. Under which of the following conditions is biologic material most sensitive to radiation exposure?
    (A) anoxic
    (B) hypoxic
    (C) oxygenated
    (D) deoxygenated

59. Which of the following conditions will demonstrate least x-ray penetrability?
    (A) fibrosarcoma
    (B) osteomalacia
    (C) paralytic ileus
    (D) ascites

60. The image intensifier's input phosphor is generally composed of:
    (A) cesium iodide
    (B) zinc cadmium sulfide
    (C) gadolinium oxysulfide
    (D) calcium tungstate

61. What does the letter *M* represent in Figure 16–7?
    (A) scaphoid
    (B) pisiform
    (C) trapezium
    (D) hamate

Figure 16–7. Courtesy of Bob Wong, R.T.

62. Hysterosalpingography may be performed for demonstration of:
    1. uterine tubal patency
    2. mass lesions in the uterine cavity
    3. uterine position
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

63. Double-contrast examinations of the stomach or large bowel are performed for better visualization of:
    (A) position of the organ
    (B) size and shape of the organ
    (C) diverticula
    (D) gastric or bowel mucosa

64. If the exposure rate at 3 feet from the fluoroscopic table is 40 mR/h, what will be the exposure rate for 30 minutes at a distance of 5 feet from the table?
    (A) 7 mR
    (B) 12 mR
    (C) 14 mR
    (D) 24 mR

65. The medical suffix *plasia* refers to:
    (A) embryonic
    (B) condition
    (C) movement
    (D) development

66. The AP axial projection (Towne method) of the skull *best* demonstrates the:
    (A) occipital bone
    (B) frontal bone
    (C) facial bones
    (D) sphenoid bone

67. Structures found within the mediastinum include all of the following, *except* the:
    (A) esophagus
    (B) thymus
    (C) heart
    (D) terminal bronchiole

68. A student radiographer who is younger than 18 years must not receive an annual occupational dose greater than:
    (A) 0.1 rem (1 mSv)
    (B) 0.5 rem (5 mSv)
    (C) 5 rem (50 mSv)
    (D) 10 rem (100 mSv)

69. Proper body mechanics includes a wide base of support. The base of support is the portion of the body:
    - (A) in contact with the floor or other horizontal surface
    - (B) in the midportion of the pelvis or lower abdomen
    - (C) passing through the center of gravity
    - (D) none of the above

70. In which of the following projections or positions will subacromial or subcoracoid dislocation be best demonstrated?
    - (A) tangential
    - (B) AP axial
    - (C) transthoracic lateral
    - (D) PA oblique scapular Y

71. Accurate operation of the AEC device is dependent on:
    1. thickness and density of the object
    2. positioning of the object with respect to the ionization chamber
    3. beam restriction
    - (A) 1 only
    - (B) 1 and 2 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

72. Major effect(s) of deoxyribonucleic acid (DNA) irradiation include:
    1. malignant disease
    2. chromosome aberration
    3. cell death
    - (A) 1 only
    - (B) 1 and 2 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

73. The voltage ripple associated with a 3-phase, 12-pulse rectified generator is approximately:
    - (A) 100%
    - (B) 32%
    - (C) 13%
    - (D) 3%

74. When a radiographer is obtaining patient history, both subjective and objective data should be obtained. An example of *subjective* data is:
    - (A) the patient appears to have a productive cough
    - (B) the patient has a blood pressure of 130/95
    - (C) the patient states he/she experiences extreme pain in the upright position
    - (D) the patient has a palpable mass in the right upper quadrant of the left breast

75. The exposed PSP is subjected to a narrow laser beam:
    - (A) on the display monitor
    - (B) in the scanner/reader
    - (C) in the cassette
    - (D) on the film emulsion

76. What is the best way to reduce magnification distortion?
    (A) use a small focal spot
    (B) increase the SID
    (C) decrease the OID
    (D) use a slow screen–film combination

77. Which of the following medical abbreviations mean *three times a day*?
    (A) TID
    (B) QID
    (C) QH
    (D) PC

78. The energy of x-ray photons has an inverse relationship with:
    1. photon wavelength
    2. applied mA
    3. applied kV
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

79. Cervical spine positions performed to demonstrate the intervertebral foramina closest to the image receptor are:
    (A) RAO and LAO
    (B) RPO and LPO
    (C) AP and lateral

80. A patient was positioned for a radiographic projection with the x-ray tube, grid, and image receptor properly aligned but the body part angled. Which of the following will result?
    (A) grid cutoff at the periphery of the image
    (B) grid cutoff along the center of the image
    (C) increased density at the periphery
    (D) image distortion

81. It is recommended that PSPs be read soon after exposure, principally to avoid:
    (A) aliasing artifacts
    (B) image fading
    (C) overdevelopment
    (D) excessive brightness

82. What does the letter *D* represent in Figure 16–8?
    (A) fundus
    (B) pylorus
    (C) body of stomach
    (D) bulb of duodenum

83. What does the letter *H* represent in Figure 16–8?
    (A) jejunum
    (B) ascending duodenum
    (C) descending duodenum
    (D) bulb of duodenum
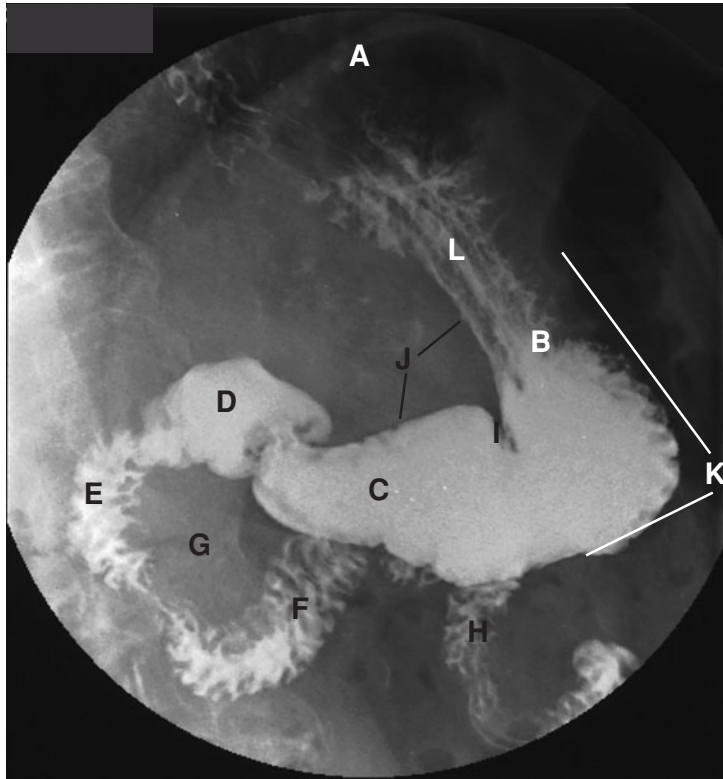
Figure 16–8. Courtesy of Stamford Hospital, Department of Radiology.

84. What structure occupies the area represented by the letter *G* in Figure 16–8?
    (A) gallbladder
    (B) right lobe of the liver
    (C) head of the pancreas
    (D) hepatic flexure of the colon

85. In what position was the radiograph seen in Figure 16–8 made?
    (A) AP
    (B) LPO
    (C) RAO
    (D) Lateral

86. What will result from using double-emulsion film in a cassette having a single intensifying screen?
    (A) double exposure
    (B) decreased density
    (C) increased recorded detail
    (D) greater latitude

87. Most laser film must be handled:
    (A) under a Wratten 6B safelight
    (B) in total darkness
    (C) under a GBX safelight
    (D) with high-temperature processors

88. Which of the following will have an effect on radiographic contrast?
    1. beam restriction
    2. grids
    3. focal spot size
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

89. Which of the following medical equipment is used to determine blood pressure?
    1. pulse oximeter
    2. stethoscope
    3. sphygmomanometer
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

90. Which of the following statements regarding human gonadal cells is/are accurate?
    1. the female oogonia reproduce only during fetal life
    2. the male spermatogonia reproduce continuously
    3. both male and female stem cells reproduce only during fetal life
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 3 only

91. Underexposure of a radiograph can be caused by all of the following, *except*:
    (A) insufficient mA
    (B) insufficient exposure time
    (C) insufficient kV
    (D) insufficient SID

92. Exposure rate increases with an increase in:
    1. mA
    2. kV
    3. SID
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

93. Characteristics of anemia include:
    1. decreased number of circulating red blood cells
    2. decreased hemoglobin
    3. hematuria
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

Figure 16–9. Courtesy of Stamford Hospital, Department of Radiology.

94. Developer solution is prevented from entering the fixer tank in automatic processing by the:
    (A) guide shoes
    (B) rollers
    (C) switch
    (D) timer

95. The artifacts seen in Figure 16–9 are representative of:
    (A) safelight fog
    (B) inadequate developer replenishment
    (C) guide shoe marks
    (D) hair braids

96. Which of these radiation exposure situations is likely to be the most harmful?
    (A) a large dose to a specific area all at once
    (B) a small dose to the whole body over a period of time
    (C) a large dose to the whole body all at one time
    (D) a small dose to a specific area over a period of time

97. Which of the following positions would best demonstrate the proximal tibiofibular articulation?
    (A) AP
    (B) 90-degree mediolateral
    (C) 45-degree internal rotation
    (D) 45-degree external rotation

98. Chemical substances that inhibit growth of pathogenic microorganisms without necessarily killing them are called:
    1. antiseptics
    2. germicides
    3. disinfectants
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

99. Which of the following is a vasopressor and may be used for an anaphylactic reaction or cardiac arrest?
    (A) nitroglycerin
    (B) epinephrine
    (C) hydrocortisone
    (D) digitoxin

100. The absorption of excessive primary radiation by a grid is called:
    (A) grid selectivity
    (B) contrast improvement factor
    (C) grid cutoff
    (D) latitude

101. Hormonal factors that increase the risk of a woman developing breast cancer include:
    1. family history
    2. early menses
    3. nulliparity
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

102. In which aspect of the orbital wall a "blowout fracture" usually occurs?
    (A) superior
    (B) inferior
    (C) medial
    (D) lateral

103. The histogram demonstration of pixel value distribution can be changed/affected by the following:
    1. selection of processing algorithm
    2. processing delay
    3. centering
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

104. What activator is required for barium fluorohalide to retain its luminous properties?
    (A) cesium
    (B) iodine
    (C) europium
    (D) gadolinium

105. By which of the following dose–response curves are late or long-term effects of radiation exposure generally represented?
    (A) linear threshold
    (B) linear nonthreshold
    (C) nonlinear threshold
    (D) nonlinear nonthreshold

106. The most important scattering object in both radiography and fluoroscopy is the:
    (A) x-ray table
    (B) x-ray tube
    (C) patient
    (D) cassette

107. Typical examples of digital imaging include:
    1. magnetic resonance imaging (MRI)
    2. computed tomography (CT)
    3. pluridirectional tomography
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

108. Special beam-shaping optics are used in the CR reader to keep the infrared laser scanning light finely focused in order to:
    1. collect analog data
    2. improve SNR
    3. maintain good spatial resolution
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

109. Which of the following is a fast acting vasodilator used to lower blood pressure and relieve the pain of angina pectoris?
    (A) digitalis
    (B) Dilantin
    (C) nitroglycerin
    (D) cimetidine (Tagamet)

110. In the parieto-orbital projection (Rhese method) of the optic canal, the median sagittal plane and central ray form what angle?
    (A) 90 degrees
    (B) 37 degrees
    (C) 53 degrees
    (D) 45 degrees

111. A radiographic image exhibiting few shades of gray between black and white is said to possess:
    (A) no contrast
    (B) high contrast
    (C) low contrast
    (D) little contrast

112. A small bottle containing a single dose of medication is termed:
    (A) an ampule
    (B) a vial
    (C) a bolus
    (D) a carafe
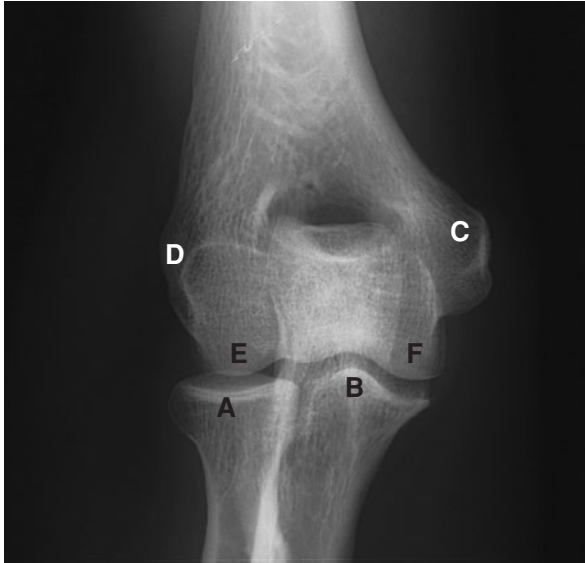
Figure 16–10. Courtesy of Stamford Hospital, Department of Radiology.

113. An increase in kV will have which of the following effects?
     1. more scatter radiation will be produced
     2. the exposure rate will increase
     3. radiographic contrast will increase
     (A) 1 only
     (B) 1 and 2 only
     (C) 2 and 3 only
     (D) 1, 2, and 3

114. Which of the following is the most proximal structure on the adult ulna?
     (A) capitulum
     (B) styloid process
     (C) coronoid process
     (D) olecranon process

115. In Figure 16–10, the letter *E* represents the:
     (A) trochlea
     (B) capitulum
     (C) lateral epicondyle
     (D) medial epicondyle

116. In Figure 16–10, the letter *D* represents the:
     (A) trochlea
     (B) capitulum
     (C) lateral epicondyle
     (D) medial epicondyle

117. What is the intensity of scattered radiation perpendicular to and 1 meter from the patient, compared to the useful beam at the patient's surface?
     (A) 0.01%
     (B) 0.1%
     (C) 1.0%
     (D) 10.0%

118. Which of the following is demonstrated in a 25-degree LPO position with the central ray entering 1-inch medial to the elevated anterosuperior iliac spine (ASIS)?
    (A) left sacroiliac joint
    (B) right sacroiliac joint
    (C) left ilium
    (D) right ilium

119. A 3-inch object to be radiographed at 36-inches SID lies 4 inches from the image receptor. What will be the image width?
    (A) 2.6 inches
    (B) 3.3 inches
    (C) 26 inches
    (D) 33 inches

120. The sternoclavicular joints are best demonstrated with the patient PA and:
    (A) in a slight oblique, affected side adjacent to image receptor
    (B) in a slight oblique, affected side away from image receptor
    (C) erect, weight bearing
    (D) erect, with and without weights

121. Which of the following criteria are required for accurate visualization of the greater tubercle in profile?
    1. epicondyles parallel to the image receptor
    2. arm in external rotation
    3. humerus in AP position
    (A) 1 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

122. All of the following positions are likely to be employed for both single-contrast and double-contrast examinations of the large bowel, *except*:
    (A) lateral rectum
    (B) AP axial rectosigmoid
    (C) right and left lateral decubitus abdomen
    (D) RAO and LAO abdomen

123. In which of the following conditions is protective or "reverse" isolation required?
    1. tuberculosis
    2. burns
    3. leukemia
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

124. Which of the following devices functions to produce hard copies of digital images?
    (A) digitizer
    (B) laser printer
    (C) histogram
    (D) CRT

125. With all other factors remaining the same, as grid ratio is increased:
     (A) recorded detail decreases
     (B) optical density decreases
     (C) focal spot distortion decreases
     (D) the scale of contrast becomes longer

126. The *best* way to control voluntary motion is:
     (A) immobilization of the part
     (B) careful explanation of the procedure
     (C) short exposure time
     (D) physical restraint

127. The manubrial notch, a bony landmark used in radiography of the sternoclavicular joints, is located at the same level as the:
     (A) vertebra prominens
     (B) first thoracic vertebra
     (C) third thoracic vertebra
     (D) ninth thoracic vertebra

128. Which of the following functions to protect the x-ray tube and patient from overexposure in the event the automatic exposure control fails to terminate an exposure?
     (A) circuit breaker
     (B) backup timer
     (C) rheostat
     (D) fuse

129. Which of the following would be appropriate cassette front material?
     1. tungsten
     2. magnesium
     3. Bakelite
     (A) 1 only
     (B) 1 and 2 only
     (C) 2 and 3 only
     (D) 1, 2, and 3

130. The following statement(s) is (are) accurate with respect to the differences between the male and female bony pelvis:
     1. the female pelvic outlet is wider
     2. the pubic angle is 90 degrees or fewer in the male
     3. the male pelvis is more shallow
     (A) 1 only
     (B) 1 and 2 only
     (C) 2 and 3 only
     (D) 1, 2, and 3

Figure 16–11. Courtesy of Stamford Hospital, Department of Radiology.

131. In the lateral projection of the foot, the:
    1. plantar surface should be perpendicular to the image receptor
    2. metatarsals are superimposed
    3. talofibular joint should be visualized
  (A) 1 only
  (B) 1 and 2 only
  (C) 2 and 3 only
  (D) 1, 2, and 3

132. The film artifact seen in Figure 16–11 is representative of:
  (A) processor artifact
  (B) exposure artifact
  (C) handling artifact
  (D) chemical fog

133. The factor(s) that can be used to regulate radiographic density is (are):
    1. milliamperage
    2. exposure time
    3. kilovoltage
  (A) 1 only
  (B) 2 only
  (C) 1 and 2 only
  (D) 1, 2, and 3

134. By which of the following tests is intensifying screen contact evaluated?
  (A) spinning top test
  (B) wire-mesh test
  (C) penetrometer test
  (D) star-pattern test

135. The mechanical device used to correct an ineffectual cardiac rhythm is a:
    (A) defibrillator
    (B) cardiac monitor
    (C) crash cart
    (D) resuscitation bag

136. The term that refers to parts closer to the source or beginning is:
    (A) cephalad
    (B) caudad
    (C) proximal
    (D) medial

137. The blue–green PSL that corresponds to the visible x-ray image occurs:
    1. immediately upon the initial prompt emission of light
    2. some time after the initial prompt emission of light
    3. upon stimulation by finely focused infrared light
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

138. As a result of the anode heel effect, the intensity of the x-ray beam is greatest along the:
    (A) path of the central ray
    (B) anode end of the beam
    (C) cathode end of the beam
    (D) transverse axis of the image receptor

139. The AP projection of the scapula requires that the:
    1. patient's arm be abducted at right angles to the body
    2. patient's elbow be flexed with hand supinated
    3. exposure be made during quiet breathing
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 3 only
    (D) 1, 2, and 3

140. The type of shock associated with pooling of blood in the peripheral vessels is classified as:
    (A) neurogenic
    (B) cardiogenic
    (C) hypovolemic
    (D) septic

141. What projection of the calcaneus is obtained with the leg extended, plantar surface vertical and perpendicular to the image receptor, and central ray directed 40-degree caudad?
    (A) axial plantodorsal projection
    (B) axial dorsoplantar projection
    (C) lateral projection
    (D) weight-bearing lateral

142. The uppermost portion of the iliac crest is approximately at the same level as the:
    (A) costal margin
    (B) umbilicus
    (C) xiphoid tip
    (D) fourth lumbar vertebra

143. Devices that serve to collect PSL and transmit it to an ADC include:
    1. photomultiplier tube
    2. photodiode
    3. charge-coupled device
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

144. What apparatus is needed for the construction of a characteristic curve?
    1. penetrometer
    2. densitometer
    3. electrolytic canister
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

145. The type(s) of radiation produced at the tungsten target is/are:
    1. photoelectric
    2. characteristic
    3. Bremsstrahlung
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

146. With the patient positioned as for a parietoacanthial projection (Waters method), and the central ray directed through the patient's open mouth, which of the following sinus groups is demonstrated through the open mouth?
    (A) frontal
    (B) ethmoid
    (C) maxillary
    (D) sphenoid

147. Characteristics of the typical diagnostic x-ray tube and its construction include:
    1. the target material should have a high atomic number and melting point
    2. the useful beam emerges from the port window
    3. the cathode assembly receives both low and high voltages
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 1, 2, and 3

148. During chest radiography, the act of inspiration:
     1. elevates the diaphragm
     2. raises the ribs
     3. depresses the abdominal viscera
   (A) 1 only
   (B) 1 and 2 only
   (C) 2 and 3 only
   (D) 1, 2, and 3

149. The stomach of an asthenic patient is *most* likely to be located:
   (A) high, transverse, and lateral
   (B) low, transverse, and lateral
   (C) high, vertical, and toward the midline
   (D) low, vertical, and toward the midline

150. The microswitch for controlling the amount of replenishment used in an automatic processor is located at the:
   (A) receiving bin
   (B) crossover roller
   (C) entrance roller
   (D) replenishment pump

151. In which body position would a patient suffering from orthopnea experience the *least* discomfort?
   (A) Fowler
   (B) Trendelenburg
   (C) recumbent
   (D) erect

152. The position illustrated in Figure 16–12 can be improved by:
   (A) bringing the chin up more
   (B) bringing the chin down more
   (C) angling the CR caudad
   (D) opening the mouth more
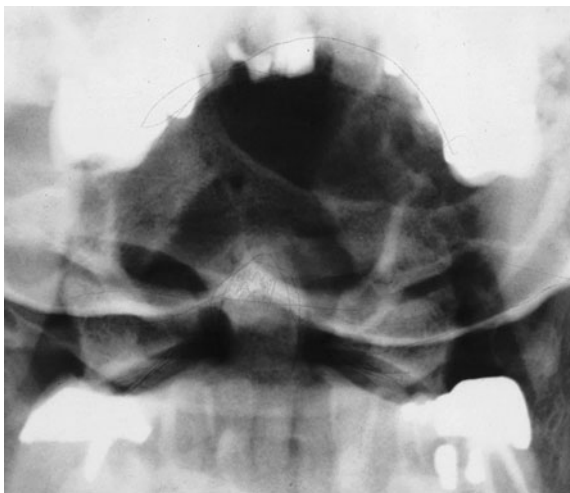
Figure 16–12. Courtesy of Stamford Hospital, Department of Radiology.

153. The medical term referring to *nosebleed* is:
    - (A) vertigo
    - (B) urticaria
    - (C) epistaxis
    - (D) aura

154. Types of positive contrast agents include:
    1. barium sulfate suspension
    2. water-based iodinated media
    3. carbon dioxide
    - (A) 1 only
    - (B) 2 only
    - (C) 1 and 2 only
    - (D) 1 and 3 only

155. Which of the following are methods used to help reduce colonic spasms during fluoroscopic filling of the large bowel?
    1. placing the patient in the Trendelenburg position
    2. administration of glucagon prior to the examination
    3. temporarily slowing or stopping the flow of barium
    - (A) 1 and 2 only
    - (B) 1 and 3 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

156. Radiation exposure to the developing fetus can cause:
    1. mental retardation
    2. growth retardation
    3. organ damage
    - (A) 1 only
    - (B) 1 and 2 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

157. Characteristics of a 16:1 grid include:
    1. absorbs more primary radiation than an 8:1 grid
    2. has more centering latitude than an 8:1 grid
    3. used with higher kV exposures than an 8:1 grid
    - (A) 1 only
    - (B) 1 and 3 only
    - (C) 2 and 3 only
    - (D) 1, 2, and 3

158. A CR histogram is a graphic representation of:
    - (A) gray scale values of the imaged part
    - (B) a characteristic curve of the imaged part
    - (C) D_{max}
    - (D) D_{min}
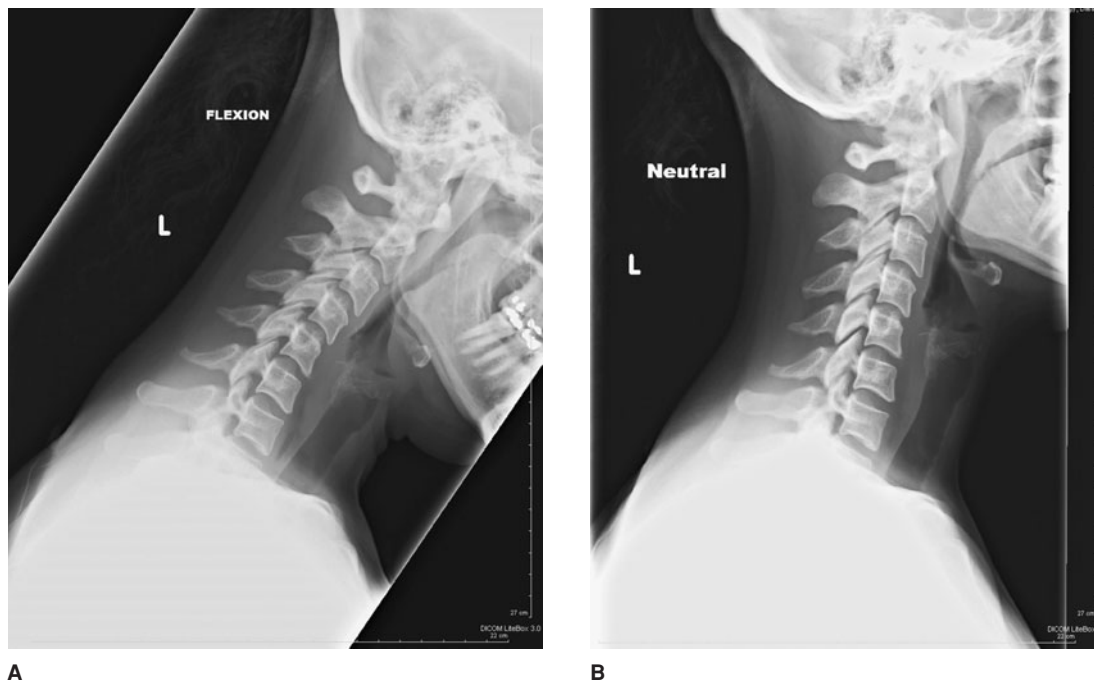
Figure 16–13. Courtesy of Conrad P. Ehrlich, MD.

159. Which of the following devices is used to overcome severe variation in patient anatomy or tissue density, providing more uniform radiographic density?
    (A) compensating filter
    (B) grid
    (C) collimator
    (D) intensifying screen

160. A radiograph demonstrating a long scale of contrast is most likely to be produced by increasing:
    (A) photon energy
    (B) screen speed
    (C) mAs
    (D) SID

161. Figures 16–13A and B are most often performed to evaluate the following condition:
    (A) subluxation
    (B) spondylolisthesis
    (C) whiplash injury
    (D) cervical rib

162. Of the following groups of technical factors, which will produce the greatest radiographic density?
    (A) 10 mAs, 74 kV, 44-inches SID
    (B) 10 mAs, 74 kV, 36-inches SID
    (C) 5 mAs, 85 kV, 48-inches SID
    (D) 5 mAs, 85 kV, 40-inches SID

163. All of the following statements regarding breast cancer management are true, *except*:
    (A) early stages of disease respond well to surgical treatment
    (B) BSE helps provide an early diagnosis
    (C) survival improves with early diagnosis
    (D) a baseline mammogram should be made once menopause begins

164. *Somatic effects* of radiation refer to effects that are manifested:
    (A) in the descendants of the exposed individual
    (B) during the life of the exposed individual
    (C) in the exposed individual and their descendants
    (D) in the reproductive cells of the exposed individual

165. The energy of ionizing electromagnetic radiations is measured in:
    (A) mA
    (B) mAs
    (C) keV
    (D) kV

166. The total number of x-ray photons produced at the target is contingent on:
    1. tube current
    2. target material
    3. square of the kilovoltage
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

167. To produce just a perceptible increase in radiographic density, the radiographer must increase the:
    (A) mAs by 30%
    (B) mAs by 15%
    (C) kV by 15%
    (D) kV by 30%

168. Which of the following is usually recommended for cleaning CR image plates?
    (A) denatured alcohol
    (B) anhydrous ethanol
    (C) soap and water
    (D) intensifying screen cleaner

169. What is the fetal dose limit for pregnant radiographers for the entire gestation period?
    (A) 0.1 rem
    (B) 0.5 rem
    (C) 5.0 rem
    (D) 10 rem

170. What type of precaution prevents the spread of infectious agents in aerosol form?
    (A) strict isolation
    (B) protective isolation
    (C) airborne precautions
    (D) contact precautions

171. Which of the following is a condition in which an occluded blood vessel stops blood flow to a portion of the lungs?
    (A) pneumothorax
    (B) atelectasis
    (C) pulmonary embolism
    (D) hypoxia

172. An accurately positioned oblique projection of the first through fourth lumbar vertebrae will demonstrate the classic "scotty dog." What bony structure does the scotty dog's "ear" represent?
    (A) superior articular process
    (B) pedicle
    (C) transverse process
    (D) pars interarticularis

173. Inspiration and expiration projections of the chest may be performed to demonstrate:
    1. pneumothorax
    2. foreign body
    3. atelectasis
    (A) 1 only
    (B) 1 and 2 only
    (C) 1 and 3 only
    (D) 1, 2, and 3

174. What minimum total amount of filtration (inherent plus added) is required in x-ray equipment operated above 70 kV?
    (A) 2.5 mm Al equivalent
    (B) 3.5 mm Al equivalent
    (C) 2.5 mm Cu equivalent
    (D) 3.5 mm Cu equivalent

175. The automatic exposure device that is located immediately under the x-ray table is the:
    (A) ionization chamber
    (B) scintillation camera
    (C) photomultiplier
    (D) photocathode

176. Proper care of leaded apparel includes:
    1. periodic check for cracks
    2. careful folding following each use
    3. routine laundering with soap and water
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

177. The image seen in Figure 16–14 was made using the following types x-ray equipment:
    (A) single phase
    (B) 3 phase, 6 pulse
    (C) 3 phase, 12 pulse
    (D) high frequency
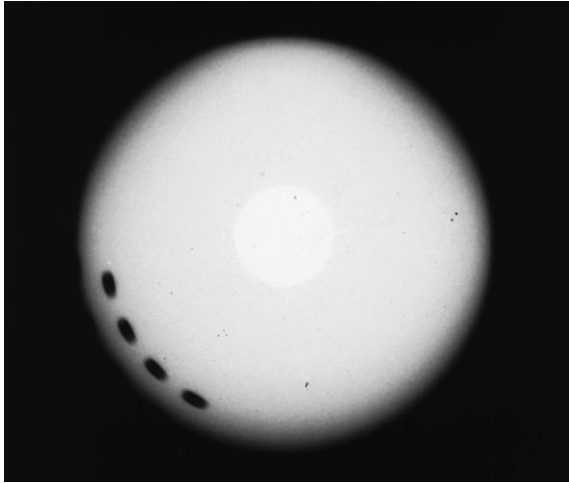
Figure 16–14.

178. If the test image seen in Figure 16–14 is known to represent correctly operating full-wave rectified equipment, then at what exposure time was it made?
   (A) 1/15 second
   (B) 1/30 second
   (C) 1/60 second
   (D) 1/120 second

179. What is meant by the term *controlled area*?
   1. one that is occupied by people trained in radiation safety
   2. one that is occupied by people who wear radiation monitors
   3. one whose occupancy factor is 1
   (A) 1 and 2 only
   (B) 2 only
   (C) 1 and 3 only
   (D) 1, 2, and 3

180. A radiograph made with a parallel grid demonstrates decreased density on its lateral edges. This is most likely caused by:
   (A) static electrical discharge
   (B) the grid off-centered
   (C) improper tube angle
   (D) decreased SID

181. All of the following statements concerning respiratory structures are true, *except*:
   (A) the right lung has two lobes
   (B) the uppermost portion of the lung is the apex
   (C) each lung is enclosed in pleura
   (D) the trachea bifurcates into mainstem bronchi

182. To demonstrate the pulmonary apices in the AP position, the:
   (A) central ray is directed 15- to 20-degree cephalad
   (B) central ray is directed 15- to 20-degree caudad
   (C) exposure is made on full exhalation
   (D) patient's shoulders are rolled forward

183. Which of the following factors impacts radiation damage to biologic tissue?
    1. radiation quality
    2. absorbed dose
    3. size of irradiated area
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 1, 2, and 3

184. The sigmoid colon is located in the:
    (A) left lower quadrant (LLQ)
    (B) left upper quadrant (LUQ)
    (C) right lower quadrant (RLQ)
    (D) right upper quadrant (RUQ)

185. A 15% increase in kV accompanied by a 50% decrease in mAs will result in a (an):
    (A) shorter scale contrast
    (B) increase in exposure latitude
    (C) increase in radiographic density
    (D) decrease in recorded detail

186. The four major arteries supplying the brain include the:
    1. brachiocephalic artery
    2. common carotid arteries
    3. vertebral arteries
    (A) 1 and 2 only
    (B) 1 and 3 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

187. The total brightness gain of an image intensifier is a result of:
    1. flux gain
    2. minification gain
    3. focusing gain
    (A) 1 only
    (B) 2 only
    (C) 1 and 2 only
    (D) 1 and 3 only

188. Radiographers use monitoring devices to record their monthly exposure to radiation. The types of devices suited for this purpose include:
    1. pocket dosimeter
    2. TLD
    3. OSL
    (A) 1 only
    (B) 1 and 2 only
    (C) 2 and 3 only
    (D) 1, 2, and 3

Figure 16–15. Courtesy of Stamford Hospital, Department of Radiology.

189. Which of the following types of adult tissues is (are) relatively insensitive to radiation exposure?
      1. muscle tissue
      2. nerve tissue
      3. epithelial tissue
  (A) 1 only
  (B) 1 and 2 only
  (C) 2 and 3 only
  (D) 1, 2, and 3

190. The radiograph seen in Figure 16–15 illustrates the joint space obscured by the:
  (A) medial femoral condyle
  (B) lateral femoral condyle
  (C) intercondylar eminences
  (D) tibial tuberosity

191. Lateral deviation of the nasal septum may be *best* demonstrated in the:
  (A) lateral projection
  (B) PA axial (Caldwell method) projection
  (C) parietoacanthial (Waters method) projection
  (D) AP axial (Towne method) projection

192. When a patient is received in the radiology department with a urinary Foley catheter bag, it is important to:
     (A) place the drainage bag above the level of the bladder
     (B) place the drainage bag at the same level as the bladder
     (C) place the drainage bag below the level of the bladder
     (D) clamp the Foley catheter

193. A slit camera is used to measure:
     1. focal spot size
     2. intensifying screen resolution
     3. source-to-image-receptor distance (SID) resolution
     (A) 1 only
     (B) 1 and 2 only
     (C) 1 and 3 only
     (D) 1, 2, and 3

194. The *most* effective method of sterilization is:
     (A) dry heat
     (B) moist heat
     (C) pasteurization
     (D) freezing

195. What should be the radiographer's main objective regarding personal radiation safety?
     (A) not to exceed his or her dose limit
     (B) to keep personal exposure as far below the dose limit as possible
     (C) to avoid whole-body exposure
     (D) to wear protective apparel when "holding" patients for exposures

196. Which of the following conditions would require an increase in exposure factors?
     1. congestive heart failure
     2. pleural effusion
     3. emphysema
     (A) 1 only
     (B) 1 and 2 only
     (C) 1 and 3 only
     (D) 1, 2, and 3

197. What structure is indicated by the *number 3* in Figure 16–16?
     (A) maxillary sinuses
     (B) mastoid sinuses
     (C) sphenoid sinuses
     (D) ethmoid sinuses

198. An exposure was made at 38-inches SID using 300 mA, 0.03-second exposure, and 80 kV with a 400 film–screen combination and an 8:1 grid. It is desired to repeat the radiograph and, to improve recorded detail, use 42-inches SID and 200 film–screen combination. With all other factors remaining constant, what exposure time will be required to maintain the original radiographic density?
     (A) 0.03 second
     (B) 0.07 second
     (C) 0.14 second
     (D) 0.36 second
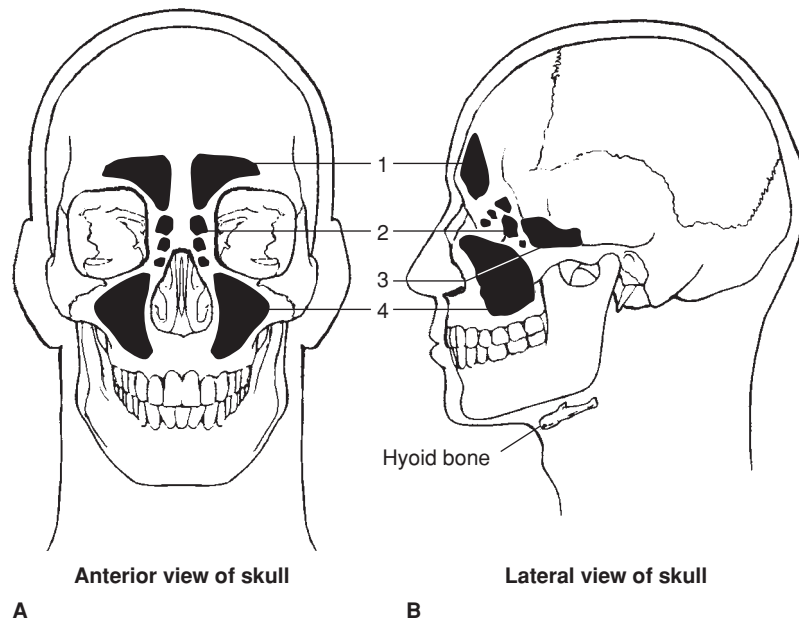
Figure 16–16.

199. The dose of radiation that will cause a noticeable skin reaction is referred to as the:
    (A) LET
    (B) SSD
    (C) SED
    (D) SID

200. You encounter a person who is apparently unconscious. Although his airway is open, there is no rise and fall of his chest and you can hear no breath sounds. You should:
    (A) begin mouth-to-mouth rescue breathing, giving two full breaths
    (B) proceed with the Heimlich maneuver
    (C) begin external chest compressions at a rate of 80 to 100 per minute
    (D) begin external chest compressions at a rate of at least 100 per minute

Answers and Explanations

1. (D) The advantages of digital fluoroscopy (DF) over conventional fluoroscopy include higher-speed acquisition and availability of postprocessing for image/contrast enhancement. Although DF appears fundamentally the same as conventional fluoroscopy, DF has special requirements: a computer, two video monitors, and an operating console that is far more complex than the conventional console. A computer is located between the TV camera (or CCD) and the TV monitor and serves to convert the analog image to a digital image. The operating console has many special function keys for patient data entry, for data acquisition, image display, and image postprocessing manipulation. Two video monitors are required—the second monitor is for display of the subtracted image *(Bushong, p. 408)*.

2. (B) The *tissue weighting factor* (W_t) represents the relative tissue radiosensitivity of irradiated material (e.g., muscle vs. intestinal epithelium vs. bone, etc.). The radiation weighting

factor (W_r) is a number assigned to different types of ionizing radiations in order to better determine their effect on tissue (e.g., x-ray vs. alpha particles). The W_r of different ionizing radiations is dependent on the LET of that particular radiation. The following formula is used to determine *effective dose (E):* Effective dose (E) = radiation weighting factor (W_r) × tissue weighting factor (W_t) × absorbed dose *(Bushong, p. 556).*

3. (B) Figure 16–1A is a medial oblique projection of the foot. The foot is rotated medially so that the *plantar surface and IR* form a 30-degree angle—the *CR and plantar surface* form a 60-degree angle. This position should demonstrate the third through fifth metatarsals completely free of superimposition, when positioned correctly. Articulations around the cuboid and sinus tarsi should be well demonstrated, as well as the tuberosity of the base of the fifth metatarsal. Figure 16–1B is the dorsoplantar projection of the foot. The CR is perpendicular to the plantar surface *(Bontrager & Lampignano, 6th ed, p. 233).*

4. (A) The PSP screen within the IP has a layer of europium-activated barium fluorohalide ($BaFX:Eu^{2+}$; X = Halogen) mixed with a binder substance. This layer serves as the *image receptor* when exposed to x-rays. Just under the barium fluorohalide layer is first a *reflective layer,* then the *base,* then an *antistatic layer* and finally a layer of *lead foil* to absorb backscatter. Over the top of the barium fluorohalide is a *protective layer.* When the barium fluorohalide absorbs x-ray energy, *electrons are released and they divide into two groups.* One electron group initiates *immediate luminescence* during the excited state of Eu^{2+}. The other electron group *becomes trapped* within the phosphor's halogen ions, forming a "color center." These are the phosphors that ultimately form the radiographic image because when exposed to a *monochromatic* (often infrared) laser light source these phosphors emit *polychromatic* light, termed *photostimulated luminescence* (PSL) *(Wolbarst, 2nd ed, p. 386).*

5. (C) The abdomen is divided into quadrants: RUQ, RLQ, LUQ, and LLQ. Structures located in the LUQ of the average adult include the left kidney and suprarenal gland, stomach, spleen, splenic flexure, and tail of the pancreas. The ascending colon is located in the right lower quadrant *(Bontrager & Lampignano, 6th ed, p. 116).*

6. (A) *Creatinine* is a normal alkaline constituent of urine and blood, but increased quantities of creatinine are present in advanced stages of renal disease. Creatinine and *BUN (blood urea nitrogen)* blood chemistry levels should be checked prior to beginning an examination requiring the use of an iodinated contrast agent. Increased levels may forecast increased possibility of contrast media–induced renal effects and poor visualization of the renal collecting systems. Normal creatinine range is 0.6 to 1.5 mg/100 mL. Normal BUN range is 8 to 25 mg/100 mL *(Ballinger & Frank, Vol 2, p. 214).*

7. (D) Adverse reactions to the intravascular administration of iodinated contrast are not uncommon, and although the risk of a life-threatening reaction is relatively rare, the radiographer must be alert to recognize and deal effectively should a serious reaction occur. Minor reaction is characterized by flushed appearance and nausea, occasionally vomiting and a few hives. *Early* symptoms of a possible anaphylactic reaction include constriction of the throat, possibly caused by laryngeal edema, dysphagia (difficulty swallowing), and itching of the palms and soles. The radiographer must maintain the patient's airway, summon the radiologist and call a "code" *(Adler & Carlton, p. 240).*

8. (C) The cervical *intervertebral foramina* lie 45 degrees to the midsagittal plane (and 15–20 degrees to a transverse plane) and are therefore demonstrated in the *oblique* position. *Intervertebral joints* are well visualized in the *lateral* projection of all the vertebral groups. Cervical articular facets (forming *apophyseal joints*) are 90 degrees to the midsagittal plane and therefore are also well demonstrated in the *lateral* projection *(Ballinger & Frank, Vol 1, p. 426).*

9. (B) The effects of a quantity of radiation delivered to a body are dependent on the amount of radiation received, the size of the irradiated area, and how the radiation is delivered in time. If the radiation is delivered in portions over a period of time, it is said to be fractionated and has a less harmful effect than if the radiation was delivered all at once. Therefore, cells have an opportunity to repair and some recovery occurs between doses *(Bushong, p. 495).*

10. (D) *Veracity* is not only telling the truth, but also not practicing deception. *Autonomy* is the ethical principle related to the theory that patients have the right to decide what will or will not be done to them. *Beneficence* is related to the idea of doing good and being kind. *Fidelity* is faithfulness and loyalty. *(Adler & Carlton, p. 308).*

11. (B) *Somatic effects* of radiation refer to those effects experienced directly by the exposed individual such as erythema, epilation, and cataracts. *Genetic effects* of radiation exposure are caused by irradiation of the reproductive cells of the exposed individual and transmitted from one generation to the next *(Statkiewicz-Sherer and Visconti, pp. 115, 131).*

12. (A) The approximately 5-foot-long large intestine (colon) functions in the formation, transport, and evacuation of feces. The colon commences at the terminus of the small intestine; its first portion is the sac-like *cecum* in the RLQ, located inferior to the ileocecal valve. The ascending colon is continuous with the cecum and is located along the right side of the abdominal cavity. It bends medially and anteriorly forming the right colic (*hepatic*) flexure. The colon traverses the abdomen as the transverse colon and bends posteriorly and inferiorly to form the left colic (*splenic*) flexure. The descending colon continues down the left side of the abdominal cavity and at about the level of the pelvic brim, in the *left lower quadrant* (*LLQ*), the colon moves medially to form the S-shaped *sigmoid* colon. The rectum, approximately 5 inches in length, lies between the sigmoid and anal canal *(Saia, p. 173).*

13. (B) Neither ultrasonography nor magnetic resonance imaging requires the use of ionizing radiation to produce an image. Computed axial tomography does require ionizing radiation to produce an image. Ultrasonography requires the use of high-frequency sound waves (ultrasound) to produce images of soft-tissue structures and certain blood vessels within the body. Magnetic resonance imaging relies on the use of a very powerful magnet and specially designed coils that send and receive radio wave signals to produce the image *(Torres et al., p. 7).*

14. (A) A *fistula* is an abnormal tubelike passageway between organs or an organ and the surface. Fistulas can result from abscesses, injuries, malignancies, inflammation of neighboring tissues, and from ionizing radiation exposure. A *polyp* is a tumor with either a pedicle (pedunculated, or having a stalk) or a broad base (sessile), commonly found in vascular organs projecting inward from its mucosal wall. They are usually removed surgically because, although usually benign, they can become malignant. A *diverticulum* is an *outpouching* from

the wall of an organ, such as the colon. An *abscess* is a localized collection of pus as a result of inflammation *(Ballinger & Frank, Vol 2, p. 127)*.

15. (C) The knee is formed by the proximal tibia, the patella, and the distal femur, which articulate to form the *femorotibial* and *patellofemoral* joints. The distal posterior femur presents two large *medial and lateral condyles* separated by the deep *intercondyloid fossa*. Two small prominences, the medial and lateral epicondyles, are just superior to the condyles. The femoral and tibial condyles articulate to form the femorotibial joint. Figure 16–2 illustrates positioning for the *intercondyloid fossa* (Camp–Coventry method). The patient is posteroanterior (PA) recumbent with knee flexed so tibia forms 40-degree angle with the tabletop and with foot rested on support. The CR is directed 40-degree caudad (perpendicular to the long axis of the tibia) to the knee joint. This results in a *PA axial* (superoinferior) projection of the intercondyloid fossa, tibial plateau, and eminences. It is referred to as the *tunnel view (Ballinger & Frank, Vol 1, p. 323)*.

16. (B) A patient going into shock may exhibit *pallor and weakness*, a significant *drop in blood pressure*, and an *increase in pulse rate*. The patient may also experience *apprehension and restlessness*, and have *cool, clammy skin*. A radiographer recognizing these symptoms should call them to the physician's attention immediately. Fever is not associated with shock *(Torres et al., p. 162)*.

17. (C) The production of red blood cells is called *erythropoiesis*. This process takes place in the bone marrow of the extremities of long bone, pelvis, ribs, sternum, and vertebrae. Red blood cells have no nucleus and a life span of approximately 120 days. After red blood cells die, they are removed from circulation by phagocytic action in the liver and spleen *(Tortora & Derrickson, p. 675)*.

18. (A) Every radiographic examination involves an *entrance skin exposure* (ESE), which can be determined fairly easily. It also involves a gonadal dose and marrow dose that, if needed, can be calculated by the radiation physicist. If the ESE of a particular examination was calculated to determine the *equivalent whole-body dose*, this is termed *effective dose*. For example, the ESE of a posteroanterior (PA) chest is approximately 70 mrem, while the effective dose is 10 mrem. The effective (whole-body) dose is much less because much of the body is not included in the primary beam *(Fosbinder & Kelsey, p. 390)*.

19. (B) When the body is erect, the diaphragm is more easily moved to a lower position during inspiration. For this reason, chest radiography is performed erect to allow maximum lung expansion. With the body in the supine position, the abdominal viscera exert greater pressure on the diaphragm, and it usually assumes a position 2 to 4 inches higher than when erect *(Ballinger & Frank, Vol 1, p. 516)*.

20. (C) A digital image is formed by a *matrix* of *pixels* (picture elements) in rows and columns. A matrix having 512 pixels in each row and column is a 512×512 matrix. The term *field of view* is used to describe how much of the patient (e.g., 150-mm diameter) is included in the matrix. The matrix and/or field of view can be changed without affecting the other, but changes in either will change pixel size. As in traditional radiography, *spatial resolution* is measured in line pairs per millimeter (*lp/mm*). As matrix size is increased, there are more and smaller pixels in the matrix, therefore improved resolution. Fewer and larger pixels result in a poor

resolution "pixelly" image, that is, one in which you can actually see the individual pixel boxes *(Fosbinder & Kelsey, p. 286).*

21. (B) With the body in the anteroposterior (AP) recumbent position, barium flows easily into the fundus of the stomach, displacing it somewhat superiorly. The fundus, then, is filled with barium, while the air that had been in the fundus is displaced into the gastric body, pylorus, and duodenum, illustrating them in double-contrast fashion. Air contrast delineation of these structures allows us to see through the stomach, to retrogastric areas and structures. Barium-filled duodenum and pylorus is best demonstrated in the right anterior oblique (RAO) position *(Ballinger & Frank, Vol 2, p. 149).*

22. (A) An *ambulatory* patient is one who is able to walk with minimal or no assistance. Outpatients as well as many inpatients are usually ambulatory. Patients who are not ambulatory are usually transported to the radiology department via stretcher *(Saia, p. 24).*

23. (D) The pictured radiograph was made in the *left lateral decubitus* position. It is part of a series of radiographs made during an air contrast (double-contrast) barium enema (BE) examination. A *double-contrast examination* of the large bowel is performed to see *through* the bowel to its posterior wall and to visualize any *intraluminal* (e.g., polypoid) *lesions* or *masses.* Various body positions are used to redistribute the barium and air. To demonstrate the medial and lateral walls of the bowel, decubitus positions are performed. The radiograph presents a left lateral decubitus position, because the *barium has gravitated* to the left side (the side of the splenic flexure). The *air rises* and delineates the medial side of the descending colon and the lateral side of the ascending colon *(Ballinger & Frank, Vol 2, p. 186).*

24. (D) Moving the image intensifier *closer to the patient* during fluoroscopy *reduces* the distance between the x-ray tube (source) and the image intensifier (image receptor), that is, the *SID* is reduced. It follows that the distance between the part being imaged (object) and the image intensifier (image receptor) is also reduced, that is, the *OID* is reduced (Fig. 16–17). The shorter OID produces *less magnification* and *better image quality.* As SID is reduced, the intensity of the x-ray photons at the image intensifier's input phosphor increases, stimulating
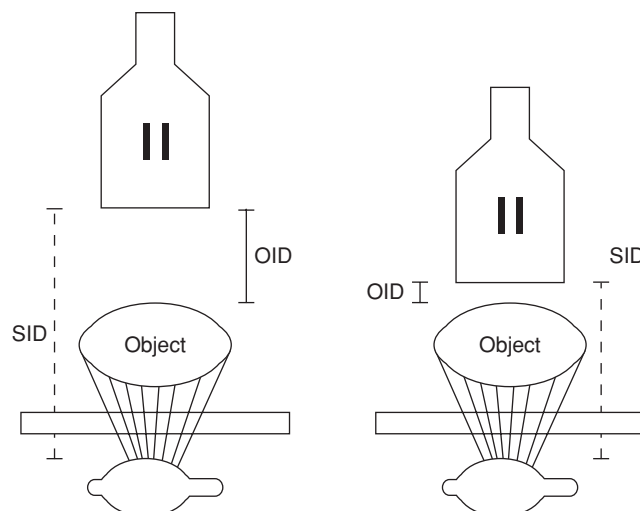
Figure 16–17.

the automatic brightness control (ABC) to decrease the mA (milliamperage), thereby *decreasing patient dose (Fosbinder & Kelsey, pp. 265–267).*

25. (D) The addition of a grid will help clean up the scatter radiation produced by higher kV, but it requires an mAs *adjustment.* According to the grid conversion factors listed below, the addition of an 8:1 grid requires that the original mAs be multiplied by a factor of 4:

No grid = 1 × original mAs
5:1 grid = 2 × original mAs
6:1 grid = 3 × original mAs
8:1 grid = 4 × original mAs
12:1 grid = 5 × original mAs
16:1 grid = 6 × original mAs

The adjustment therefore requires 32 mAs at 90 kV *(Saia, p. 324).*

26. (A) One of the biggest advantages of CR/DR is the *latitude* it offers. While in screen–film imaging there is a "range of correct exposure" limited by the toe and shoulder of the characteristic curve, in CR/DR, the dynamic range is a *linear* relationship between the exposure given the PSP and its resulting luminescence as it is scanned by the laser. This affords much *greater exposure latitude;* technical inaccuracies can be effectively eliminated. In Figure 16–4, *curve A* illustrates the linear relationship between the exposure, given the PSP and its resulting luminescence. *Curve B* illustrates the characteristic curve used in screen–film imaging and its "range of correct exposure" limited by the toe and shoulder of the curve.

Overexposure of up to 500% and underexposure of up to 80% are reported as recoverable, thus eliminating most retakes. *This affords increased efficiency, but this does not mean that images can be exposed arbitrarily (Shephard, p. 330).*

27. (D) The closer the x-ray source is to the barrier (wall), the greater the thickness necessary. Occupancy factor refers to the degree of occupancy of the room adjacent to the barrier; a stairway would require less shielding than a busy work area. Workload is important in determining barrier thickness and refers to the number of examinations performed in the x-ray room measured in mA-min/wk—the greater the number of examinations per week, the greater the barrier thickness required. Use factor is also important in determining barrier thickness, and refers to the amount of time x-rays are directed to a particular wall—the greater the amount of time, the greater the thickness required *(Sherer et al., p. 204).*

28. (D) Sterilization is the complete elimination of all living microorganisms and can be accomplished by several methods. *Pressurized steam,* in an *autoclave,* is probably the most familiar means of sterilization; the pressure allows higher temperatures to be achieved. *Gas* or *chemical* sterilization is used for items unable to withstand moisture and/or high temperatures. Other methods of sterilization include *dry heat,* ionizing *radiation,* and microwaves (*non*ionizing radiation) *(Torres et al., pp. 115, 116).*

29. (C) When examining the third through fifth fingers in the lateral position, the *medial* side of the forearm (*ulnar side*) should be closest to the image receptor. This *minimizes magnification* by achieving the shortest possible OID (object-to-image-receptor distance). The terms *medial*

and *lateral* are identified while viewing the part in the anatomic position *(Ballinger & Frank, Vol 1, p. 103).*

30. (B) The image intensifier's input phosphor receives the remnant radiation emerging from the patient and converts it into a fluorescent light image. Very close to the input phosphor, separated by a thin, transparent layer, is the photocathode. The photocathode is made of a photoemissive alloy, usually an antimony and cesium compound. The fluorescent light image strikes the photocathode and is converted to an electron image that is focused by the electrostatic lenses to the output phosphor *(Fosbinder & Kelsey, p. 260).*

31. (C) Minimizing magnification through the use of *increased* SID (source-to-image-receptor distance) and *decreased* OID (object-to-image-receptor distance) functions to improve recorded detail. Decreasing *focal spot size* decreases blur, thereby increasing recorded detail. *Motion*, voluntary or involuntary, is most detrimental to good recorded detail. Although all other detail factors may be adjusted to maximize detail, if motion occurs during exposure, detail is lost. The most important ways to reduce the possibility of motion are by using the shortest possible exposure time, by careful patient instruction (for suspended respiration), and by adequate immobilization when necessary. *(Selman, pp. 319–320, 327).*

32. (A) *Primary radiation barriers* protect against direct exposure from the primary (useful) x-ray beam and have much greater attenuation capability than *secondary barriers*, which protect only from leakage and scattered radiation. Examples of primary barriers are the lead *walls* and *doors* of a radiographic room, that is, any surface that could be struck by the useful beam. Primary protective barriers of typical installations generally consist of walls with 1/16-inch (1.5 mm) lead thickness and 7-feet high.

Secondary radiation includes *leakage and scattered* radiation. The control booth wall is a secondary barrier; therefore, the primary beam must never be directed toward it. The x-ray tube housing must reduce leakage radiation to less than 100 mR/h at a distance of 1 meter from the housing. Lead aprons, lead gloves, portable x-ray barriers, and the like are also designed to protect the user from exposure to *scattered* radiation and will not protect from the primary beam *(Sherer et al., pp. 205, 206).*

33. (D) The number of *heat units* produced during a given exposure with single-phase equipment is determined by multiplying mA × second × kV. Correction factors are required with three-phase equipment. Unless the equipment manufacturer specifies otherwise, three-phase, *six*-pulse heat units are determined by multiplying mA × second × kV × 1.35. Three-phase, 12-pulse heat units are determined by multiplying mA × second × kV × 1.41 *(Selman, p. 220).*

34. (D) *Indirect contact* involves transmission of microorganisms via *airborne* contamination, *fomites*, and *vectors.* Airborne precaution *requires the patient to wear a mask* to avoid the spread of acid-fast bacilli (in bronchial secretions of TB patients) or other pathogens during coughing. If the patient is unable or unwilling to wear a mask, the radiographer must wear one. The radiographer should wear gloves, but a gown is required only if flagrant contamination is likely. Patients infected with *airborne precaution* require a *private, specially ventilated (negative pressure) room.* A private room is indicated for all patients on *droplet precaution*, that is, diseases transmitted via large droplets expelled from the patient while speaking, sneezing, or coughing. The pathogenic droplets can infect others when they come in contact with mouth or

nasal mucosa or conjunctiva. *Rubella* ("German measles"), *mumps,* and *influenza* are among the diseases spread by droplet contact; *a private room is required* for the patient, and health care practitioners must use *gown and gloves (Adler & Carlton, p. 196).*

35. (D) Image storage is located in a *pixel,* which is a two-dimensional "picture element" (see Fig. 14–21) measured in the "XY" direction. The third dimension in the matrix of pixels is the *depth* that together with the pixel is referred to as the *voxel* (see Fig. 14–22), measured in the "Z" direction.

A digital image is formed by a *matrix* of *pixels* in rows and columns. The *matrix* is the number of pixels in the XY direction. *The larger the matrix size, the better the image resolution* (see Fig. 14–23).

A matrix having 512 pixels in each row and column is a 512 × 512 matrix. The term *field of view* is used to describe how much of the patient (e.g., 150-mm diameter) is included in the matrix. The matrix and/or field of view can be changed without one affecting the other, but changes in either will change pixel size. *As in traditional radiography, spatial resolution is measured in line pairs per millimeter (lp/mm). As matrix size is increased, there are more and smaller pixels in the matrix, therefore improved resolution.* Fewer and larger pixels result in a poor-resolution "pixelly" image, that is, one in which you can actually see the individual pixel boxes (see Fig. 14–23).

Typical image matrix sizes used in radiography are:

- Nuclear medicine   128 × 128
- Digital subtraction angiography (DSA)   512 × 512
- Computed tomography (CT)   512 × 512
- Chest radiography   2048 × 2048

(Fosbinder & Kelsey, p. 284).

36. (A) The anteroposterior (AP) projection provides a general survey of the abdomen, showing the size and shape of the liver, spleen, and kidneys. When performed *erect,* it should demonstrate both hemidiaphragms. The *erect* position is used to demonstrate air/fluid levels (as seen in the radiograph, Fig. 16–4). Air or fluid levels will be clearly demonstrated only if the central ray is directed *parallel* to them. The manner (direction) in which the levels are seen indicates the position in which the image was made *(Ballinger & Frank, Vol 2, p. 80).*

37. (A) In the *photoelectric effect,* a relatively low-energy incident photon uses all of its energy to eject an inner-shell electron, leaving a vacancy. An electron from the next shell will drop to fill the vacancy, and *a characteristic ray is given up* in the transition. This type of interaction is more harmful to the patient, as all the photon energy is transferred to tissue *(Bushong, pp. 176–178).*

38. (C) The exposed CR cassette is placed into the CR scanner reader, where the PSP plate is automatically removed. The latent image appears as the PSP is scanned by a narrow high-intensity *helium–neon laser* to obtain the pixel data. As the plate is scanned in the CR reader, it releases a violet light—a process referred to as *photostimulated luminescence.*

The luminescent light is converted to electrical energy representing the *analog* image. The electrical energy is sent to an *analog-to-digital converter* (*ADC*) where it is digitized and

becomes the *digital* image that is eventually displayed (after a short delay) on a high-resolution monitor and/or printed out by a laser printer. The digitized images can also be manipulated in postprocessing, electronically transmitted, and stored/archived *(Shephard, p. 328)*.

39. (B) The posteroanterior (PA) axial projection (Haas method/nuchofrontal projection) of the skull requires that the central ray be angled 25-degree cephalad to the perpendicular orbitomeatal line (OML). This position is used to demonstrate the *occipital bone* in kyphotic patients and other patients who are unable to assume the AP recumbent position. If positioned accurately, the *dorsum sella and posterior clinoid processes* will be demonstrated within the foramen magnum. If the central ray is angled excessively, the *posterior aspect of the arch of C1* will appear in the foramen magnum *(Ballinger & Frank, Vol 2, p. 320)*.

40. (C) A profile view of the glenoid fossa can be obtained in the anteroposterior (AP) oblique projection (*left posterior oblique [LPO]* or *right posterior oblique [RPO]*, Grashey method). In the anatomic position, the bony glenoid fossa is seen to project *posteriorly and laterally* approximately 40 degrees. Therefore, if the shoulder is positioned with the body rotated 35- to 45-degree toward the affected side, the glenoid fossa will be placed parallel with the CR (*perpendicular to the image receptor*) and a profile view of the fossa is obtained *(Ballinger & Frank, Vol 1, pp. 188–189)*.

41. (D) *Nonstochastic* effects are somatic effects that are predictable, threshold responses; that is, a certain quantity of radiation must be received before the effect occurs, and the greater the dose the more severe the effect. Examples of nonstochastic effects are erythema, blood changes, cataract formation, and epilation. *Stochastic* effects of radiation are nonthreshold and randomly occurring. Examples of stochastic effects include carcinogenesis and genetic effects. The chance of occurrence of stochastic effects is directly related to the radiation dose; that is, as radiation dose increases there is a greater likelihood of genetic alterations or development of cancer *(Sherer et al., p. 60)*.

42. (C) Some chemical agents used in health care facilities function to kill pathogenic microorganisms, while others function to inhibit the growth/spread of pathogenic microorganisms. Germicides and disinfectants are used to kill pathogenic microorganisms, and antiseptics (like alcohol) are used to stop their growth/spread. *Sterilization* is another associated term and refers to killing of all microorganisms and their spores *(Ballinger & Frank, Vol 1, p. 16)*.

43. (B) Tomography is a procedure that uses reciprocal motion between x-ray tube and image receptor-to-image structures at a particular level in the body, while blurring everything above and below that level. The thickness of the level visualized can be varied by changing the tube angle (amplitude). In general, the greater the tube angle, the thinner the section imaged. Thinner sections may be used for imaging small or intricate structures *(Bushong, p. 316)*.

44. (B) As blood pulsates through the arteries, a throb can be detected. This throb or *pulse* can be readily palpated where the arteries are superficial (examples are *wrist, groin, neck*, and posterior surface of the *knee*). The apical pulse can be detected with a stethoscope *(Torres, pp. 143–145)*.

45. (B) The *image intensifier* in mobile fluoroscopic ("C" arm) equipment has the same function as the image intensifier in fixed equipment; that is, it brightens the x-ray image so that it can

be viewed in a room having normal lighting. The *TV camera/CCD* transmits the fluoroscopic image from the output phosphor of the image intensifier to the *TV monitor* for viewing. Mobile fluoroscopes/"C" arms have no *spot-film device,* although they frequently have features such as "last image hold" and capacity for digital recording *(Fosbinder & Kelsey, pp. 266–268).*

46. (B) Radiograph *A* was performed *posteroanterior* (*PA*) and radiograph *B* was performed *anteroposterior* (*AP*) as evidenced by the bony pelvis anatomy. The PA projection (image A) shows the ilia more foreshortened, giving the pelvis a "closed" appearance, while in the AP projection the ilia and bladder area appears more "open." There was an appropriate selection of exposure factors, for the required anatomic structures are well visualized: renal shadows, psoas muscle, lumbar transverse processes, and inferior margin of the liver. There is no evidence of the radiographs having been done erect, as the hemidiaphragms are not included, and the gas patterns appear without leveling *(Bontrager, pp. 109, 110).*

47. (A) Inside the CR cassette is the *photostimulable phosphor* (*PSP*) image plate, sometimes referred to simply as an *image plate* or *IP.* This PSP or IP with its layer of europium-activated barium fluorohalide serves as the *image receptor* as it is exposed in the traditional manner and receives the latent image. The PSP can *store* the latent image for several hours; after approximately 8 hours noticeable image fading will occur. Once the CR cassette is placed into the CR processor (*scanner* or *reader*), the PSP plate is automatically removed. The latent image on the PSP is changed to a manifest image as it is scanned by a narrow high-intensity *helium–neon laser* to obtain the pixel data. As the plate is scanned in the "reader," it releases a violet light—a process referred to as *photo-* (or light) *stimulated luminescence (Shephard, pp. 325–327).*

48. (A) The knee (tibiofemoral joint) is the largest joint of the body, formed by the articulation of the femur and tibia. However, it actually consists of three articulations: the patellofemoral joint, the lateral tibiofemoral joint (lateral femoral condyle with tibial plateau), and the medial tibiofemoral joint (medial femoral condyle with tibial plateau). Although the knee is classified as a synovial (diarthrotic) hinge-type joint, the patellofemoral joint is actually a gliding joint, and the medial and lateral tibiofemoral joints are hinge type *(Tortora & Derrickson, p. 282).*

49. (D) When performing gastrointestinal (GI) radiography, the position of the stomach may vary depending on the respiratory phase, the body habitus, and the patient position. *Inspiration* causes the lungs to fill with air and the diaphragm to descend, thereby pushing the abdominal contents downward. On *expiration,* the diaphragm will rise, allowing the abdominal organs to ascend. Body *habitus* is an important factor in determining the size and shape of the stomach. An asthenic patient may have a long, J-shaped stomach, while the stomach may be transverse on a hypersthenic patient. The body habitus is an important consideration in determining the positioning and placement of the image receptor. The patient *position* can also alter the position of the stomach. If a patient turns from the right anterior oblique (RAO) position into the anteroposterior (AP) position, the stomach will move into a more horizontal position. Although the cardiac sphincter and the pyloric sphincter are relatively fixed, the fundus is quite mobile and will vary in position *(Dowd & Tilson, Vol 2, p. 778).*

50. (C) Ribs below the diaphragm are best demonstrated with the diaphragm elevated. This is accomplished by placing the patient in a recumbent position and by taking the exposure at the end of exhalation. Conversely, the ribs above the diaphragm are best demonstrated with

the diaphragm depressed. Placing the patient in the erect position and taking the exposure at the end of deep inspiration accomplishes this *(Ballinger & Frank, Vol 1, p. 520)*.

51. (B) Protective barriers are classified as either primary or secondary. Primary barriers protect from the useful, or primary, x-ray beam and consist of a certain thickness of lead. They are located anywhere the primary beam can possibly be directed, for example, the walls of the x-ray room. The walls of the x-ray room usually require 1/16-inch (1.5-mm) thickness of lead 7-feet high. Secondary barriers protect from secondary (scattered and leakage) radiation. Secondary barriers are control booths, lead aprons and gloves, the wall of the x-ray room above 7 feet. Secondary barriers require much less lead than primary barriers *(Bushong, p. 569)*.

52. (B) Syncope, or fainting, is a result of a drop in blood pressure caused by insufficient blood (oxygen) to the brain. The patient should be helped into a dorsal recumbent position with feet elevated to facilitate blood flow to the brain *(Adler & Corlton, pp. 247–248)*.

53. (D) The phenomenon in which the radiographic information recorded on the PSP/IP upon exposure to x-rays *decreases* with the elapsed time until it is read by the scanner/reader is termed *fading*. This occurs because the photoelectrons generated by x-ray excitation upon exposure of the photostimulable phosphor are thermally released over time and therefore are unable to contribute to photostimulated luminescence upon scanning/reading. Luminescence decreases by approximately 25% within 8 hours of exposure. The greater the elapsed time and the greater the environmental temperature, the greater will be the degree of fading *(Shephard, p. 325)*.

54. (C) According to Bergonié and Tribondeau, the most radiosensitive cells are undifferentiated, rapidly dividing cells such as lymphocytes, intestinal crypt (of Lieberkühn) cells, and spermatogonia. Liver cells are among the types of cells that are somewhat differentiated and capable of mitosis. These characteristics render them somewhat radiosensitive. Muscle cells, as well as nerve cells and red blood cells, are highly differentiated and do not divide. Therefore, in order of *decreasing* sensitivity (from least to greatest sensitivity), the cells are intestinal crypt cells, liver cells, and muscle cells *(Bushong, p. 495)*.

55. (D) Distortion is caused by *improper alignment of the tube, body part, and image receptor*. Anatomic structures within the body are rarely parallel to the image receptor in a simple recumbent position. In an attempt to overcome this distortion, we position the part to be parallel with the image receptor, or angle the central ray to "open up" the part. Examples of this technique are obliquing the pelvis to place the ilium parallel to the image receptor, or angling the central ray cephalad to "open up" the sigmoid colon *(Shephard, pp. 231–234)*.

56. (C) Although the *inferosuperior axial* projection can be used to evaluate the glenohumeral joint, the required abduction of the arm would be contraindicated when evaluating a shoulder for possible dislocation. The *transthoracic* lateral projection is used to evaluate the glenohumeral joint and upper humerus when the patient is unable to abduct the arm (as in dislocation). The *scapular Y* projection is an oblique projection of the shoulder and is used in demonstrating anterior or posterior dislocation *(Ballinger & Frank, Vol 1, pp. 175, 186)*.

57. (B) *Oral* administration of barium sulfate is used to demonstrate the upper digestive system, esophagus, fundus, body and pylorus of the stomach, and barium progression through

the small bowel. The large bowel, including sigmoid colon, is usually demonstrated via *rectal* administration of barium *(Gurley & Callaway, p. 113).*

58. (C) Tissue is most sensitive to radiation exposure when in an *oxygenated* condition. Anoxic refers to a general lack of oxygen in tissue; hypoxic refers to tissue with little oxygen. Anoxic and hypoxic tumors are typically avascular (with little or no blood supply) and therefore more radioresistant *(Sherer et al., pp. 96–97).*

59. (D) The ability of x-ray photons to penetrate a body part has a great deal to do with the composition of that part (e.g., bone vs. soft tissue vs. air) and the presence of any pathologic condition. Pathologic conditions can alter the normal nature of the anatomic part. Some conditions such as osteomalacia, fibrosarcoma, and paralytic ileus (obstruction) result in a decrease in body tissue density. When body tissue density decreases, x-rays will penetrate the tissues more readily, that is, more x-ray penetrability. In conditions such as ascites, where body tissue density increases as a result of accumulation of fluid, x-rays will not readily penetrate the body tissues, that is, less x-ray penetrability *(Carlton & Adler, p. 259).*

60. (A) The image intensifier's input phosphor receives the remnant beam from the patient and converts it to a fluorescent light image. To maintain resolution, the input phosphor is made of cesium iodide crystals. *Cesium iodide* is much more efficient in this conversion process than was the phosphor previously used, zinc cadmium sulfide. Calcium tungstate was the phosphor used in cassette-intensifying screens for many years prior to the development of rare earth phosphors such as gadolinium oxysulfide *(Bushong, p. 360).*

61. (D) The wrist is composed of eight carpal bones arranged in two rows (proximal and distal). The proximal row consists of (from lateral to medial) the scaphoid, the lunate, the triquetrum, and the pisiform. The distal row (from lateral to medial) includes the trapezium, the trapezoid, the capitate, and the hamate. The radiograph seen in *Figure 16–7* is a *posteroanterior (PA) projection of the wrist.* The letter *L* represents the *scaphoid,* which is the most *lateral* carpal of the *proximal* row. Letter *M* points out the most *medial* carpal of the *distal* row, the *hamate.* The joints of the wrist include the *intercarpal joints* and the *radiocarpal joint (Ballinger & Frank, Vol 1, p. 91).*

62. (D) Hysterosalpingography may be performed for demonstration of uterine tubal patency, mass lesions in the uterine cavity, and uterine position. Although hysterosalpingography is often performed to check tubal patency, the uterine anatomy, position, and morphology are exhibited. Additionally, polyps, fibroids, or space occupying lesions within the uterus are well demonstrated *(Ballinger & Frank, Vol 2, p. 260).*

63. (D) Double-contrast studies of the stomach or large intestine involve coating the organ with a thin layer of barium sulfate, and then introducing air. This permits seeing through the organ to structures behind it, and most especially allows visualization of the mucosal lining of the organ. A barium-filled stomach or large bowel demonstrates position, size, and shape of the organ, and any lesion that projects out from its walls, such as diverticula. Polypoid lesions, which project inward from the wall of an organ, may go unnoticed unless a double-contrast examination is performed *(Ballinger & Frank, Vol 2, p. 140).*

64. (A) The intensity or exposure rate of radiation at a given distance from a point source is inversely proportional to the square of the distance. This is the inverse square law of radiation

and is expressed in the following equation:

$$\frac{I_1}{I_2} = \frac{D_2^2}{D_1^2}$$

Substituting known values:

$$\frac{40 \text{ mR/h}}{x \text{ mR/h}} = \frac{25}{9}$$

$$25x = 360$$

$$x = 14.4 \text{ mR/h, therefore 7.2 mR in 30 minutes}$$

(Bushong, p. 59).

65. (D) The medical suffix *plasia* refers to development, formation, growth, or proliferation. The suffix denoting embryonic is *blast*. Condition is indicated by the suffix *osis*. The suffix *kinesia* is used to refer to motion or movement. *(Taber's, p. 1683).*

66. (A) The *anteroposterior* (*AP*) *axial* projection (Towne method) of the skull is used to demonstrate the *occipital* bone. The skull is positioned AP and the CR is directed caudally. This serves to project the anterior structures inferiorly and away from superimposition on the occipital bone. The frontal bone is best demonstrated in the PA projection; the facial bones in the parietoacanthial (Waters) position. The sphenoid bone can be seen in the lateral and basal projections *(Ballinger & Frank, Vol 2, p. 314–315).*

67. (D) The mediastinum is the space between the lungs that contains the heart, great vessels, trachea, esophagus, and thymus gland. It is bound anteriorly by the sternum and posteriorly by the vertebral column and extends from the upper thorax to the diaphragm *(Ballinger & Frank, Vol 1, pp.535, 536).*

68. (A) Because the established dose-limit formula guideline is used for occupationally exposed persons 18 years of age and older, guidelines had to be established in the event a student entered the clinical component of a radiography educational program prior to age 18 years. The guideline states that the occupational dose limit for students *younger than 18 years* is *0.1 rem* (100 mrem or 1 mSv) in any given year. It is important to note that this 0.1 rem *is included* in the 0.5 rem dose limit that allowed the student as a member of the general public *(Bushong, p. 559).*

69. (A) Proper body mechanics includes a wide base of support. The *base of support* is the part of the body in touch with the floor or other horizontal plane. The *center of gravity* is the midpoint of the pelvis or lower abdomen, depending on body build. The *line of gravity* is the abstract line passing through the center of gravity, vertically. Proper body mechanics can help prevent painful back injuries by making proficient use of the muscles in the arms and legs *(Torres et al., pp. 82–83).*

70. (D) The "scapular Y" refers to the characteristic *Y* formed by the body of the scapula, acromion, and coracoid processes. The patient is positioned in a posteroanterior (PA) oblique position—a right anterior oblique (RAO) or left anterior oblique (LAO), depending on which is the affected side. The midcoronal plane is adjusted approximately 60 degrees to the image

receptor, and the affected arm is left relaxed at the patient's side. The scapular Y position is employed *to demonstrate anterior (subcoracoid) or posterior (subacromial) humeral dislocation.* The humerus is normally superimposed on the scapula in this position; any deviation from this may indicate dislocation *(Bontrager, p. 185).*

71. (C) The automatic exposure control (AEC) automatically terminates the exposure when the proper density has been recorded on the image receptor. The important advantage of the phototimer, then, is that it can accurately duplicate radiographic densities. It is very useful in providing accurate comparison in follow-up examinations, and in decreasing patient exposure dose by decreasing the number of "retakes" because of improper exposure. The AEC automatically adjusts the exposure required for body parts having different *thicknesses and densities.* Remember that proper functioning of the AEC depends on accurate positioning by the radiographer. The correct *ionization chamber*(s) must be selected, and the anatomic part of interest must completely cover the ionization chamber to achieve the desired density. If *collimation* is inadequate, and a field size larger than the part is used, excessive scattered radiation from the body or tabletop can cause the AEC to terminate the exposure prematurely, resulting in an underexposed radiograph *(Shephard, pp. 289–291).*

72. (D) *Chromosome aberration, cell death, and malignant disease* are major effects of deoxyribonucleic acid (DNA) irradiation, often as a result of abnormal metabolic activity. If the damage happens to the DNA of a germ cell, the radiation response may not occur until one or more generations later *(Bushong, p. 527).*

73. (D) Voltage ripple refers to the percentage drop from maximum voltage each pulse of current experiences. In single-phase rectified equipment, the entire pulse (half-cycle) is used; therefore, there is first an increase to maximum (peak) voltage value and a subsequent decrease to zero potential (90-degree past peak potential). The entire waveform is used; if 100 kV (kilovolts) were selected, the actual average kilovoltage output would be approximately 70. Three-phase rectification produces almost constant potential with just small ripples (drops) in maximum potential between pulses. Approximately a 13% voltage ripple (drop from maximum value) characterizes the operation of three-phase, six-pulse generators. Three-phase, 12-pulse generators have approximately a 4.0% voltage ripple *(Selman, p. 254).*

74. (C) Obtaining a complete and accurate history from the patient for the radiologist is an important aspect of a radiographer's job. Both subjective and objective data should be collected. *Objective* data include signs and symptoms that can be observed, such as a cough, a lump, or elevated blood pressure. *Subjective* data relate to what the patient feels, and to what extent. A patient may experience pain, but is it mild or severe? Is it localized or general? Does the pain increase or decrease under different circumstances? A radiographer should explore this with a patient and document additional information on the requisition for the radiologist *(Adler & Carlton, p. 137).*

75. (B) Computed radiography (CR) uses special phosphor plates inside image plates (IPs) to record the radiologic image. No film is used, hence the term *filmless* radiography. The IP is exposed just like a conventional screen–film cassette. Upon exposure, a latent image is produced on the photostimulable phosphor (PSP), which is located inside the IP. The IP is placed in the CR reader, and the PSP is automatically removed. The PSP is scanned with a

narrow laser beam to obtain the pixel data, which can then be displayed on a monitor as the radiographic image *(Shephard, pp. 325–327)*.

76. (C) There are two types of distortion: size and shape. *Shape distortion* relates to the alignment of the x-ray tube, the part to be radiographed, and the image receptor. There are two kinds of shape distortion: *elongation* and *foreshortening. Size distortion* is *magnification* and is related to the object-to-image-receptor distance (OID) and source-to-image-receptor distance (SID). Magnification can be reduced by either increasing the SID or decreasing the OID. However, an increase in SID must be accompanied by an increase in mAs (milliampere-seconds) to maintain density. It is therefore preferable, in the interest of exposure time, to reduce OID whenever possible *(Selman, pp. 348, 356)*.

77. (A) Three times a day is indicated by the abbreviation *TID*. The abbreviation *QID* means four times a day. Every hour is represented by *QH*, and *PC* means after meals *(Ehrlich et al., p. 277)*.

78. (A) As kV is increased, more *high-energy* photons are produced and the overall energy of the primary beam is increased. *Photon energy is inversely related to wavelength;* that is, as photon energy increases, wavelength decreases. An increase in milliamperage serves to increase the number of photons produced at the target, but is unrelated to their energy *(Selman, p. 177)*.

79. (A) The cervical intervertebral foramina lie 45 degrees to the midsagittal plane and 15 to 20 degrees to a transverse plane. When the *posterior oblique* position (LPO, RPO) is used, the cervical intervertebral foramina demonstrated are those *further* from the image receptor. There is therefore some magnification of the foramina. In the *anterior oblique* position (LAO, RAO), the foramina disclosed are those *closer* to the image receptor *(Ballinger & Frank, Vol 1, p. 428–429)*.

80. (D) Proper *alignment* of the x-ray tube, body part, and image receptor is required to avoid image *distortion* in the form of *foreshortening* or *elongation. Foreshortening* will usually result when the *part* is out of alignment. *Elongation* is often a result of *angulation of the x-ray tube.* Grid lines or *grid cutoff* will occur when the *grid* itself is off center or is not in alignment with the x-ray tube *(Shephard, p. 232)*.

81. (B) Image "*fading*" will occur if there is delay in reading the PSP. This is because after a time, trapped photoelectrons are released from the "color center" and are therefore unable to participate in PSL. PSL intensity *decreases* in the interval between x-ray exposure and the image reading process. If the exposed PSL is not delivered to the reader/processor for 8 hours, PSL decreases by approximately 25%. Fading also increases as environmental temperature increases.

It is recommended that the PSP be scanned in the reader at right angles to grid line direction to avoid/reduce aliasing artifacts *(Bushong, 9th ed, p.•••)*.

82. (D); **83. (A)**; **84. (C)**   The *stomach* is the dilated, sac-like portion of the gastrointestinal (GI) tract. When the stomach (or a portion of it) is empty, its mucosal lining forms soft folds called *rugae* (*L*). Exteriorly, the stomach presents a *greater curvature* (K) on its lateral surface and a *lesser curvature* (J) on its medial surface. The proximal opening of the stomach is the cardiac

sphincter; the pyloric sphincter is located at its distal end. The portion of the stomach around the distal esophagus is called the cardia; that portion superior to the esophageal juncture is the *fundus* (*A*). The major portion of the stomach is the *body* (*B*); the distal portion is the *pylorus* (C). The *incisura angularis* (*I*) is located on the lesser curvature and marks the beginning of the pylorus (C). The distal opening of the pylorus is the pyloric sphincter. The small intestine is composed of the duodenum, jejunum, and ileum. The duodenum is the shortest portion (approximately 12 inches). It begins just beyond the pyloric sphincter and is divided into four portions: the *duodenal cap or bulb* (*D*), *descending duodenum* (E), transverse duodenum, and *ascending duodenum* (F). These portions form the C-shaped *duodenal loop* that is occupied by the *head of the pancreas* (G). The ascending duodenum terminates at the duodenojejunal flexure that marks the beginning of the 9-foot *jejunum* (H) *(Ballinger & Frank, Vol 2, p. 86)*.

85. (C) Because the fundus is the most *posterior* portion of stomach, it readily fills with barium when the patient is in the *anteroposterior (AP)* or *left posterior oblique (LPO)* position. With the patient *posteroanterior (PA)* or *right anterior oblique (RAO)*, the barium moves to the more distal portions of the stomach. Figure 16–8 illustrates the RAO position. It is in this position that peristalsis is most active and the stomach's emptying mechanism can be evaluated. To evaluate the stomach adequately, preliminary patient preparation is required. The upper gastrointestinal (GI) tract must be empty; patients should be questioned about their preparation, and a preliminary "scout image" taken to check abdominal contents *(Ballinger & Frank, Vol 2, p. 147)*.

86. (B) Single-screen cassettes are made to be used with single emulsion film, such as in mammography. The single fluorescing screen is adjacent to, and exposes, the single emulsion. If double emulsion (duplitized) film is placed in a single screen cassette, it will receive only *one-half the intended exposure* and the resulting image will exhibit decreased density *(Fauber, p. 146)*.

87. (B) Most laser film is sensitive to both the Wratten 6B and the GBX safelight filters. Laser film will fog if handled under these safelight conditions. Most laser film is loaded into a film magazine in total darkness. Processing temperatures are the same for laser film as for regular x-ray film *(Shephard, pp. 92, 94)*.

88. (B) Radiographic contrast is described as the difference between densities, or scale of grays, in the radiographic image. Because the function of *grids* is to collect scattered radiation, they serve to shorten the scale of contrast. *Beam restrictors* function to limit the x-ray field size, thereby reducing the production of scattered radiation, and shorten the scale of contrast. *Focal spot size* is one of the geometric factors affecting recorded detail and has no effect on the scale of contrast. It is the function of radiographic contrast to make details visible. The sum of subject contrast and film contrast equals radiographic contrast *(Carlton & Adler, pp. 385–389)*.

89. (C) A *pulse oximeter* is used to measure a patient's pulse rate and oxygen saturation level. A *stethoscope and a sphygmomanometer* are used together to measure blood pressure. The first sound heard is the systolic pressure and the normal range is 110 to 140 mm Hg. When no more sound is heard, the diastolic pressure is recorded. The normal diastolic range is 60 to 90 mm Hg. Elevated blood pressure is called *hypertension. Hypotension*, low blood pressure, is not of concern unless it is caused by injury or disease; in that case, it results in shock *(Adler & Carlton, pp. 161–167)*.

90. (C) The development of male and female reproductive stem cells has important radiation protection implications. Male reproductive stem cells reproduce continuously. However, the female reproductive stem cells develop only during fetal life; women are born with all the reproductive cells they will ever have. It is exceedingly important to shield children whenever possible, as they have their reproductive futures ahead of them *(Bushong, p. 523)*.

91. (D) Insufficient milliamperage and/or exposure time will result in lack of radiographic density. Insufficient kV (kilovolts) results in underpenetration and excessive contrast. Insufficient source-to-image-receptor distance (SID), however, will result in increased exposure rate and radiographic *overexposure (Selman, pp. 331–333)*.

92. (B) The *quantity* of x-ray photons produced at the target is the function of mAs. The *quality* (wavelength, penetration, energy) of x-ray photons produced at the target is the function of kV. The kV also has an effect on exposure rate, because an increase in kV will increase the number of high-energy x-ray photons produced at the target. Exposure rate *decreases* with an increase in source-to-image-receptor distance (SID) *(Selman, pp. 332–333)*.

93. (B) Anemia is a blood condition characterized by a decreased number of circulating red blood cells and decreased hemoglobin, and has many causes. Adequate hemoglobin is required to provide oxygen to the body. Anemia is treated according to its cause. Hematuria is the term used to describe blood in the urine and is unrelated to anemia *(Tortora & Derrickson p. 689)*.

94. (B) In manual processing there is a *stop bath* between the developer and fixer solutions that serves to remove developer solution from the film surface and stop the development process. Automatic processing has no stop bath; film travels directly from the developer into the fixer solution. However, the processor's transport *rollers* serve to squeeze the solution from the film surface, and the acid fixer stops the (alkaline) development process. *Guide shoes* are found in turnaround assemblies and help direct the film as it bends from one direction to another *(Bushong, p. 210)*.

95. (D) Before the radiologic examination begins, patients often need to change their clothing and/or remove radiopaque objects (e.g., jewelry, dentures, braided hair) from superimposition on structures of interest. *Figure 16–9* illustrates multiple *braids* of hair superimposed on skull structures. While loose hair is radiolucent, hair that is braided becomes more dense and is often imaged radiographically. The ensuing artifacts can interfere with accurate diagnosis *(Saia, p. 79)*.

96. (C) The greatest effect of, and response to, irradiation is brought about by a *large dose of radiation, to the whole body, delivered all at one time.* Whole-body radiation can depress many body functions. With a fractionated dose, the effects would be less severe because the body would have an opportunity to repair between doses *(Bushong, p. 551)*.

97. (C) In the *anteroposterior (AP)* projection, the proximal fibula is at least partially superimposed on the lateral tibial condyle. *Medial rotation* of 45 degrees will "open" the proximal tibiofibular articulation. *Lateral rotation* will obscure the articulation even more *(Ballinger & Frank, Vol 1, p. 305)*.

98. (A) Some chemical agents used in health care facilities function to *kill* pathogenic microorganisms, while others function to *inhibit the growth*/spread of pathogenic microorganisms.

Germicides and disinfectants are used to kill pathogenic microorganisms and antiseptics (like alcohol) are used to stop their growth/spread. Sterilization is another associated term and refers to killing of all microorganisms and their spores *(Torres et al., p. 116)*.

99. (B) Epinephrine (Adrenalin) is the vasopressor used to treat an anaphylactic reaction or cardiac arrest. *Nitroglycerin* is a vasodilator. *Hydrocortisone* is a steroid that may be used to treat bronchial asthma, allergic reactions, and inflammatory reactions. *Digitoxin* is used to treat cardiac fibrillation *(Saia, p. 56)*.

100. (C) Grids are used in radiography to *absorb scattered radiation* before it reaches the image receptor, thus improving radiographic contrast. Contrast obtained with a grid compared to contrast without a grid is termed *contrast improvement factor.* The greater the percentage of scattered radiation absorbed compared to absorbed nonscattered radiation, the greater the "selectivity" of the grid. If a grid absorbs an abnormally large amount of primary radiation because of improper centering, tube angle, or tube distance, *grid cutoff* occurs *(Selman, p. 370)*.

101. (C) Changes in *hormone* levels affect changes in the glandular tissue of the breast. For example, breast tissue changes are seen during breast development, during pregnancy and lactation, and during menopause. Women at higher risk of developing breast cancer include those having had early menses (before age 12 years), late menopause (after age 52 years), and nulliparity (no full- or late-term pregnancies). Risks *other* than hormonal include family history and age *(Ballinger & Frank, Vol 2, p. 464)*.

102. (B) The bony walls of the orbit are thin, fragile, and subject to fracture. A direct blow to the eye results in a pressure that can cause fracture. That fracture is usually to the *orbital floor* (inferior aspect of the bony orbit). Because the fracture results from increased pressure within the eye, it is referred to as a "blowout" fracture *(Ballinger & Frank, Vol 2, p. 296)*.

103. (D) Histogram appearance can be affected by a number of things. *Positioning and centering accuracy* can have a significant effect on histogram appearance (see Fig. 12–8). Other factors affecting histogram appearance include selection of the *correct processing algorithm* (e.g., chest vs. femur), changes in *scatter, SID, OID,* and *collimation.* In short, anything that affects scatter and/or dose. Another factor affecting histogram appearance is *delay in processing* from time of exposure. Processing delay can result in *fading* of the image *(Shephard, p. 341)*.

104. (C) When the barium fluorohalide absorbs x-ray energy, electrons are released and they divide into two groups. One electron group initiates *immediate luminescence* during the excited state of Eu^{2+}. The other electron group becomes trapped within the phosphor's halogen ions, forming a "color center." These are the phosphors that ultimately form the radiographic image because when exposed to a *monochromatic* laser light source these phosphors emit *polychromatic* light, termed *photostimulated luminescence* (PSL).

The PSP layer (or Storage Phosphor Screen/SPS) can *store* its latent image for several hours, however, after approximately 8 hours noticeable image *fading* will occur. The Europium activator is important for the *storage* characteristic of the PSPs; it also has function similar to the sensitization specks within film emulsion—without europium, the image will not become manifest *(Bushong, 9th ed, p. 413)*.

105. (B) Late, long-term, effects of radiation can occur in tissues that have survived a previous irradiation months or years earlier. These late effects, such as carcinogenesis and genetic effects,

are "all-or-nothing" effects—either the organism develops cancer or it does not. Most late effects *do not have a threshold dose*; that is, *any* dose, however small, theoretically can induce an effect. Increasing that dose will increase the likelihood of the occurrence, but will not affect its severity; these effects are termed *stochastic. Nonstochastic effects* are those that will not occur below a particular threshold dose, and that increase in severity as the dose increases *(Sherer et al., pp. 120–121).*

106. (C) The patient, as the first scatterer, is the most important scatterer. At 1 m from the patient, the intensity of the scattered beam is 0.1% of the intensity of the primary beam. Compton scatter emerging from the patient is almost as energetic as the primary beam entering the patient *(Selman, p. 520).*

107. (B) Computed tomography (CT) and magnetic resonance imaging (MRI) are two common examples of *digital imaging*. Special equipment is also available for digital radiography (DR), or computed radiography (CR): images produced by either a fan-shaped x-ray beam received by linearly arrayed radiation detectors or a traditional fan shaped x-ray beam received by a light stimulated phosphor plate. Digital images can also be obtained in digital subtraction angiography (DSA), nuclear medicine, and diagnostic sonography. *Analog* images are conventional images that can be converted to digital images with a device called a digitizer. Pluridirectional tomography refers to conventional tomographic equipment that is capable of several x-ray tube movements *(Bushong, p. 396).*

108. (C) After exposure, the IP is placed into the CR *reader* where the PSP screen is automatically removed, moved at a constant speed, and scanned by a narrow high-intensity helium–neon (infrared) laser or a solid state laser to obtain the pixel data. The appropriate wavelength is absorbed by the "color center" and the electrons trapped there, causing PSL to occur during the excited state of Eu^{2+}.

The phosphors are activated by a monochromatic laser light, however, PSL is a *different* color (bluish-purple, blue-green, etc.). These two lights (PSL and laser) must not interfere with each other. To improve the image SNR, the PSL (carrying the x-ray image) must be a different wavelength/color than, and physically separate from, the laser excitation light. An *optical filter/beam-shaping optics* is used that permits *transmission* of the PSL, but *attenuates* the laser light; this filter/beam-shaper is mounted in front of a PMT.

The PMT or photodiode detects the PSL and converts it to electrical signals that are sent to an ADC where it becomes the digital image displayed on a high-resolution monitor. The digitized images can also be manipulated in postprocessing, electronically transmitted, and stored/archived *(Bushong, 9th ed, p. 420).*

109. (C) Angina pectoris is a spasmodic chest pain frequently caused by oxygen deficiency in the myocardium. The pain often radiates down the left arm and up to the left jaw. Angina pectoris attacks are frequently associated with exertion or emotional stress in individuals with coronary artery disease. Pain may be relieved with a vasodilator such as *nitroglycerin* given sublingually or transdermally. *Digitalis* is used to treat congestive heart failure. *Dilantin* is used in the control of seizure disorders, and *Tagamet* is used to treat duodenal ulcers *(Adler & Carlton, p. 265).*

110. (B) In the parieto-orbital projection (Rhese method), the patient is prone with the acanthiomeatal line perpendicular to the image receptor. The head rests on the forehead, nose,

and chin, and the MSP should form 53 degrees with the image receptor (37 degrees with the central ray). Radiographically, the optic canal should appear in the *lower outer quadrant* of the orbit. Incorrect *rotation* of the MSP results in *lateral or medial displacement,* and incorrect positioning of the *baseline* results in *longitudinal displacement of the optic canal (Ballinger & Frank, Vol 2, p. 335).*

111. (B) Radiographic contrast is described as the difference between densities in the radiographic image. It is the function of radiographic contrast to make details visible. Radiographs exhibiting many shades of gray are said to possess *long-scale,* or *low,* radiographic contrast; that is, there are *many grays,* and there is only *little difference between the various shades of gray.* Conversely, radiographs exhibiting *few shades of gray* are said to possess *short-scale,* or *high,* radiographic contrast. These images have a very *noticeable difference between radiographic densities (Shephard, p. 194).*

112. (A) Injectable medications are available in two different kinds of containers. An *ampule* usually holds a single dose of medication. A *vial* is a small bottle that holds several doses of the medication. The term *bolus* is used to describe an amount of fluid to be injected. A *carafe* is a narrow-mouthed container not likely to be used for medical purposes *(Adler & Carlton, p. 279).*

113. (B) An increase in kilovoltage (photon energy) will result in a *greater number* (i.e., exposure rate) of scattered photons (Compton interaction). These scattered photons carry no useful information and contribute to radiation *fog,* thus decreasing radiographic contrast *(Selman, p. 364).*

114. (D) The distal humerus articulates with the proximal radius and ulna to form the elbow joint. At its proximal end, the ulna presents the *olecranon process,* found at the proximal and posterior end of the *semilunar (trochlear) notch.* The *coronoid process* is seen at the distal and anterior end of the semilunar notch. Specifically, the semilunar notch of the ulna articulates with the trochlea of the distal medial humerus. The *capitulum* is lateral to the trochlea and articulates with the radial head *(Saia, p. 88).*

115. (B); **116. (C)** Figure 16–10 shows an anteroposterior (AP) projection of the elbow joint. The distal humerus articulates with the radius and ulna to form the elbow joint. The lateral aspect of the distal humerus presents a raised, smooth, rounded surface, the *capitulum* (E), that articulates with the superior surface of the *radial head* (A). The *trochlea* (F) is on the medial aspect of the distal humerus and articulates with the semilunar notch of the ulna. Just proximal to the capitulum and trochlea are the *lateral* (D) and *medial* (C) *epicondyles;* the medial is more prominent and palpable. The coronoid fossa is found on the anterior distal humerus and functions to accommodate the *coronoid process* (B) with the elbow in flexion *(Saia, p. 89).*

117. (B) The patient is the most important radiation scatterer during both radiography and fluoroscopy. In general, at 1 m from the patient, *the intensity is reduced by a factor of 1000,* to approximately 0.1% of the original intensity. Successive scatterings can render the intensity to unimportant levels *(Bushong, p.•••).*

118. (B) The sacroiliac joints angle posteriorly and medially 25 degrees to the median sagittal plane (MSP). Therefore, to demonstrate the sacroiliac joints with the patient in the *anteroposterior (AP)* position, the *affected* side must be elevated 25 degrees. This places the joint space

perpendicular to the image receptor and parallel to the central ray. Therefore, the *left posterior oblique (LPO)* position will demonstrate the *right sacroiliac joint* and the right posterior oblique (RPO) position will demonstrate the left. When performed with the patient *posteroanterior (PA)*, the *unaffected* side will be elevated 25 degrees *(Bontrager, p. 271)*.

119. (B) Magnification is part of every radiographic image. Anatomic parts within the body are at various distances from the image receptor and therefore have various degrees of magnification. The formula used to determine amount of image magnification is:

$$\frac{\text{Image size}}{\text{Object size}} = \frac{\text{SID}}{\text{SOD}}$$

Substituting known values:

$$\frac{x}{3''} = \frac{36'' \text{ SID}}{32'' \text{ SOD}} (\text{SOD} = \text{SID} - \text{OID})$$
$$32x = 108$$
$$x = 3.37'' \text{ image width}$$

(Bushong, p. 321).

120. (A) Sternoclavicular joints should be performed posteroanterior (PA) whenever possible to keep OID to a minimum. The *oblique* position (approximately 15 degrees) opens the joint *closest* to the image receptor. The erect position may be used, but is not required. Weight-bearing images are not recommended *(Ballinger & Frank, Vol 1, p. 508)*.

121. (D) The greater and lesser tubercles are prominences on the proximal humerus separated by the intertubercular (bicipital) groove. The anteroposterior (AP) projection of the humerus/shoulder places the *epicondyles parallel to the image receptor* and the shoulder in *external rotation* and demonstrates the *greater tubercle in profile*. The lateral projection of the humerus places the shoulder in extreme internal rotation with the epicondyles perpendicular to the image receptor and demonstrates the lesser tubercle in profile *(Ballinger & Frank, Vol 1, p. 156)*.

122. (C) Radiographic examinations of the large bowel generally include the anteroposterior (AP) or posteroanterior (PA) axial position to "open" the S-shaped sigmoid colon, the lateral position especially for the rectum, and the left anterior oblique (LAO) and right anterior oblique (RAO) (or left posterior oblique [LPO] and right posterior oblique [RPO]) to "open" the colic flexures. Left and right decubitus positions are usually employed only in double-contrast barium enemas to better demonstrate double contrast of the medial and lateral walls of the ascending and descending colon *(Ballinger & Frank, Vol 2, pp. 176–178)*.

123. (C) Protective or "reverse" isolation is used to keep the susceptible patient from becoming infected. Patients who have suffered burns have lost a very important means of protection, their skin, and therefore have increased susceptibility to bacterial invasion. Patients whose immune systems are depressed lose the ability to combat infection, and hence are more susceptible to infection. Active tuberculosis requires airborne precautions *(Gurley & Callaway, p. 153)*.

124. (B) Conventional screen–film images can be scanned and digitized by a special machine called a film digitizer. Interpretation of digital images is made from the *CRT* display monitor; this is referred to as "soft copy display." "Hard copies" can be made with a *laser printer*. A *laser camera* records the displayed image by exposing a film with laser light; it can also record several images on one film. The *laser printer* is connected for processing of the images *(Shephard, p. 360)*.

125. (B) Because lead content increases as grid ratio increases, more scattered radiation (*and* nonscattered remnant radiation) is absorbed before reaching the image receptor. There are, therefore, fewer x-ray photons interacting with the image receptor, with a resulting *decrease* in optical/radiographic density as grid ratio increases. Scale of contrast would *decrease* with an increase in grid ratio *(Carlton & Adler, p. 396)*.

126. (B) Patients who are able to cooperate are usually able to control *voluntary* motion if they are provided with an adequate explanation of the procedure. Once patients understand what is needed, most will cooperate to the best of their ability (by suspending respiration and holding still for the exposure). Certain body functions and responses, such as heart action, peristalsis, pain, and muscle spasm, cause *involuntary* motion uncontrollable by the patient. The best way to control involuntary and voluntary motion is by always selecting the shortest possible exposure time. Voluntary motion may also be minimized by careful explanation, immobilization, and (as a last resort and only in certain cases) restraint *(Ballinger & Frank, Vol 1, pp. 18–19)*.

127. (C) The *manubrial or jugular notch* is the depression on the superior border of the manubrium and is located at the level of the *third thoracic* vertebra. The *vertebra prominens* is at the level of the *seventh cervical* vertebra *(Ballinger & Frank, Vol 1, p. 62)*.

128. (B) An AEC (automatic exposure control) is calibrated to produce radiographic densities as required by the radiologist for interpretation purposes. Once the part being radiographed has been exposed to produce the required optical density, the AEC automatically terminates the exposure. The manual timer should be used as a *backup timer* should the AEC fail to terminate the exposure, thus protecting the patient from overexposure and the x-ray tube from excessive *heat* load. *Circuit breakers* and *fuses* are circuit devices used to protect circuit elements from overload. In case of current surge, the circuit will be broken (opened), thus preventing equipment damage. A *rheostat* is a type of variable resistor *(Shephard, pp. 286–287)*.

129. (C) The cassette is used to support the intensifying screens and x-ray film. It should be strong and provide good screen–film contact. The cassette front should be made of a sturdy material with a low atomic number, because attenuation of the remnant beam is undesirable. Bakelite (the forerunner of today's plastics) and magnesium (the lightest structural metal) are the most commonly used materials for cassette fronts. The high atomic number of tungsten makes it inappropriate as a cassette front material *(Selman, p. 274)*.

130. (B) The female pelvis differs from the male pelvis in that it is more shallow and its bones are generally lighter and more delicate (see Fig. 6–26). The pelvic outlet is wider and more circular in the female, the ischial tuberosities and acetabula are farther apart, the angle formed by the pubic arch is also greater in the female. All these bony characteristics facilitate childbearing and birth *(Saia, p. 106)*.

131. (B) When the foot is positioned for a lateral projection, the plantar surface should be perpendicular to the image receptor, so as to superimpose the metatarsals. This may be accomplished with the patient lying on either the affected or unaffected side (usually affected), that is, mediolateral or lateromedial. The talofibular articulation is best demonstrated in the medial oblique projection of the ankle *(Ballinger & Frank, Vol 1, p. 268)*.

132. (B) Exposure-type artifacts are those that appear on the radiograph as a result of image formation processes. A *foreign body* in the cassette or within the body part will cast its image on the radiographic image. As the exposed film is removed from the cassette, *static electrical discharge* will expose the film in a characteristic manner. These are *exposure-type artifacts.* In *Figure 16–11*, a right lateral decubitus of the gallbladder, the foam pad, and sheet have been imaged to produce the exposure artifact. *Processor artifacts* are not placed on the film during image formation, but rather during chemical processing. They can result from mechanical and/or chemical problems. Several kinds of artifacts can be produced by careless *handling* during production of the radiographic image. X-ray film is sensitive and requires proper handling and storage. Tree-like, branching black marks on a radiograph are usually caused by static electrical discharge, especially prevalent during cold dry weather *(Saia, p. 78)*.

133. (D) Factors that regulate the number of x-ray photons produced at the target are used to control radiographic density, namely milliamperage and exposure time (mAs). Radiographic density is directly proportional to mAs (milliampere-seconds); if the mAs is cut in half, the radiographic density will decrease by one-half. Although kilovoltage is used primarily to regulate radiographic contrast, it may also be used to regulate radiographic density in variable kV (kilovolts) techniques, according to the 15% rule *(Selman, p. 332)*.

134. (B) Perfect film–screen contact is essential to sharply recorded detail. Screen contact can be evaluated with a *wire-mesh test.* A *spinning-top test* is used to evaluate timer accuracy and rectifier operation. A *penetrometer* (aluminum step-wedge) is used to illustrate the effect of kV on contrast. A *star pattern* is used to measure resolving power of the imaging system *(Selman, pp. 234–235)*.

135. (A) The mechanical device used to correct an ineffectual cardiac rhythm is a *defibrillator.* The two paddles attached to the unit are placed on a patient's chest and used to introduce an electric current in an effort to correct the dysrhythmia. A *cardiac monitor* is used to display, and sometimes record, electrocardiogram (ECG) readings and some pressure readings. The *crash cart* is a supply cart with various medications and equipment necessary for treating a patient who is suffering from a myocardial infarction or other serious medical emergencies. It is periodically checked and restocked, usually by nursing, although radiographers may be responsible for a daily check of the plastic throwaway locks. These locks are used to ensure that the cart has not been tampered with or supplies inadvertently used in nonemergency situations. A resuscitation bag is used for ventilation, as during cardiopulmonary resuscitation *(Tortora & Derrickson, p. 731)*.

136. (C) There are many terms (with which the radiographer must be familiar) that are used to describe radiographic positioning techniques. *Cephalad* refers to that which is toward the head, and *caudad* to that which is toward the feet. Structures close to the source or beginning are said to be *proximal,* while those lying close to the midline are said to be *medial (Ballinger & Frank, Vol 1, p. 75)*.

137. (C) When barium fluorohalide absorbs x-ray energy, *electrons are released and they divide into two groups.* One electron group initiates *immediate* luminescence during the excited state of Eu^{2+}. The other electron group becomes *trapped* within the phosphor's halogen ions, forming a "color center." These trapped phosphors are the phosphors that ultimately form the radiographic image because when exposed to a *monochromatic* laser light source these phosphors emit *polychromatic* light, termed *photostimulated luminescence* (PSL).
The PSP layer *stores* its latent image for several hours, however, after approximately 8 hours noticeable image *fading* will occur. The europium activator is important for the *storage* characteristic of the PSPs; it also has function similar to the sensitization specks within film emulsion—without europium, the image will not become manifest *(Bushong, 9th ed, p. 415)*.

138. (C) Because the anode's focal track is beveled (angled, facing the cathode), x-ray photons can freely diverge toward the cathode end of the x-ray tube. However, the "heel" of the focal track prevents x-ray photons from diverging toward the anode end of the tube. This results in varying intensity from anode to cathode, fewer photons at the anode end, and more photons at the cathode end. *The anode heel effect is most noticeable using large image receptor sizes, short SIDs (source-to-image-receptor distances), and steep target angles (Saia, p. 296)*.

139. (D) With the patient in the anteroposterior (AP) position, the scapula and upper thorax are normally superimposed. With the arm abducted, the elbow flexed, and hand supinated, much of the scapula is drawn away from the ribs. The patient should not be rotated toward the affected side, as this causes superimposition of ribs on the scapula. The exposure is made during quiet breathing to obliterate pulmonary vascular markings *(Ballinger & Frank, Vol 1, p. 212)*.

140. (A) The type of shock associated with pooling of blood in the peripheral vessels is classified as *neurogenic shock.* This occurs in cases of trauma to the central nervous system resulting in decreased arterial resistance and pooling of blood in peripheral vessels. *Cardiogenic shock* is related to cardiac failure, as a result of interference with heart function. It can occur in cases of cardiac tamponade, pulmonary embolus, or myocardial infarction. *Hypovolemic shock* is related to loss of large amounts of blood, from either internal bleeding or hemorrhage associated with trauma. *Septic shock*, as well as *anaphylactic shock,* is generally classified as *vasogenic shock (Torres et al., pp. 165–167)*.

141. (B) An axial *dorsoplantar* projection is described; the central ray enters the dorsal surface of the foot and exits the plantar surface. The *plantodorsal* projection is done *supine* and requires cephalad angulation. The central ray enters the plantar surface and exits the dorsal surface *(Ballinger & Frank, Vol 1, pp. 279–281)*.

142. (D) Surface landmarks, prominences, and depressions are very useful to the radiographer in locating anatomic structures not visible externally. The *costal margin* is at about the same level as L3. The *umbilicus* is approximately at the same level as the L3–L4 interspace. The *xiphoid* tip is at about the same level as T10. The fourth lumbar vertebra is approximately at the same level as the *iliac crest (Saia, p. 74)*.

143. (D) In the CR reader, a photomultiplier tube (PMT) or photodiode (PD) is used to detect PSL and convert it to electrical signals. The electrical energy is sent to an *analog-to-digital*

converter (*ADC*) where it becomes the *digital* image that is displayed, after a short delay, on a high-resolution monitor.

In indirect capture DR, a flat-panel detector uses cesium iodide or gadolinium oxysulfide as the scintillator, i.e., that which captures x-ray photons and emits light. That light is then transferred directly to the ADC via a photodetector coupling agent—a *charge coupled device* (CCD) or *thin film transistor* (TFT) *(Bushong, 9th ed p. 420)*.

144. (A) Only two pieces of apparatus are needed to construct a characteristic curve (see Fig. 11–59). First, a *penetrometer* (aluminum step-wedge) is used to expose a film. Once the film is processed, a *densitometer* is needed to read the resulting densities. Log relative exposure is charted along the *x* (horizontal) axis; an increase in log relative exposure of 0.3 results from doubling the exposure. Optical density is plotted on the *y* (vertical) axis and represents the amount of light transmitted through a film compared to the amount of light striking the film (expressed as a logarithm) *(Bushong, p. 275)*.

145. (C) X-ray photons are produced in two ways as high-speed electrons interact with target atoms. First, if the high-speed electron is attracted by the nucleus of a tungsten atom and changes its course, the energy given up as the electron is "braked" in the form of an x-ray photon. This is called *bremsstrahlung* ("braking") radiation and is responsible for the majority of x-ray photons produced at the conventional tungsten target. Second, a high-speed electron may eject a tungsten K-shell electron, leaving a vacancy in the shell. An electron from a higher energy level, for example, the L shell, drops down to fill the vacancy, emitting the difference in energy as a K characteristic ray. *Characteristic radiation* comprises only approximately 15% of the primary beam *(Saia, p. 217)*.

146. (D) This is a modification of the parietoacanthial projection (Waters method) in which the patient is requested to first open the mouth, and then the skull is positioned so that the *orbitomeatal line (OML) forms a 37-degree angle* with the image receptor. The central ray is directed through the *sphenoid sinuses* and *exits the open mouth*. The routine parietoacanthial projection (with mouth closed) is used to demonstrate the maxillary sinuses projected above the petrous pyramids. The frontal and ethmoidal sinuses are best visualized in the posteroanterior (PA) axial position (modified Caldwell method) *(Ballinger & Frank, Vol 1, p. 414)*.

147. (D) Anode target material of *high atomic number* produces higher energy x-rays more efficiently. Because a great deal of heat is produced at the target, the material should have a *high melting point* so as to avoid damage to the target surface. Most of the x-rays generated at the focal spot are directed downward and pass through the x-ray tube's *port window*. The cathode filament receives *low-voltage* current to heat it to the point of thermionic emission. Then *high voltage* is applied to drive the electrons across to the focal track *(Selman, pp. 204–211)*.

148. (C) With inspiration, the diaphragm is depressed, that is, moved into a lower position. The ribs and sternum are elevated. As the ribs are elevated, their angle is decreased. Radio-graphic density can vary considerably in appearance depending on which phase of respiration the exposure is made *(Ballinger & Frank, Vol 1, p. 494)*.

149. (D) The four body types (from largest to smallest) are hypersthenic, sthenic, hyposthenic, and asthenic. The abdominal viscera of the *asthenic* person are generally located quite low,

vertical, and toward the midline. The opposite is true of the *hypersthenic* individual: organs are located high, transverse, and laterally *(Saia, p. 72).*

150. (C) The *wider* dimension of the x-ray film is usually placed on the feed tray and fed into the processor in that direction. The *entrance roller* is the first roller of the transport system located at the end of the feed tray; this is where the microswitch that determines amount of replenishment is located. The *length* of the film (the shorter dimension) activates the microswitch and replenisher is added according to the length of the film; a 10 × 12-inch film will receive less replenisher than will a 14 × 17-inch film. Crossover rollers are located between the different tanks. The receiving bin is where the films exit the processor. The replenishment pump is activated by the microswitch *(McKinney, p. 106).*

151. (D) Orthopnea is a respiratory condition in which the patient has difficulty breathing (*dyspnea*) in any position other than erect. The patient is usually comfortable in the erect, standing, or seated position. The *Trendelenburg position* places the patient's head lower than the rest of the body. *Fowler position* is a semierect position, and the *recumbent* position is lying down *(Taber's, p. 1535).*

152. (B) The radiograph in *Figure 16–12* shows the odontoid process superimposed on the base of the skull. The maxillary teeth can be seen very superior to the base of the skull. *Bringing the chin down* will move the base of the skull up and permit visualization of the C1–C2 structures. A diagnostic image of C1–C2 depends on adjusting the flexion of the neck *so that the maxillary occlusal plane and base of the skull are superimposed.* Accurate adjustment of these structures will usually allow good visualization of the odontoid process and the atlantoaxial articulation. Too much flexion superimposes teeth on the odontoid process; too much extension superimposes the base of the skull on the odontoid process *(Bontrager, p. 292).*

153. (C) The medical word for nosebleed is *epistaxis. Vertigo* refers to the feeling of "whirling" or the sensation that the room is spinning. Some possible causes of vertigo include inner ear infection or an acoustic neuroma. *Urticaria* is a vascular reaction resulting in dilated capillaries and edema that cause the patient to break out in hives. An *aura* may be classified as either a feeling or a motor response (such as flashing lights, tasting metal, smelling coffee) that precedes an episode such as a seizure or a migraine headache *(Adler & Carlton, p. 247).*

154. (C) Contrast media may be described as either positive (radiopaque) or negative (radiolucent). *Positive,* or *radiopaque, contrast agents* have a higher atomic number than the surrounding soft tissue, resulting in a greater attenuation or absorption of x-ray photons, thereby producing a higher radiographic contrast. Examples of positive contrast media are iodinated agents (both water and oil based) and barium sulfate suspensions. *Negative,* or *radiolucent, contrast agents* used are air and various gases. Because the atomic number of air is also quite different from that of soft tissue, an artificially high subject contrast can be produced. The advantage of carbon dioxide over air is that it is absorbed more rapidly by the body *(Bushong, p. 184).*

155. (C) As the colon begins to fill with barium, filling often slows down in the rectosigmoid region. Unless preventative measures are taken, severe abdominal cramping and urge to defecate can occur. *Stopping* the flow of barium momentarily will usually be sufficient to relieve the patient's discomfort. Some patients have repeated cramping throughout the examination.

These patients should be instructed to *breathe deeply* through their mouth, and the enema bag should be lowered a few inches to reduce the pressure of barium flow. Many patients benefit from the administration of *glucagon* to relax the intestine. The *Trendelenburg* position is frequently used to separate redundant loops of bowel *(Ballinger & Frank, Vol 2, p. 168)*.

156. (D) The *developing fetus* is particularly sensitive to radiation exposure. The law of Bergonié and Tribondeau states that *stem cells,* which give rise to a specific type of cell, as in hematopoiesis, are particularly radiosensitive, as are *young cells* and tissues. It also states that *cells with a high rate of proliferation* (mitosis) are more sensitive to radiation. Radiation exposure, especially between the second and sixth week following conception (the period of major organogenesis) can cause *organ damage, mental and growth retardation, microcephaly,* and *genital deformities (Sherer et al., pp. 129, 130)*.

157. (B) High-kilovoltage exposures produce large amounts of scattered radiation, and high-ratio grids are often used with high-kilovoltage techniques in an effort to absorb more of this scattered radiation. However, as more scattered radiation is absorbed, *more primary radiation is absorbed* as well. This accounts for the *increase in mAs required* when changing from 8:1 to 16:1 grid. Additionally, precise *centering and positioning become more critical*; a small degree of inaccuracy is *more likely to cause grid cutoff* in a high-ratio grid *(Selman, pp. 362–363)*.

158. (A) As in traditional radiography, numerous density values represent various tissue densities, for example bone, muscle, fat, blood-filled organs, air/gas, metal, contrast media, pathologic processes, etc. In CR, the CR scanner recognizes these numerous values and constructs a *gray-scale histogram* of these values represented in the imaged part. A histogram is a *graphic representation* defining all these values. The radiographer selects a *processing algorithm* by selecting the anatomical part and particular projection on the computer. The CR unit then matches that information with a particular *Lookup Table* (*LUT*)—a characteristic curve that best matches the anatomical part being imaged. Hence, *histogram analysis* and use of the appropriate *LUT* together function to produce predictable image quality in CR *(Shephard, p. 243)*.

159. (A) A *compensating filter* is used when the part to be radiographed is of uneven thickness or density (in the chest, mediastinum vs. lungs). The filter (made of aluminum or lead acrylic) is constructed so as to absorb much of the primary radiation that would expose the low-tissue-density area, while allowing the primary radiation to pass unaffected to the high-tissue-density area. A *collimator* is used to decrease the production of scattered radiation by limiting the volume of tissue irradiated. The *grid* functions to trap scattered radiation before it reaches the image receptor, thus reducing scattered radiation fog *(Shephard, p. 193)*.

160. (A) An increase in photon *energy* accompanies an increase in *kilovoltage.* Kilovoltage regulates the penetrability of x-ray photons; it regulates their *wavelength,* the amount of *energy* with which they are associated. The higher the related energy of an x-ray beam, the greater its *penetrability* (kilovoltage and photon energy are directly related; kilovoltage and wavelength are inversely related). Adjusting kilovoltage is the preferred method of adjusting radiographic contrast: as kilovoltage (photon energy) is increased, the number of grays increases, thereby producing a longer scale of contrast. In general, as *screen speed* increases, so does contrast (resulting in a shorter scale of contrast). An increase in *mAs* is frequently accompanied by an appropriate decrease in kilovoltage, which would also shorten the contrast scale. SID and radiographic contrast are unrelated *(Bushong, p. 167)*.

161. (C) Fractures and/or dislocations of the cervical spine are usually caused by acute *hyperflexion* or *hyperextension* as a result of indirect trauma. *Whiplash* injury is caused by a sudden, forced movement in one direction and then the opposite direction (as in rear-end automobile impacts). Whiplash symptoms frequently include neck pain and stiffness, headache, and pain and numbness of the upper extremities. Whiplash is often evidenced radiographically by straightening or reversal of the normal lordotic curve, and demonstrated in lateral projections performed in flexion and extension.

162. (B) If A and B are reduced to 5 mAs (milliampere-seconds) for mAs consistency, the kV (kilovolts) would increase in both cases to 85 kV, thereby balancing radiographic densities. Thus, the greatest density is determined by the shortest source-to-image-receptor distance (SID) (greatest exposure rate) *(Shephard, p. 307).*

163. (D) Breast cancer is very successfully treated earlier if it is diagnosed. Every effort is made to detect breast cancer before it is palpable. Early detection, diagnosis, and treatment (e.g., radiation therapy, surgery) have steadily increased breast cancer survival rates. Regular BSE (breast self-examination), along with appropriate and regular mammography, contributes to early detection and treatment. A baseline mammogram is recommended before the onset of menopause *(Ballinger & Frank, Vol 2, p. 461).*

164. (B) *Somatic effects* of radiation refer to those effects experienced directly by the exposed individual such as erythema, epilation, and cataracts. *Genetic effects* of radiation exposure are caused by irradiation of the reproductive cells of the exposed individual and transmitted from one generation to the next *(Sherer et al., p. 115).*

165. (C) The components of the electromagnetic spectrum are identified in different ways. *Wavelength* is used to identify visible light. *Frequency* is used to identify radio waves. Units of *energy* are used to identify ionizing electromagnetic radiations. The unit *keV (kilo-electron volt)* is used to identify the x-ray photon energies produced by diagnostic x-ray equipment. The unit *kV (kilovolts)* describes the voltage required to produce the x-rays within the x-ray tube. The units mA and mAs are quantitative units identifying the number or quantity of x-rays available *(Bushong, p. 63).*

166. (D) The greater the *number of electrons* comprising the electron stream and bombarding the target, the greater the number of x-ray photons produced. Although kV (kilovoltage) is usually associated with the energy of the x-ray photons, because *a greater number of more energetic electrons* will produce more x-ray photons, an increase in kV will also increase the *number* of photons produced. Specifically, the quantity of radiation produced increases as the *square* of the kilovoltage. The material composition of the tube target also plays an important role in the number of x-ray photons produced. The higher the *atomic number*, the denser and more closely packed the atoms comprising the material; therefore, the greater the chance of an interaction between a high-speed electron and target material *(Bushong, pp. 156–158).*

167. (A) If a radiograph lacks sufficient blackening, an increase in mAs is required. The mAs regulates the number of x-ray photons produced at the target. An increase or decrease of at least 30% in mAs is necessary to produce a perceptible effect. Increasing the kV 15% will have about the same effect as doubling the mAs *(Carlton & Adler, p. 370).*

168. (B) CR *image plates* (IPs) should be cleaned monthly. It is important that *anhydrous ethanol* be used for cleaning most CR IPs. A small amount of anhydrous ethanol is placed on a lint-free cloth for cleaning and removal of any dust or other particles. Water and remnant moisture must not be used as it can cause phosphor swelling. *Dust* on IPs has the same effect as dust on intensifying screens—a clear pinhole artifact. IPs should also be checked for physical damage. Scratches will appear as clear areas on the resulting image. CR *cassettes* should be visually checked for physical damage; inserting a damaged CR cassette into the scanner–reader can result in mechanical failure and system shutdown *(Ballinger & Frank, Vol 3, p. 366; Fuji Medical Systems CR Users Guide, p. 35)*.

169. (B) The pregnant radiographer poses a special radiation-protection consideration, as the safety of the unborn individual must be considered. It must be remembered that the developing fetus is particularly sensitive to radiation exposure. Established guidelines state that the occupational radiation exposure to the *fetus* must not exceed 0.5 rem (500 mrem, or 5 mSv) during the entire gestation period—not to exceed 50 mrem in 1 month *(Bushong, p. 560)*.

170. (C) Category-specific isolations have been replaced by *transmission-based precautions: airborne, droplet,* and *contact.* Under these guidelines, some conditions or diseases can fall into more than one category. *Airborne precaution* is employed with patients suspected or known to be infected with the *tubercle bacillus* (*TB*), *chickenpox* (*varicella*), and *measles* (*rubeola*). Airborne precaution *requires that the patient wear a mask* to avoid the spread of bronchial secretions or other pathogens during coughing. If the patient is unable or unwilling to wear a mask, the radiographer must wear one. The radiographer should wear gloves, but a gown is required only if flagrant contamination is likely. Patients under *airborne precaution* require a *private, specially ventilated (negative pressure) room.*

   A private room is also indicated for all patients on *droplet precaution,* that is, diseases transmitted via *large droplets* expelled from the patient while speaking, sneezing, or coughing. The pathogenic droplets can infect others when they come in contact with mouth or nasal mucosa or conjunctiva. *Rubella* ("German measles"), *mumps,* and *influenza* are among the diseases spread by droplet contact; *a private room is required* for the patient, and health care practitioners should use *gown and gloves.* Any diseases spread by direct or close *contact,* such as *MRSA* (methicillin-resistant *Staphylococcus aureus*), *conjunctivitis,* and *hepatitis A,* require *contact precaution. Contact precaution* procedures require a *private patient room,* and the use of *gloves, mask, and gown* for anyone coming in direct contact with the infected individual or his environment *(Adler & Carlton, p. 215)*.

171. (C) Blood pressure in pulmonary circulation is relatively low, and therefore pulmonary vessels can easily become blocked by blood clots, air bubbles, or fatty masses, resulting in a *pulmonary embolism.* If the blockage stays in place, it results in an extra strain on the right ventricle, which is now unable to pump blood. This occurrence can result in congestive heart failure. *Pneumothorax* is air in the pleural cavity. *Atelectasis* is a collapsed lung or part of a lung. *Hypoxia* is a condition of low tissue oxygen *(Torres et al., pp. 167–168)*.

172. (A) The 45-degree oblique position of the lumbar spine is generally performed for demonstration of the *apophyseal joints.* In a correctly positioned oblique lumbar spine, *scotty dog* images are demonstrated. The scotty's *ear* corresponds to the superior articular process,

his *nose* to the transverse process, his *eye* is the pedicle, his *neck* is the pars interarticularis, his *body* is the lamina, and his *front foot* is the inferior articular process *(Saia, p. 131).*

173. (D) Phase of respiration is exceedingly important in thoracic radiography; lung expansion and the position of the diaphragm strongly influence the appearance of the finished radiograph. Inspiration and expiration radiographs of the chest are taken to demonstrate air in the pleural cavity (*pneumothorax*), to demonstrate *atelectasis* (partial or complete collapse of one or more pulmonary lobes) degree of *diaphragm excursion,* or to detect the presence of a *foreign body.* The expiration image will require a somewhat greater exposure (6 to 8 kV more) to compensate for the diminished quantity of air in the lungs *(Ballinger & Frank, Vol 1, p. 542).*

174. (A) The x-ray tube's glass envelope and oil coolant are considered inherent ("built-in") filtration. Thin sheets of aluminum are added to make *a total of at least 2.5 mm Al equivalent filtration in equipment operated above 70 kV (kilovolts).* This is done to remove the low-energy photons that serve to contribute only to patient skin dose *(Sherer et al., p. 155).*

175. (A) AEC (automatic exposure control) devices are used in today's equipment and serve to produce consistent and comparable radiographic results. In one type of AEC, there is an *ionization chamber* just beneath the tabletop above the image receptor. The part to be examined is centered to it (the sensor) and radiographed. When a predetermined quantity of ionization has occurred (equal to the correct density), the exposure terminates automatically. In the other type of AEC, the *phototimer/photomultiplier,* a small fluorescent screen is positioned beneath the image receptor. When remnant radiation emerging from the patient exposes the IR and exits the cassette, the fluorescent screen emits light. Once a predetermined amount of fluorescent light is "seen" by the photocell sensor, the exposure is terminated. A scintillation camera is used in nuclear medicine. A photocathode is an integral part of the image intensification system *(Saia, pp. 443–444).*

176. (A) Protective aprons and gloves are made of lead-impregnated vinyl or leather. They should be checked annually for cracks via radiographic or fluoroscopic means. Otherwise, minimal care is required. Lead aprons and gloves should always be hung on appropriate hangers. Glove supports permit air to circulate within the glove. Apron hangers provide convenient storage without folding. If lead aprons are folded, or left in a careless heap, cracks are more likely to form. If lead aprons or gloves become soiled, cleaning with a damp cloth and appropriate solution is all that is required. Excessive moisture should be avoided *(Bushong, p. 596).*

177. (A) The spinning-top test is used to evaluate *timer accuracy* or *rectifier failure.* With *single-phase,* full-wave rectified equipment (120 pulses/second), individual dots are seen that represent x-ray impulses. *Figure 16–14* was made by using single-phase, full-wave rectified equipment. Because three-phase and high-frequency equipment is almost constant potential, a special synchronous spinning top (or an oscilloscope) is used and a solid black arc is obtained rather than dots. The number of degrees formed by the arc is measured and equated to a particular exposure time *(Fosbinder & Kelsey, p. 339).*

178. (B) When a spinning top is used to test the timer efficiency of full-wave rectified single-phase equipment, the result is a *series of dots* or dashes, with each dot representing a pulse of radiation. With full-wave rectified current, and a possible 120 pulses (dots) available per second, one should visualize 12 dots at 1/10 second, 6 dots at 0.05 second, etc.

If 4 dots of a possible 120 are seen, then the exposure time was:

$$\frac{4}{120} = \frac{1}{30} \text{ second}$$

The spinning-top test may be used to test timer accuracy in single-phase equipment. A spinning top is a metal disk with a small hole placed in its outer edge, and placed on a pedestal approximately 6-inches high. The exposure is made while the top spins. Because three-phase equipment produces almost constant potential—rather than pulsed radiation—the standard spinning top cannot be used. An oscilloscope or synchronous spinning top must be employed to test timers of three-phase equipment *(Selman, p. 233)*.

179. (D) A controlled area is one that is occupied by radiation workers trained in radiation safety and who wear radiation monitors. The exposure rate in a *controlled area* must not exceed 100 mR/wk; its occupancy factor is considered to be 1, indicating that the area may always be occupied, and therefore requiring maximum shielding. An *uncontrolled area* is one occupied by the general population; the exposure rate there must not exceed 10 mR/wk. Shielding requirements vary according to several factors, one being *occupancy factor (Sherer et al., p. 204)*.

180. (D) The lead strips in a parallel grid are *parallel to each other* and therefore *not to the x-ray beam.* The more divergent the x-ray beam, the more likely there will be cutoff/decreased density at the lateral edges of the radiograph. This problem becomes more pronounced at short source-to-image-receptor distances (SIDs). If there were a centering or tube angle problem, there would more likely be a noticeable density loss on one side *or* the other *(Shephard, p. 260)*.

181. (A) The trachea (windpipe) bifurcates into left and right *mainstem bronchi,* each entering its respective lung hilum. The *left* bronchus divides into *two* portions, one for each lobe of the left lung. The *right* bronchus divides into *three* portions, one for each lobe of the right lung (Fig. 6–76). The lungs are conical in shape, consisting of upper pointed portions, termed the *apices* (pleural for apex), and the broad lower portions (or *bases*). The lungs are enclosed in a double-walled serous membrane called the *pleura (Saia, pp. 158–159)*.

182. (A) When the shoulders are relaxed, the clavicles are usually carried below the pulmonary apices. To examine the portions of the lungs lying behind the clavicles, the central ray is directed cephalad 15 to 20 degrees to project the clavicles above the apices when the patient is examined in the anteroposterior (AP) position *(Ballinger & Frank, Vol 1, p. 568)*.

183. (D) Radiation quality determines degree of penetration and the amount of energy transferred to the irradiated tissue (linear energy transfer [LET]). Certainly, the larger the absorbed radiation dose, the greater the effect. Biologic effect is increased as the size of the irradiated area is increased. The nature of the effect is influenced by the location of irradiated tissue (bone marrow vs. gonads and so on) *(Selman, p. 190)*.

184. (A) The approximately 5-foot-long large intestine (colon) functions in the formation, transport, and evacuation of feces. The colon commences at the terminus of the small intestine; its first portion is the sac-like *cecum* in the right lower quadrant (RLQ), located inferior to the ileocecal valve. The *ascending colon* is continuous with the cecum and is located along

the right side of the abdominal cavity. It bends medially and anteriorly forming the right colic *(hepatic)* flexure. The colon traverses the abdomen as the *transverse colon* and bends posteriorly and inferiorly to form the left colic (*splenic*) flexure. The *descending colon* continues down the left side of the abdominal cavity and at about the level of the pelvic brim, in the *left lower quadrant (LLQ),* the colon moves medially to form the S-shaped *sigmoid* colon. The rectum, approximately 5 inches in length, lies between the sigmoid and anal canal *(Saia, p. 174).*

185. (B) A 15% increase kV (kilovolts) with a 50% decrease in mAs (milliampere-seconds) serves to produce a radiograph *similar* to the original, but with some obvious differences. The overall blackness (*radiographic/optical density*) *is cut in half* because of the decrease in mAs. But the loss of blackness is compensated for by the *addition of grays* (therefore, *longer* scale contrast) from the increased kV. The increase in kV also *increases exposure latitude*; a greater margin for error in higher kV ranges. Recorded detail is unaffected by changes in kV *(Shephard, pp. 178, 181).*

186. (C) Major branches of the common carotid arteries (internal carotids) function to supply the anterior brain, while the posterior brain is supplied by the vertebral arteries (branches of the subclavian). The brachiocephalic (innominate) artery is unpaired and is one of the three branches of the aortic arch, from which the right common carotid artery is derived. The left common carotid artery comes directly off the aortic arch *(Tortora & Derrickson, p. 767).*

187. (C) The brightness gain of image intensifiers is 5000 to 20,000. This increase is accomplished in two ways. First, as the electron image is focused to the output phosphor, it is accelerated by high voltage (this is *flux gain*). Second, the output phosphor is only a fraction of the size of the input phosphor, and this image size decrease represents another brightness gain, termed *minification gain. Total brightness gain is equal to the product of minification gain and flux gain (Saia, p. 459).*

188. (C) The OSL (optically stimulated luminescence) is rapidly becoming the most commonly used personnel monitor today. Film badges and TLDs (thermoluminescent dosimeters) have been successfully used for years. A pocket dosimeter is used primarily when working with large amounts of radiation and when a daily reading is desired *(Selman, p. 401).*

189. (B) Because *muscle* and *nerve* tissues perform specific functions and do not divide, they are relatively *insensitive* to radiation exposure. *Epithelial* cells cover the outer surface of the body, and line body cavities as well as tubes and passageways leading to the exterior. They contain very little intercellular substance and are devoid of blood vessels. Because *epithelial* cells constantly regenerate through mitosis, they are very *radiosensitive (Sherer et al., p. 108).*

190. (A) The knee is formed by the proximal tibia, the patella, and the distal femur, which articulate to form the femorotibial and patellofemoral joints. The distal posterior femur presents two large medial and lateral condyles separated by the deep intercondyloid fossa. Two small prominences, the medial and lateral epicondyles, are just superior to the condyles. The femoral and tibial condyles articulate to form the femorotibial joint. In the lateral position, the *medial femoral condyle, being farther from the image receptor, is magnified.* Its magnified image obscures the knee joint space unless correction is made. Angulation of 5-degree cephalad will *superimpose the magnified medial femoral condyle on the lateral condyle* and permit a *better view of the joint space (Saia, p. 111).*

191. (C) The full length of the nasal septum is best demonstrated in the parietoacanthial (Waters method) projection. This is also the single best view for facial bones. The posteroanterior (PA) axial (Caldwell method) projection superimposes petrous structures over the nasal septum, while the lateral projection superimposes and obscures good visualization of the septum *(Bontrager, p. 395).*

192. (C) When caring for a patient with an indwelling Foley catheter, place the drainage bag and tubing *below the level of the bladder* to maintain the gravity flow of urine. Placement of the tubing or bag above or level with the bladder will allow backflow of urine into the bladder. This reflux of urine can increase the chance of urinary tract infection (UTI) *(Torres, pp. 329).*

193. (A) A quality control program requires the use of a number of devices to test the efficiency of various parts of the imaging system. A *slit camera*, as well as a star-pattern or pinhole camera, is used to test focal spot size. A parallel-line–type resolution test pattern is used to test the resolution capability of intensifying screens *(Selman, p. 326).*

194. (B) The most effective method of sterilization is moist heat, using steam under pressure. This is known as autoclaving. Sterilization by dry heat requires higher temperatures for longer periods of time than moist heat. Pasteurization is moderate heating with rapid cooling and is frequently used in commercial preparation of milk and alcoholic beverages such as wine and beer. It is not a form of sterilization. Freezing can also kill some microbes, but is not a form of sterilization *(Adler & Carlton, p. 208).*

195. (B) Even the smallest exposure to radiation can be harmful. It must, therefore, be every radiographer's objective to keep his or her occupational exposure as far below the dose limit as possible. Radiology personnel should never hold patients during an x-ray examination *(Bushong, p. 8).*

196. (B) *Emphysema* is abnormal distention of alveoli (or tissue spaces) with air. The presence of abnormal amounts of air makes it necessary to decrease from normal exposure factors. *Congestive heart failure* and *pleural effusion* involve abnormal amounts of fluid in the chest and thus require an *increase* in exposure factors *(Carlton & Adler, p. 258).*

197. (C) There are four sets of paranasal sinuses: *frontal, ethmoidal, maxillary*, and *sphenoidal* (Fig. 16–16). The left and right *frontal* sinuses (*number 1*) are usually asymmetrical and are located behind the glabella and superciliary arches of the frontal bone. The *ethmoidal* sinuses (*number 2*) are composed of 6 to 18 thin-walled air cells occupying the bony labyrinth of the ethmoid bone. The *frontal and ethmoidal sinuses* are demonstrated in the PA axial projection (Caldwell position). The *maxillary* sinuses (antra of Highmore; *number 4*) are the largest of the paranasal sinuses and are located in the body of the maxillae. They are particularly prone to infection and collections of stagnant mucus. The maxillary sinuses are well demonstrated in the *parietoacanthial* projection (Waters position). The *sphenoidal* sinuses (*number 3*) are located in the body of the sphenoid bone and are usually asymmetrical. They are well demonstrated in the *SMV* projection. All paranasal sinuses are demonstrated in the *lateral* projection, although the left and right of each group are superimposed. Radiography of the paranasal sinuses must be performed in the erect position so that any *fluid levels* may be demonstrated and to distinguish between fluid and other pathology such as *polyps (Ballinger & Frank, Vol 2, p. 412).*

198. (B) A review of the problem reveals that *three changes* are being made: an increase in *SID (source-to-image-receptor distance)*, a change from a 400-*speed system* to a 200-speed system, and a change in *exposure time* (to be considered last). Because the original mAs (milliampere-seconds) was 9, reducing the speed of the system by half (from 400 to 200) will require a doubling of the mAs, to 18, in order to maintain density. Now we must deal with the distance change. Using the density maintenance formula (and remembering that 18 is now the *old* mAs), we find that the required new mAs at 42 inches is 22:

$$\frac{18 \text{ mAs}}{x} = \frac{1444\,(38^2)}{1764\,(42^2)}$$
$$1444x = 31752$$
$$x = 21.98(22) \text{ mAs}$$

Because we are not changing mA, we must determine the *exposure time* that, used with 300 mA, will yield 22 mAs:

$$300x = 22$$
$$x = 0.07 \text{ second exposure } \textit{(Selman, pp. 332, 335–336).}$$

199. (C) Erythema is the reddening of skin as a result of exposure to large quantities of ionizing radiation. It was one of the first somatic responses to irradiation demonstrated to the early radiology pioneers. The effects of radiation exposure to the skin follow a *nonlinear, threshold dose–response relationship.* An individual's response to skin irradiation depends on the dose received, the period of time over which it was received, the size of the area irradiated, and the individual's sensitivity. The dose that it takes to bring about a noticeable erythema is referred to as the *skin erythema dose (SED) (Bushong, p. 521).*

200. (A) The *airway* of the victim is first opened by tilting back the head and lifting the chin. However, if the victim might have suffered a spinal cord injury, the spine should not be moved and the airway should be opened using the jaw-thrust method.

The rescuer next *listens to breathing* sounds and watches for rise and fall of the chest to indicate breathing. If there is no breathing, the rescuer pinches the victim's nose and delivers *two full breaths via mouth-to-mouth rescue* breathing. If rise and fall of the chest is still not present, the Heimlich maneuver is instituted. If ventilation does not take place during the two full breaths, the victims circulation is checked next (using the carotid artery). If there is no pulse, external chest compressions are begun at a rate of 80 to 100/min for the adult and at least 100/min for infants *(Torres, p. 171).*

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Note: Page numbers followed by *f* indicate figures; those followed by *t* indicate tables; those followed by *b* indicate boxed material.

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Abbreviations

IP	Image plate
PSP	Photostimulable phosphor
PSL	Photostimulable luminescence
SPS	Storage phosphor screen
CR	Computed radiography
SNR	Signal-to-noise ratio
MTF	Modulation transfer function
PMT	Photomultiplier tube
PD	Photodiode
ADC	Analog-to-digital converter
EDR	Exposure data recognizer
DQE	Detective quantum efficiency
CCD	Charge coupled device
TFT	Thin film transistor
HIS	Hospital information system
RIS	Radiology information system
PACS	Picture archiving and communication system
DICOM	Digital imaging and communications in medicine
EDR	Exposure data recognition

PSP Screen Layers
- Protective coat
- BaFX:Eu^{2+} phosphors in binder material
- Reflective backing
- Polyester base support material
- Antistatic layer
- Lead foil backing

Terminology Comparison

S/F IMAGING	CR/DR IMAGING
Latitude	Dynamic range
Contrast	Contrast resolution
Density	Brightness
Recorded detail/sharpness	SNR
Resolution	Spatial frequency

CR Spatial Frequency/Resolution Increases As
- PSP crystal size decreases
- Laser beam size decreases
- Monitor matrix size increases

PACS Features
- Image acquisition
- Image display and interpretation
- Image archival and retrieval
- Image communication

Causes of CR Graininess
- Underexposure
- Incorrect processing algorithm
- Excess SR; inadequate collimation
- Grid misalignment; cutoff

Electronic Imaging
- Brightness/density changes with changes in window *level*.
- Contrast changes with changes in window *width*.
- Has wide dynamic range
- Has greater exposure latitude
- Fading can occur with delayed processing.
- IPs are very sensitive to fog.

CR ARTIFACT	CAUSE
Fog	Exposure to scattered radiation
Image fading	Delay in processing
Black spots	In need of erasure before use
Slight additional anatomic image	Incomplete erasure

Typical Image Matrix Sizes Used in Imaging

Nuclear medicine	128 × 128
Digital subtraction angiography (DSA)	1024 × 1024
CT	512 × 512
Chest radiography	2048 × 2048

Advantages of DF Photospots
- No chemical processing needed
- Decreased patient dose
- Postprocessing capability
- "Road-mapping" capability

Gonadal Shielding Should Be Used If
- The gonads lie in, or within 5 cm of, the collimated field
- The patient has reasonable reproductive potential
- Diagnostic objectives permit.

Comparisons Between Large and Small FOV

LARGER FIELD OF VIEW
- Focal point closer to output screen
- Less magnification of perceived image
- Brighter image; less exposure required

SMALLER FIELD OF VIEW
- Focal point farther from output screen
- Magnified image
- Less brightness; more exposure required

Radiation Weighting (W$_r$) Factors

X- or gamma	1
Protons	2
Neutrons: 10–100 keV	10
Neutrons: 100 keV–2 MeV	20
Alpha particles	20

Tissue Weighting (W$_t$) Factors

Skin	0.01
Thyroid	0.05
Breast	0.05
Lung	0.12
Gonads	0.20

Types of DNA Damage
- Main chain, double side rail break
- Main chain, single side rail break
- Main chain breakage, cross-linking
- Base damage, point mutations

Ways To Reduce Risk to Recently Fertilized Ovum
- Elective scheduling/10-day rule
- Patient questionnaire
- Posting

Beam Restriction
- Reduces patient dose
- Improves image quality

Beam Restrictor Types
- Aperture diaphragm
- Cone
- Collimator

Abbreviations

IP	Image plate
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PSL	Photostimulable luminescence
SPS	Storage phosphor screen
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RIS	Radiology information system
PACS	Picture archiving and communication system
DICOM	Digital imaging and communications in medicine
EDR	Exposure data recognition

Attenuation Characteristics of Lead Aprons

X-ray attenuation at:

Pb EQUIVALENT THICKNESS	75 kV	100 kV
0.25 mm	66%	51%
0.50 mm	88%	75%
1.0 mm	99%	94%

Primary Barriers
- Protect from the useful beam

Secondary Barriers
- Protect from scattered and leakage radiation

Radiation Protection Rules
- Time
- Distance
- Shielding

Traditional and SI Equivalents

$1R = 2.58 \times 10^{-4}$ C/kg
100 rad = 1 Gy (1000 mGy)
100 rem = 1 Sv (1000 mSv)

Origin of Scattered Radiation and Methods for Controlling Its Production
- The larger the x-ray field size, the more scattered the radiation produced.
Solution: collimate!
- The higher the kilovoltage, the greater the production of scattered radiation (a result of the higher incidence of Compton scatter interactions).
Solution: use optimum kV.
- The thicker and more dense the body tissues, the greater the amount of scattered radiation produced.
Solution: when possible, compression of the part or use of the prone position to decrease the effect of fatty tissue.

Correction Factors

SINGLE PHASE	THREE PHASE
χ mAs	2/3χ for 3φ (6p)
χ mAs	1/2χ for 3φ (12p)
χ kV	χ −12% for 3φ

The Anode Heel Effect Is Emphasized Under the Following Conditions
- At short SIDs
- With large cassettes
- With small anode angle x-ray tubes

As Grid Ratio Increases
- Scattered radiation cleanup increases and contrast resolution improves
- Contrast scale decreases (higher contrast produced)
- Exposure factors (usually mAs) must increase
- Positioning latitude decreases

ARRT Standards of Ethics Composed of
- Code of Ethics (aspirational)
- Rules of Ethics (enforceable)

Conditions for Valid Patient Consent
- The patient must be of legal age.
- The patient must be of sound mind.
- The patient must give consent freely.
- The patient must be adequately informed of the procedure about to take place.

Factors in Infection Transmission/Cycle of Infection
1. An infectious agent
2. Reservoir or environment for agent to live and multiply
3. A portal of exit from the reservoir
4. A means of transmission
5. A portal of entry into a susceptible new host

Methods of Drug Administration
ORAL
- PO (by mouth), through digestive system

PARENTERAL
- Topical
- Subcutaneous
- Intradermal
- Intramuscular
- Intravenous

GRID RATIO	mAs CONVERSION FACTOR
- no grid	1
- 5:1	2
- 6:1	3
- 8:1	4
- 10/12:1	5
- 16:1	6

GRID CONVERSION FORMULA

$$\frac{mAs_1}{mAs_2} = \frac{\text{Conversion factor}_1}{\text{Conversion factor}_2}$$

INVERSE SQUARE LAW FORMULA

- To determine the exposure rate/dose:
$$\frac{I_1}{I_2} = \frac{D^2_2}{D^2_1}$$

- Density maintenance formula:
$$\frac{mAs_1}{mAs_2} = \frac{D^2_1}{D^2_2}$$

HEAT UNIT FORMULA

HU = mA × s × kV (single phase)

HEAT UNIT FORMULA WITH 3 PHASE CORRECTION FACTOR

- HU = mA × s × kV × 1.35 (3φ 6P)
- HU = mA × s × kV × 1.41 (3φ 12P)

FILTRATION REQUIREMENTS

- <50 kVp = 0.5 mm Al equiv
- 50–70 kVp = 1.5 mm Al equiv
- >70 kVp = 2.5 mm Al equiv