ASSISTING WITH DIAGNOSTIC IMAGING

SCENARIO

Sara Elwood, CMA (AAMA), is employed by Metro Urgicenter, an urgent care clinic in an urban setting. Metro is staffed around the clock and sees patients with urgent problems that are not immediately life-threatening. Facilities at the center include an x-ray department where films of the spine and the extremities are taken to evaluate injuries for possible fractures. Chest films also are taken to aid the diagnosis of patients with respiratory complaints. The center's staff physicians read the x-ray films as they are taken. Afterward, the films are sent to a local hospital for formal interpretation by a radiologist. Sara often assists David Swain, the radiographer, by preparing patients for x-ray examinations and processing the films. Sometimes she is responsible for sending the films to the hospital for interpretation and then filing them when they are returned. When a patient is sent to some other facility for special imaging studies, Sara makes the arrangements and provides the patient with a preliminary explanation of the procedure.

While studying this chapter, think about the following questions:

- To fulfill her job description at Metro Urgicenter, what does Sara need to know about preparing patients for routine x-ray examinations?
- How should a film be processed so that it has no handling artifacts?
- What should Sara know about various diagnostic procedures so that she can effectively provide patient education and answer patient's scheduling questions?

LEARNING OBJECTIVES

1. Define, spell, and pronounce the terms listed in the vocabulary.
2. Apply critical thinking skills in performing the patient assessment and patient care.
3. Identify the principal components of an x-ray machine.
4. Describe the cassette and film image receptor system and explain its function in radiography.
5. Recognize the precautions to be taken when unloading, loading, and processing radiographic film and cassettes.
6. Distinguish among the three body planes and use these terms correctly when discussing radiographic positions.
7. Identify anteroposterior (AP), posteroanterior (PA), lateral, oblique, and axial radiographic projections.
8. Compare and contrast radiography and fluoroscopy and give examples of appropriate applications of each.
9. List and describe imaging modalities that do not involve x-rays.
10. Explain the patient preparation guidelines for typical diagnostic imaging examinations.
11. Outline the general procedure for assisting with an x-ray examination.
13. Apply patient education principles when providing instructions for preparing for diagnostic procedures.
14. Describe the health risks associated with low doses of x-ray exposure, such as those used in radiography.
15. Summarize the steps for ensuring that patients receive the least possible exposure during x-ray procedures.
16. Describe precautions for ensuring the safety of equipment operators and staff members during x-ray procedures.
17. Explain the legal responsibilities associated with x-ray procedures and the administrative management of diagnostic images.
angiography (an-je-o-kahr-de-og'-ruh-fe) Radiography of the heart and great vessels using an iodine contrast medium.

angiography (an-je-o'-rg'-fe) Radiography of blood vessels using an iodine contrast medium.

angioplasty (an'-je-o-plas-te) An interventional technique in which a catheter is used to open or widen a blood vessel to improve circulation.

anteroposterior (AP) (an-ruh-roh-per-o-nar'-e-ohr) A frontal projection in which the patient is supine or facing the x-ray tube.

aortogram (a-uhr-tog'-ram) Radiography of the aorta using an iodine contrast medium.

arteriography (ahr-sar-te-o-kahr-de-og'-ruh-fe) Radiography of arteries using an iodine contrast medium.

arthrogram (ahr'-thro-gum) Fluoroscopic examination of the soft tissue components of joints with direct injection of a contrast medium into the joint capsule.

axial projections Radiographs taken with a longitudinal angulation of the x-ray beam; sometimes referred to as semiaxial projections.

bucky A moving grid device that prevents scatter radiation from fogging the film.

cathartics Laxative preparations.

computed tomography (CT) A computerized x-ray imaging modality that provides axial and three-dimensional scans.

contrast media Radiopaque substances used to enhance the visibility of soft tissues in imaging studies.

coronar plane The plane that divides the body into anterior and posterior parts.

coulombs per kilogram (C/kg) The international unit of radiation exposure.

dosimetry A badge for monitoring radiation exposure of personnel.

embolization An interventional technique in which a catheter is used to block off a blood vessel to prevent hemorrhage.


frontal projection A radiographic view in which the coronal plane of the body or body part is parallel to the film plane; AP or PA.

gantry A doughnut-shaped portion of a scanner that surrounds the patient and functions, at least partly, to gather imaging data.

Gray (Gy) The international unit of radiation dose.

intravenous urogram (IVU) Radiographic examination of the urinary tract using intravenous injection of an iodine contrast medium.

latent image Invisible changes in exposed film that become an image when the film is processed.

lateral projections Radiographic views in which the sagittal plane of the body or body part is parallel to the film.

limited radiography Limited-scope radiography practice, usually in an outpatient setting, that does not require the same credentials as for professional radiologic technology; also called practical radiography.

lower gastrointestinal series Fluoroscopic examination of the colon, usually using rectal administration of barium sulfate as a contrast medium; also called a barium enema.

magnetic resonance imaging (MRI) An imaging modality that uses a magnetic field and radiofrequency pulses to create computer images of both bones and soft tissues in multiple planes.

myelography (mi-'uh-log'-ruh-fe) Fluoroscopic examination of the spinal canal with spinal injection of an iodine contrast medium.

NPO Nothing by mouth, from the Latin nil per os.

nuclear medicine An imaging modality that uses radioactive materials injected or ingested into the body to provide information about the function of organs and tissues.

oblique projections Radiographic views in which the body or part is rotated so that the projection is neither frontal nor lateral.

phosphors (fos'-fors) Fluorescent crystals that give off light when exposed to x-rays.

posteroanterior (PA) A frontal projection in which the patient is prone or facing the x-ray film or image receptor.

rad The conventional unit of radiation dose.

radiograph An x-ray image.

radiographer A person qualified to perform radiographic examinations.

radiography The process of taking diagnostic images using x-rays.

radiologist A physician who specializes in medical imaging or therapeutic applications of radiation.

radioluent (ra-de-o-loo'-sint) Pertaining to a substance that is easily penetrated by x-rays; these substances appear dark on radiographs.

rem The conventional unit of radiation dose equivalent.

roentgen (R) (ron'-ten-jen) The conventional unit of radiation exposure.

sagittal plane The plane that divides the body into right and left parts.

Sievert (Sv) (si-vuhr) The international unit of radiation dose equivalent.

sonography (suh-nog'-ruh-fe) An imaging modality that uses sound waves to produce images of soft tissues; also called diagnostic ultrasound.

tracers Radioactive substances administered to patients for nuclear medicine imaging procedures.

transducer The part of the sonography machine that is in contact with the patient; the transducer sends high-frequency sound waves and receives the sound echoes from the patient's body.

transverse plane The plane that divides the body into superior and inferior parts.

upper gastrointestinal (UGI) series Fluoroscopic examination of the esophagus, stomach, and duodenum using oral administration of barium sulfate as a contrast medium.
Physicians have been using x-ray images for more than 100 years to examine the internal structures of the body. The fascinating field of medical imaging now includes a wide variety of diagnostic imaging methods. This chapter provides an overview of imaging modalities and introduces you to radiography. Emphasis is placed on x-ray examinations, because these are the procedures most commonly performed in the medical assistant's practice setting.

**BASIC PRINCIPLES OF RADIOGRAHY**

**Radiography**

Radiography is the process of making an x-ray image called a radiograph. X-rays are produced in a vacuum tube when electrons traveling at high speed strike certain materials, such as tungsten. When the x-rays are emitted from the tube, they diverge into space, forming the cone-shaped x-ray beam. The cross section of the x-ray beam at the point of use is called the radiation field (Figure 50-1). The patient or part to be x-rayed is placed in the radiation field, between the x-ray tube and the image receptor or film.

X-rays can penetrate most substances to some degree, but some substances, such as metals and bones, are more difficult to penetrate and are said to be radiopaque. Air, gases, and soft tissues such as fat, skin, and lungs are much easier to penetrate than bone and are said to be radiolucent. During the exposure, x-rays from the tube pass through the patient. Some of the x-rays are absorbed by the patient and others are not, resulting in a pattern of varying intensity in the x-ray beam that exits on the opposite side of the patient and exposes the film. The film then has a pattern of exposure, a latent image, and must be processed to develop the latent image into one that is visible. On the finished radiograph, radiopaque objects appear light and radiolucent objects appear dark or black (Figure 50-2).

Routine plain films are simple radiographs taken of specific body structures, such as the chest or the bones of the extremities or spine. These are the examinations most often performed in ambulatory care centers and most likely to be performed by medical assistants qualified to practice radiography.

**X-Ray Exposure**

**Prime Factors**

The radiographer must take a number of factors into consideration in determining the proper technique and exposure factors for an x-ray examination. The four principal exposure factors are called the prime factors of exposure. The interaction of these factors determines the level of x-ray production and ultimately the amount of the patient’s x-ray exposure. Prime factors include the following:

- **Milliamperage (mA)**—the electrical control setting that determines how rapidly the radiation is produced; the higher the mA setting, the more x-rays produced per second.
- **Exposure time (seconds)**—the duration of the patient’s x-ray exposure; most exposures are less than 1 second, so the total time a patient is exposed to the x-ray is measured in milliseconds. The amount of x-rays produced depends on the length of exposure.
- **Kilovoltage (kVp)**—the electrical control setting that determines the penetrating power of the x-ray beam; voltage controls the speed and power of x-ray beams; the higher the voltage, the shorter the x-ray wavelengths and the greater the energy of the x-ray beam.
- **Source-to-image distance (SID)**—the distance between the x-ray tube and the film or other image receptor; the greater the distance, the more widely the x-ray beam will spread and the lower the intensity of the beam.

The total amount of radiation in an exposure is indicated by the milliampere-seconds (mAs), which is determined by
multiplying the rate of x-ray current flow (milliamperage) by the exposure time. The total amount of x-ray exposure used to perform a particular diagnostic study is a combination of kilovoltage, milliamperage, exposure time, and source-to-image distance.

**Technique Charts**
A technique chart located near the control console provides the radiographer with a listing of recommended milliampereseconds, kilovoltage, and source-to-image distance settings for x-ray studies of various body parts in patients of different sizes. The radiographer must refer to technique charts before performing the ordered radiographic procedure. Some control consoles have computerized units that are preprogrammed with the required exposure settings for the selected body part and size.

**Radiographic Equipment**

**X-Ray Tube and Housing**
The x-ray tube, where the x-rays form, is surrounded by a lead-lined, protective housing (Figure 50-3). The housing absorbs any radiation that is not part of the x-ray beam. The housing protects and insulates the x-ray tube itself while providing a base for attachments that allow the radiographer to manipulate the x-ray tube and to control the size and shape of the x-ray beam.

The principal attachment to the tube housing is the collimator, a boxlike device mounted beneath the opening of the housing. Collimators allow the radiographer to vary the size of the radiation field and to indicate with a light beam the size, location, and center of the field. Usually a centering light also helps align the cassette tray (Figure 50-4).

**X-Ray Tube Support**
The tube housing may be attached to a ceiling mount or a tube stand. Both types of mountings provide support and mobility for the heavy tube. The ceiling mount moves on a system of tracks to allow positioning of the tube at locations throughout the room. A tube stand (Figure 50-5) is a vertical support with a horizontal arm that suspends the tube over the radiographic table. The tube stand rolls along a track that is secured to the floor (and sometimes also the ceiling), allowing horizontal motion. Outpatient x-ray departments are more likely to have a tube stand.

**Radiographic Table**
The radiographic table is a specialized unit that is more than just a support for the patient. Some tables are adjustable in height for easy patient access, and some are designed to tilt into upright and Trendelenburg positions. A floating tabletop is a feature that assists in aligning the patient to the tube and film. Using the table to move the patient allows for x-ray imaging in a variety of angles and positions.

**Grids and Bucky Devices**
Beneath the table surface is a moving grid device called a bucky (Figure 50-6). X-ray film is placed in a cassette tray, which is then put in the bucky device under the radiographic table. This allows the cassette inside the bucky to be moved up and down the table to a point directly under the area to be x-rayed. The grid is situated between the tabletop and the film inside the cassette. It is a plate made of tissue-thin lead strips that are mounted on edge to
protect the film from being fogged by scatter radiation that is displaced when the x-ray study is performed. Because the strips must be carefully aligned with the path of the x-ray beam, precise alignment of the x-ray tube in relation to the bucky is essential. When the x-ray image is actually taken, the bucky automatically moves the grid so that it is not visible on the radiograph. Bucky grids generally are used only for body parts that are more than 10 to 12 cm thick (about the size of an adult's neck or knee). When a grid is not needed, the cassette is placed on the tabletop.

**Upright Cassette Holder**

The upright cassette holder, as its name implies, is a device that holds the film in an upright position for radiography. It usually is placed against a wall, and its height is adjustable. It may incorporate a bucky or stationary grid. When a grid is included, the unit may be referred to as a grid cabinet or upright bucky. When the patient is sitting or standing at the upright cassette holder for radiography, such as for a chest x-ray, the tube is angled to face the wall and cassette holder. The distance from the tube to the film may be adjusted to 40 or 72 inches, depending on the requirements of the procedure.

**Control Console**

The control console, located in the control booth, is the access point for the radiographer to determine exposure factors and to take the x-ray image (Figure 50-7). Radiographic control consoles have buttons, switches, dials, or digital readouts for some or all of the following functions:

- Off/On—controls the power to the control panel
- mA—allows the operator to set the milliamperage, the rate at which the x-rays are produced
- kVp—controls the kilovoltage, determining the penetrating power of the x-ray beam
- Timer—controls the duration of the exposure
- mAs—some units have an mAs control instead of mA and time settings
- Bucky—activates the motor control of the bucky device so that the grid moves during the exposure
- Automatic exposure controls—special settings available on certain units that allow termination of exposure when a certain amount of radiation has reached the film
- Meters or digital readouts—indicate the status of the settings

**Image Receptor Systems**

**Cassettes and Intensifying Screens**

The cassette (Figure 50-8) serves as the film holder during the x-ray procedure. It provides a light-tight, rigid structure to protect the film and also houses intensifying screens. Most cassettes have two intensifying screens, one front and one back, with the film sandwiched between them. Intensifying screens are plates coated with phosphors (fluorescent crystals) that give off light when exposed to x-rays. Their purpose is to reduce the amount of exposure required. Without intensifying screens, as much as 50 to 100 times more exposure would be needed. Intensifying screens greatly reduce the exposure of a patient to radiation during an x-ray procedure.
Each cassette has a small area where there is no intensifying screen and where exposure is blocked from the film by lead foil. This area is reserved for the photographic imprint of the patient identification. Its location is indicated on the front of the cassette by the position of the identifying label.

Intensifying screens are expensive and easily damaged. Damaged areas, dirt, or stains on the screens prevent light from exposing the film and result in artifacts on the image. For these reasons, it is important to avoid touching the screens and to keep the film processing area free of dust and dirt.

**Film**

Radiographic film is manufactured with a particular sensitivity to the light emitted by intensifying screens. Green-sensitive film is used with screens that emit green light, and blue-sensitive film is matched with blue-emitting screens. Film for routine radiography is coated on both sides so that the film responds to light from both intensifying screens. This double-emulsion system reduces the exposure required by half. Because both sides of the film are identical, a sheet of double-emulsion film does not have a “right” or “wrong” side. Film and cassettes come in standard sizes.

**Film Care and Handling.** Film must be stored correctly to prevent fog, a generalized exposure that reduces image quality. A good storage area is clean, cool, and dry and is protected from radiation and processing chemical fumes. Film boxes should stand on edge with the expiration date visible. This date is checked to ensure that older film is used before its expiration date.

To prevent artifacts from improper film handling, be sure your hands are clean and dry and touch only the corner of the film when removing it from the cassette. Prevent bending, crimping, and scraping of the film by allowing it to hang vertically when holding it with only one hand (Figure 50-9). To place it horizontally, use both hands and hold by opposite corners.

**Film Processing.** Comprehensive darkroom orientation is needed before you try to develop patients’ films. It is especially important to know how to turn on the processor properly and to recognize when it has warmed up sufficiently for correct processing.

The exposed cassette is taken to the darkroom for processing under safelight conditions. Safelights provide a red or orange light that is quite dim but provides just enough illumination for you to see where things are located. Make sure the darkroom door is locked so that no one will open it while you are processing the film.

Film identification is essential for knowing the identity of the patient represented in the image and the date and location of the examination. Serious errors in diagnosis and treatment might occur if films are not correctly identified. The identification information is typed on a card that is inserted into the photographic printer in the darkroom. The printer is used to stamp the information on the film after it has been removed from the cassette and before it is processed (Figure 50-10).

The film is then fed into the automatic processor. The cassette is reloaded with a single sheet of fresh film (Figure 50-11) from the film bin, a storage unit located under the counter. A tone or a red light on the processor indicates when it is safe to feed another film or to turn on the lights.

The reloaded cassette should be returned immediately to the proper place so that it is ready for use. Correct locations for cassettes are essential, because you cannot determine by looking at the cassette whether the film has been exposed. Only by following established routines and facility policies can you be confident that a cassette is unexposed and ready for use.

**Daylight Processing.** Some departments have a “daylight” system for processing film without a darkroom. These systems include a special film processor and a daylight film identification camera that uses special cassettes. Films can be identified while still in the cassette, and the entire cassette then is fed into the processor. The processor automatically removes and processes the film and then reloads the cassette with fresh film.
**Computed and Digital Radiography**

Computed radiography (CR) is a radiographic imaging system that does not use film. An image receptor, similar to an intensifying screen, is exposed in a special cassette using conventional x-ray equipment. The radiographer inserts the exposed cassette into a special processor and selects the type of examination from a menu so that the image is processed correctly. A small beam from a high-intensity laser in the processor converts the latent image to a visible image that is converted into an electronic signal and stored in a computer. The image then can be displayed on a high-resolution monitor. Hard copies can be produced with a laser film pritner.

Digital radiography is another type of filmless imaging system. Special radiographic tables and upright cabinets contain digital receptors that react to the pattern of the radiation from the patient and transmit a digital signal directly to the computer system. No cassettes and no processing are involved. Although digital radiography has been used for some time for special applications, such as fluoroscopy and angiography, technical limitations and cost factors have prevented widespread adoption of digital systems for general radiography.

Once stored in the computer system, digital images from either computed or digital radiography are organized and cataloged and can be accessed on screen from multiple locations connected to the system network. These digital images can be manipulated electronically to enhance visibility. Conventional radiographs can be added to the system by scanning them with a laser device called a film digitizer.

The computer hardware and software technology used to manage digital images in hospitals and large health care systems is called a picture archiving and communication system (PACS). These systems provide image storage, connect images with patient database information, facilitate laser printing of images, and display both images and information at workstations throughout the network as needed. PACS may include transmission equipment for teleradiology, allowing images to be viewed in remote locations, such as a physician’s home, and receiving images from remote locations, such as outlying clinics. PACS technology can transmit images directly over telephone lines and via the Internet.

**FIGURE 50-12** Anatomic position. (From Frank et al: Merrill’s atlas of radiographic positioning and procedures, ed 11, St Louis, 2007, Mosby.)

These advanced technologies will become more commonplace as computerized medical record systems become more widespread.

**RADIOGRAPHIC POSITIONING**

The medical assistant may be involved in explaining x-ray positions to a patient or in actually helping the patient into various positions, so it is important that you become familiar with commonly used terms. Terms that indicate the surfaces, directions, and planes of various body locations are based on the anatomic position.

As shown in Figure 50-12, anatomic position is a view of the body in which the individual is standing, facing the observer, with the palms of the hands forward. Terms that describe locations on and within the body include the following:

- **Anterior:** Forward or front portion of the body or body part.
- **Cephalic:** Pertaining to the head; toward the head.
- **Caudal:** Toward the tail or end of the body; away from the head; the opposite of cephalic.
- **Distal:** Away from the source or point of origin. For example, the wrist is distal to the elbow, the elbow distal to the shoulder.
- **External:** To the outside, at or near the surface of the body or a body part.
- **Inferior:** Below, farther from the head. For example, the diaphragm is inferior to the lungs.
- **Internal:** Deep, near the center of the body or a part; the opposite of external.
- **Lateral:** Referring to the side, away from the center to the left or right.
- **Medial:** Toward the center of the body or body part; the opposite of lateral.
- **Palmar**: Referring to the palm (anterior surface) of the hand.
- **Plantar**: Referring to the sole of the foot.
- **Posterior**: Backward or back portion of the body or body part; the opposite of anterior.
- **Proximal**: Toward the source or point of origin; the opposite of distal. For example, the part of the femur that is attached at the hip is the proximal end of the femur, and the part of the bone that is located at the knee is the distal end of the femur.
- **Superior**: Above, toward the head; the opposite of inferior. For example, the esophagus is superior to the stomach.

Besides anatomic positional terms, procedures for radiographic positioning also are described using the planes of the body (Figure 50-14). The **sagittal plane** divides the body into right and left parts, and the mid sagittal plane divides the body into equal right and left parts. The **coronal plane** (sometimes called the frontal plane) divides the body into anterior and posterior parts. The midcoronal or midfrontal plane divides the body into relatively equal parts; it passes through the external auditory meatus (the opening of the ear), the center of the shoulder, the greater trochanter (the bony prominence in the lateral hip area), and the lateral malleolus (the bony prominence on the lateral surface of the ankle). The **transverse plane** divides the body into superior and inferior portions. It may be drawn at any level.

The medical assistant may assist with radiographic procedures by helping position the patient for a particular x-ray view. These positions can be used as follows in x-ray positioning:
- **Prone**: Lying face down
- **Recumbent**: Lying down; the position may be further described by adding the name of the body surface on which the patient is lying:
  - **Dorsal recumbent**: Lying on the back (supine) with the knees bent and the feet flat on the table
  - **Lateral recumbent**: Lying on the side
  - **Ventral recumbent**: Lying face down, prone
- **Supine**: Lying on the back face up
- **Upright**: Standing or seated

**Projections**

A radiographic projection indicates the relative positions of the body part to be x-rayed, the film, and the placement of the x-ray tube.

For a **frontal projection**, the coronal plane of the body or body part is parallel to the film plane and the central ray is perpendicular to both. If the patient is supine, or facing the x-ray tube, the projection is said to be **anteroposterior (AP)** (Figure 50-14). If the patient is prone, or facing the film, the projection is said to be **posteroanterior (PA)** (Figure 50-15). Note that these terms indicate the direction of the x-ray beam, from front to back or back to front.

**Lateral projections** are those in which the sagittal plane of the body or body part is parallel to the film. Lateral projections are always named for the side of the patient that is nearest the film; that is, either left or right lateral (Figure 50-16).

**Oblique projections** are those in which the body or part is rotated so that the projection is neither frontal nor lateral. Oblique projections also are named for the part of the body nearest the film. For example, in a right anterior oblique (RAO) projection, the patient’s right, anterior aspect is closest to the film. Figure 50-17 illustrates all four oblique projections: RAO, right posterior oblique (RPO), left anterior oblique (LAO), and left posterior oblique (LPO).

**Axial projections**, sometimes referred to as **sagittal projections**, are radiographs taken with a longitudinal angulation of the x-ray beam. The x-ray beam is projected at an angle, either cephalad (toward the head) or caudad (away from the head) (Figure 50-18).
DIAGNOSTIC IMAGING MODALITIES

Fluoroscopy and Contrast Media

Fluoroscopy

Fluoroscopy is a technique in which special equipment is used to allow the radiologist to view x-ray images in motion. Fluoroscopy also allows the physician to survey an area quickly, without the delay involved in taking and processing films. Most fluoroscopic units are properly called radiographic/fluoroscopic (R/F) units, because they are designed to take both x-ray images and fluoroscopic views. The x-ray films taken during a fluoroscopic procedure, which are called spot films, record the image as seen on the fluoroscope; sometimes the entire fluoroscopic examination is recorded digitally. After the fluoroscopic portion of the study is complete, larger radiographs usually are taken for comprehensive visualization of the entire anatomic region.

An example of a fluoroscopic diagnostic procedure is a barium swallow. If the physician suspects that the patient has difficulty swallowing, a fluoroscope is used to visualize the actual movement of the substance down the esophagus and into the stomach while the patient is in the act of swallowing. Fluoroscopic procedures typically require the use of a contrast medium, such as barium.

X-Ray Studies Using Contrast Media

Although the lungs and bony structures of the body produce clear x-ray images on plain film radiographs, internal organs, such as the stomach and the kidneys, are difficult to see because they absorb radiation to the same degree as the tissues that surround them. To enhance visibility of these structures, special agents,
TABLE 50-1 Radiographic Procedures Using Contrast Media

<table>
<thead>
<tr>
<th>EXAMINATION</th>
<th>CONTRAST MEDIUM</th>
<th>ROUTE OF ADMINISTRATION</th>
<th>STRUCTURES SHOWN</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angiocardiography</td>
<td>Iodine compounds</td>
<td>Intracardial injection via femoral or brachial catheter</td>
<td>Heart and large vessels</td>
</tr>
<tr>
<td>Angiography</td>
<td>Iodine compounds</td>
<td>Intracardial or intravenous injection</td>
<td>Blood vessels</td>
</tr>
<tr>
<td>Arteriography</td>
<td>Iodine compounds</td>
<td>Intracardial injection via catheter</td>
<td>Arteries</td>
</tr>
<tr>
<td>Arthrography</td>
<td>Iodine compounds</td>
<td>Direct injection into joint capsule</td>
<td>Joints, especially knee, shoulder, and ankle</td>
</tr>
<tr>
<td>Barium swallow</td>
<td>Barium sulfate suspension</td>
<td>Oral</td>
<td>Esophagus</td>
</tr>
<tr>
<td>Hysterosalphingography</td>
<td>Iodine compounds</td>
<td>Direct injection via cannula</td>
<td>Uterus and fallopian tubes</td>
</tr>
<tr>
<td>Intravenous urography</td>
<td>Iodine compounds</td>
<td>Intravenous injection</td>
<td>Kidneys, ureters, and urinary bladder</td>
</tr>
<tr>
<td>Lower gastrointestinal (GI) series (barium enema)</td>
<td>Barium sulfate suspension, sometimes also with air</td>
<td>Rectal catheter</td>
<td>Colon</td>
</tr>
<tr>
<td>Lymphangiography</td>
<td>Iodine compounds</td>
<td>Direct injection into lymphatic vessels in the feet</td>
<td>Lymphatic vessels and lymph nodes</td>
</tr>
<tr>
<td>Myelography</td>
<td>Iodine compounds</td>
<td>Intrathecal injection (spinal tap)</td>
<td>Spinal canal</td>
</tr>
<tr>
<td>Upper GI series</td>
<td>Barium sulfate suspension</td>
<td>Oral</td>
<td>Esophagus, stomach, and duodenum</td>
</tr>
</tbody>
</table>

called contrast media, can be used to fill hollow organs and demonstrate their inner contours. Although gases such as air and carbon dioxide sometimes are used as contrast media, the use of radiopaque substances, such as barium sulfate or iodine compounds, is far more common. The agent and the technique vary with the structures to be viewed (Table 50-1).

Among the most common fluoroscopic examinations are studies of the upper and lower gastrointestinal (GI) tract using barium sulfate as a contrast medium. Both require careful patient instruction and advance preparation for a successful study. For an upper gastrointestinal (UGI) series (Figure 50-19), the patient swallows a barium sulfate suspension; this study is performed to aid the diagnosis of ulcers, tumors, and other abnormalities of the esophagus, stomach, and duodenum.

A lower gastrointestinal series (Figure 50-20) involves a barium enema that fills the colon and aids visualization of its inner surfaces. This procedure is especially useful in the diagnosis of polyps, tumors, and diverticulosis. For this examination the inner lining of the large intestine must be clean and free of all fecal matter. Commercial bowel preparation kits usually are made available by the radiology department to ensure complete emptying of the large intestine. If the preparation is not adequate, the examination must be rescheduled.

Water-soluble iodine compounds are used as contrast media for a wide variety of applications. When injected intravenously (IV), the contrast agent circulates in the blood and is excreted by the kidneys, causing the urine to become radiopaque. Radiography of the kidneys, ureters, and bladder after IV injection of a
contrast medium is called an intravenous urogram (IVU) (it previously was called an intravenous pyelogram, or IVP); this study is useful for identifying kidney stones, tumors, and other abnormalities of the urinary tract. Preparation for an IVU involves fasting and bowel cleansing, because material in the colon can obstruct a clear picture of the urinary system.

Iodine contrast agents also can be injected into joint capsules to produce an arthrogram, an image of the soft tissue components of joints, especially the knee and the shoulder. Myelography involves injection of iodine compounds into the spinal canal to demonstrate pathologic spinal conditions, such as tumors and herniated intervertebral disks.

Part of the screening process for diagnostic procedures that use iodine contrast injections is careful questioning of the patient regarding a history of iodine allergy. All patients who are allergic to shellfish also will be allergic to iodine dye and are at risk for a serious anaphylactic reaction if the contrast agent is injected. The medical assistant is responsible for clarifying allergies with the patient and/or family members and alerting the diagnostic facility if the patient has an iodine allergy. In addition, patients need to understand that it is normal to feel flushed or a heat rush when the dye is injected and that some patients initially experience waves of nausea. However, both of these sensations pass quickly.

## Cardiovascular and Interventional Radiography

The highly specialized radiographic procedures that display blood vessels are collectively known as angiography. A cerebral angiogram, for example, demonstrates the vessels of the brain (Figure 50-21), and renal angiograms show the arteries and veins of the kidneys. An angiogram is a contrast study that shows the interior of the heart chambers and the great vessels that enter and exit the heart, and an aortogram demonstrates the aorta. Selective angiography, or cardiac catheterization, is used to display the coronary arteries. Arteriograms are pictures of specific arteries, and venograms are studies of veins.

For all these examinations, iodine compounds are injected for radiographic contrast and a rapid series of films is taken or fluoroscopy is used to show the area of concern. Direct injection may be used for some angiographic studies, such as those of the extremities, but the preferred injection method for angiography, aortography, and most arteriography, procedures is to use a special catheter. A large artery (usually the femoral or brachial artery) is entered with a large-bore needle, and a guidewire is threaded through the needle and into the artery under fluoroscopic control. The needle is removed, the guidewire is left in the vessel, and the catheter is threaded over the wire. The wire is then removed, and the catheter remains in the artery for the duration of the examination. Further manipulation of the catheter may be needed to ensure correct placement in the vessel before injection. For selective catheterization of smaller vessels, the catheter tip is maneuvered into the root of the vessel of interest, such as the coronary, celiac, renal, or carotid artery.

A timed sequence of images is taken during and after injection of the contrast medium, usually with the aid of an automatic power injector that is electronically coordinated with a programmable film changer and automated exposure control. Digital receptors are replacing film and film changers, and for some studies, such as angiograms and angio-angiography, digital fluoroscopy equipment may be used to record the images.

Because these procedures are expensive and involve a relatively high degree of risk, angiography has been replaced somewhat by technologic advances in other imaging modalities discussed in this chapter, particularly Doppler ultrasound, nuclear medicine, magnetic resonance angiography (MRA), and computed tomography angiography (CTA).

Despite these advances, angiography continues to be used extensively because it provides the best anatomic view of structures within the circulatory system and also offers the opportunity for immediate therapeutic interventions to treat vascular problems as they are identified. Specialized catheter techniques are used for vessel repair, called angioplasty, to widen or open arteries that are narrowed or occluded. Embolization is a therapeutic intervention technique that reduces or stops blood flow to control hemorrhage, cut off the blood supply to a tumor, or reduce blood loss during surgery.

### Computed Tomography

Computed tomography (CT), formerly called computerized axial tomography (CAT) scanning, uses a special x-ray scanner to produce detailed pictures of a cross section of tissue. The x-ray studies are taken in the transverse plane and also can be "reconstructed" by the computer to display anatomic structures in other planes. The images are viewed in a variety of formats, called windows, which are designed to enhance the views of specific tissues (Figure 50-22). Multiple levels of pictures can be taken in a very short period, with up to 25 continuous images recorded in the time it takes the patient to hold a single breath. Most CT examinations are noninvasive, painless, and do not require any special patient preparation. However, patients may feel apprehensive about the equipment, because standard machines require the
patient enter a tube for the procedure. Careful explanations are necessary to achieve the patient’s cooperation and a satisfactory outcome of the study.

The CT scanner (Figure 50-23) consists of a movable table with remote control, a circular gantry structure that supports the x-ray tube and detectors, an operator console with a monitor, and a supporting computer system. The CT unit also includes both hardware and software to archive and manage data and to produce hard copies of images. During a scan the x-ray tube rotates around the patient to collect data. In conventional CT units, the tube makes a complete rotation to gather data for each slice. The table then moves, and the tube rotates again to obtain the next slice. A newer generation of equipment, designated as spiral or helical scanners, scans a spiral path around the patient and can collect data on a larger volume of tissue. These scanners can reconstruct views to create three-dimensional images.

The versatility of CT is illustrated by its wide range of applications, including studies of the brain, spine, abdomen, pelvis, chest, neck, and paranasal sinuses. CT is a valuable tool for emergency use, especially in the detection of intracerebral or intra-abdominal hemorrhage. It also is used for orthopedic examinations of the extremities and for contrast-enhanced vascular studies. CT is useful for localizing both lesions and needle position during needle aspiration biopsy, a nonsurgical method of obtaining cells for laboratory examination, and it often is used with myelography to expand the range of information available.

Although many CT examinations do not require contrast media, the use of contrast agents vastly increases the scope of CT imaging. Studies of the abdomen usually use oral contrast media to help differentiate the GI tract from the surrounding tissues. The patient ingests a special barium compound or an oral iodine preparation over a specified period before the study. The amount of contrast medium and the time period vary, depending on whether the examination includes only the upper abdomen or the entire abdomen and pelvis. For these studies, the patient is instructed not to eat for 12 hours and to report to the facility early to drink the contrast preparation before the procedure is scheduled. Some departments have the patient take the contrast medium home with instructions to drink it before reporting for the appointment.

IV injection of an iodine contrast medium also may be used to increase the contrast level of the patient’s tissues. This is advantageous for studies of the chest, abdomen, and soft tissues of the neck, because it highlights blood vessels and enhances the visibility of vascular organs such as the liver and spleen. The contrast defines the internal structures of the kidneys, ureters, and bladder as the agent is excreted in the urine. In selected cases, IV contrast agents are used in CT scans of the head to demonstrate brain lesions.

### Magnetic Resonance Imaging

Magnetic resonance imaging (MRI) is a noninvasive diagnostic modality that allows visualization of anatomic structures without the use of radioactive x-rays. A powerful magnetic field and radiofrequency pulses are combined to produce a radio signal in the body that can be detected and processed electronically to provide images on a computer monitor. The images can be managed in a computer database and can also be stored on magnetic tape and photographed with a special camera to produce film copies that appear similar to x-ray images.

The MRI gantry houses the magnet and the main radiofrequency coil. Conventional gantries are tubular, 5 to 8 feet long, and typically require the body part being studied to be placed in the tube during the scanning process. An open gantry design, the
open MRI, provides better accommodation for large or claustrophobic patients, but it does not always provide image quality equal to that produced by conventional units.

MRI provides excellent imaging of the soft tissues of the nervous system (Figure 50-24). It is useful in the diagnosis of many types of pathology, including brain and spinal cord tumors and diseases such as multiple sclerosis. MRI also is used for the diagnosis of herniated intervertebral disks and to obtain images of the soft tissue components of joints, particularly the knee, shoulder, and temporomandibular joint. A more recent advance in MRI is MRA, which uses magnetic resonance technology to study the cardiovascular system. MRA aids in the diagnosis and treatment of heart disorders, stroke, and blood vessel diseases.

The typical scan time for a series of slice-like images ranges from 1 to 10 minutes, and several series demonstrating different body planes and using a variety of radiofrequency pulse sequences may be included in an examination. The average time for an MRI study is 30 to 45 minutes. It is critical that the patient remain still, maintaining the desired position, throughout the procedure.

Although contrast media are not required for most MRI studies, special paramagnetic agents sometimes are injected intravenously. These agents provide contrast enhancement of certain lesions, particularly brain and spinal cord tumors, and help differentiate disk material from scar tissue in postoperative spinal examinations. Contrast injections also are used in MRA studies. Typically, a series of images is recorded, the contrast agent is injected intravenously, and a second series of images is taken.

The unique MRI environment requires special safety precautions. Conditions that affect patient safety involve both the powerful magnetic field in the gantry and the thermal effects of radiofrequency pulses on certain materials that could overheat and possibly burn the patient. The principal means of ensuring patient safety during an MRI is careful patient screening before the procedure. Although extensive patient interviews are conducted in the magnetic resonance department, preliminary screening of patients should be conducted by the medical assistant before the appointment is made. The magnetic field or the rapid radiofrequency pulses may be hazardous for patients with artificial heart valves, aneurysm clips, neurostimulators, middle ear prostheses, or intrauterine devices. Cardiac pacemakers are a particular hazard, and patients with pacemakers cannot have MRI examinations. Fatalities have resulted from overheating of these implanted devices when patients with pacemakers were scanned.

Other factors that would prohibit the use of MRI technology include patients with orthopedic pins and screws and metal fragments or shrapnel in the soft tissues. Metalworkers who might have steel slivers in their tissues must have a screening x-ray or CT head examination to detect fragments that could damage the eyes or brain, because the pull of the magnetic field is so strong that it could cause the fragments to move. Although the energies involved in MRI have not been demonstrated to cause complications with pregnancy, the current philosophy is to avoid examination of pregnant patients except in urgent cases, especially during the first trimester.

Patients should be assured that everything possible will be done to provide assistance in dealing with both physical and emotional discomfort. Few people are completely comfortable for any length of time in a tightly enclosed space. Even patients with no history of claustrophobia may feel anxious when entering a conventional tubular MRI gantry. Occasionally, this anxiety is so severe that it creates panic, preventing the patient from continuing the examination.

Patients may be reassured if they know what to expect in advance. The procedure requires that the patient lie down on the MRI table, which then automatically moves into the gantry. Plenty of air is available, and there is no physical discomfort except for the need to lie still. The machine makes a very loud “knocking” noise during the scanning process (similar to a jack hammer or heavy machinery). Earplugs or earphones with recorded music may be offered. Patients can communicate with the technologist through an intercom, and the technologist is watching and listening from an adjacent area throughout the procedure. The patient is given a “panic button” to push in case the procedure needs to be stopped because of patient discomfort or anxiety. Because no radiation danger exists, a friend or family member can sit in the room if the patient feels more comfortable with company. Severely claustrophobic patients may be scheduled at a facility with an open-gantry MRI or may be given an antianxiety medication before the procedure. Analgesic medications may be administered to patients whose pain makes it impossible to lie still for the duration of the study.

**Sonography**

Diagnostic medical **sonography** is a noninvasive procedure that is considered very safe for the patient. Sonography was introduced in Chapter 41, because it is used extensively for fetal imaging. This imaging modality, often referred to as **diagnostic ultrasound**, uses high-frequency sound waves to produce echoes in the body. As the echoes return to the sending point, or **trans-**
ducer, their strength and timing are interpreted by a computer to produce a map or graphic image of the echo distribution.

The transducer is covered with a lubricant and moved over the surface of the body so that the image can be viewed in real time on a computer monitor. Special transducer probes can be inserted into body cavities such as the rectum and the vagina to obtain more detailed examinations of the prostate gland and the uterus. Any interface between structures or tissues of varying density produces an ultrasound echo, which makes sonography an effective technique for showing the shape, size, and condition of organs such as the heart, spleen, gallbladder, breast, and pancreas (Figure 50-25). Sonography, therefore, can be used to diagnose or investigate gallstones or suspicious masses in the breast. For example, if a woman has a suspicious breast mass, the mass can be visualized with a sonogram, and while the radiologist has a clear view of the location of the mass, a needle biopsy sample of the suspicious tissue is collected and sent to the pathologist for examination. This procedure limits the need for invasive surgical biopsies.

Sonography can also be used to detect an abscess, a cyst, or a tumor in adipose tissue. Recent advances in ultrasound technology include computer integration of data to produce three-dimensional images. In addition, Doppler ultrasound is used to detect vascular disease, such as atherosclerosis in the carotid arteries and venous thrombosis of the lower extremities.

Nuclear Medicine

Nuclear medicine images are created by scanning the patient after special radioactive materials, called tracers, have been swallowed or injected intravenously (Table 50-2). Tracers are similar to substances that are commonly used by the body, so they enter into the same chemical reactions and are metabolized in a similar way. They are taken up in the target organ or tissue over a period that may vary from half an hour to several days. The tracer then can be detected and its location recorded by a special nuclear medicine scanner called a gamma camera. Two types of tracers used in diagnostic studies are radioactive iodine and radioactive carbon.

Nuclear medicine scans do not provide clear images of anatomic structures. They are used to obtain information about the function of organs and tissues. Abnormal tissues are demonstrated on the image because the tracer is metabolized at a different rate, at a different location, or to a greater or lesser extent than in normal tissue.

Figure 50-26 is an example of a nuclear medicine bone scan. The tracer is absorbed by the bones and appears in greater or lesser amounts, depending on the level of metabolic activity within the bone. In this scan, the region of the right shoulder shows a high level of radioactivity, which indicates an inflammatory process. Tumors of the bone can be diagnosed by “hot spots” in the x-ray image; these show up much more brightly because of rapid cellular division, which results in a higher level of metabolic activity.

Structures visualized with nuclear medicine techniques include the thyroid gland, liver, lungs, brain, skeletal system, kidneys, heart, and blood vessels. Thallium stress studies of the heart are nuclear medicine examinations that permit the physician to view the coronary arteries to diagnose or rule out blockage. Incomplete visualization of the myocardium after administration of a

![Figure 50-25 Abdominal sonogram. (From Ballinger PW, Frank Merrill’s atlas of radiographic positions and radiologic procedures, ed 10, vol 2, St Louis, 2003, Mosby.)](image)

**Figure 50-26** Bone scan showing increased tracer uptake in the right shoulder region as a result of inflammation.

**Table 50-2** Common Nuclear Medicine Procedures

<table>
<thead>
<tr>
<th>PROCEDURE</th>
<th>PURPOSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bone scan</td>
<td>Helps detect fractures, tumors, and inflammation; used to determine bone growth</td>
</tr>
<tr>
<td>Brain scan</td>
<td>Often used with other imaging methods to detect tumors and vascular problems</td>
</tr>
<tr>
<td>Liver scan</td>
<td>Useful for diagnosing cirrhosis and hepatitis and for detecting tumors and liver abscesses</td>
</tr>
<tr>
<td>Lung scan</td>
<td>Often done to detect emboli, blood clots that have traveled through the bloodstream to the lungs</td>
</tr>
<tr>
<td>Positron emission tomography (PET) scan</td>
<td>Done for cancer investigation, evaluation of myocardial blood supply, investigation of central nervous system disorders</td>
</tr>
<tr>
<td>Thallium stress test</td>
<td>Used to evaluate cardiac condition and response to stress</td>
</tr>
<tr>
<td>Thyroid scan</td>
<td>Rate of contrast uptake is an indicator of thyroid function and also is useful for detecting tumors</td>
</tr>
</tbody>
</table>
nuclear tracer indicates lack of blood supply to the area and damage to the muscle of the heart.

The radioisotopes used in nuclear medicine decay within a short time, from a few hours to a few days, and are eliminated in the urine or feces. They have a very low level of radioactivity and involve less patient exposure than most x-ray examinations. Positron emission tomography (PET) and single photon emission computed tomography (SPECT) are highly specialized nuclear medicine techniques that use different types of tracers and scanners than conventional nuclear medicine, but the basic principle is the same. Radioactive substances from within the body are detected and mapped by specialized equipment to obtain information about the function of organs, tissues, or systems. Most PET scans today are combined with CT to merge the technology of nuclear medicine procedures with the multiplane view of CT scanners. PET/CT scans are ordered for the following purposes:

- To diagnose a cancerous tumor, evaluate its spread, or determine whether cancer has returned after treatment
- To evaluate the blood flow to the heart
- To determine the extent of damage to the myocardial wall after a heart attack
- To investigate lung lesions visualized with traditional x-rays
- To diagnose central nervous system disorders, including epilepsy, Alzheimer's disease, Parkinson's disease, and strokes, and to locate brain tumors

**DEXA Scan**

Dual energy x-ray absorptiometry (DEXA) scans use x-ray technology to evaluate a patient’s bone density level. A decrease in bone density is diagnostic proof of osteoporosis; evidence of bone density loss (osteopenia) may indicate the individual’s risk of developing osteoporosis over time. The test typically evaluates the bone density of the hip. For the examination, the patient lies prone on an x-ray table with the knees flexed and the lower legs elevated (Figure 50-27). The DEXA scanner directs an x-ray from two different sources toward the hip. The greater the mineral density of the bone, the longer the x-ray image is transmitted, the higher the test number that is recorded. The scan is completed within a few minutes and can be used to evaluate the density of the spine and legs as well. The patient’s density results are compared with standard bone density tables to determine the presence and/or level of demineralization. These numbers are used to predict the patient’s risk of an osteoporosis-related fracture. DEXA scans are recommended for the following individuals:

- Women with multiple risk factors for osteoporosis
- Women with long-term estrogen deficiencies
- Individuals taking steroids for an extended period
- Individuals taking osteoporosis medications (to evaluate the effectiveness of treatment)
- Patients with unexplained fractures and/or deformities of the vertebra

**BASIC RADIOGRAPHIC PROCEDURE**

**Patient Preparation and Explanation**

Before a patient undergoes x-ray studies, a physician examines the individual and orders one or more specific x-ray procedures to help diagnose the patient’s problem or to follow up on a previously diagnosed condition. The physician is responsible for getting the patient’s informed consent for any procedure, but he or she may ask the medical assistant to make sure the consent form is signed. The patient may not have to sign a consent form for noninvasive diagnostic studies, because acceptance of the procedure is adequate evidence of consent. In some facilities, however, patients may be asked to sign a consent form regardless of the type of radiographic procedure. If it is your duty to answer patients’ questions about the procedure or to assist with obtaining consent, make sure you are prepared to do so.

Patients often express concern about radiation exposure. You can assure them with confidence that the risks are extremely small and outweigh the health risks of treatment without the information the examination will provide. It may help to point out that the radiographer is well trained in radiation safety and that the equipment is designed to provide good images with the least possible exposure. You can explain that the amount of radiation involved in the procedure is less than the exposure to natural background radiation that people in general receive every year.

Patient preparation for routine radiography involves having the patient remove the outer clothing from the area to be radiographed and instructing the person to wear a gown if appropriate. Underwear usually is not a problem. No metal objects should be included in the radiation field, because these items appear as artifacts on the images. This includes jewelry; zippers, snaps, and other clothing fasteners; underwear brass; and the contents of pockets. Nonmetal objects that are thick or heavy should also be removed. Buttons and the heavy seams in jeans are examples of other clothing items that can cause artifacts or radiographs if they are in the imaging field. Metal items that are not in the radiation field are not a problem, so patients need not remove jewelry or clothing from areas that will not be included in the radiograph.

When the patient is ready, the next step is to assist the patient into the general position required for the x-ray examination (Figure 50-28). For example, if a hand is to be imaged, the

![DEXA scanner. (From Monchiori D: Clinical imaging, ed 2, St Louis, 2004, Mosby.)](image-url)
patient can be seated at the end of the x-ray examination table (Figure 50-28, A). If a chest examination has been ordered, the patient stands at an upright film holder (Figure 50-28, B). For a spinal examination, the patient may need to lie on the table (Figure 50-28, C).

The radiographer then selects the correct cassette, places a lead marker on it to identify the patient’s right or left side, and places the cassette in position for the exposure (Figure 50-29). Next, the patient is positioned precisely and the x-ray tube is aligned with the body part and the film at a specific distance (Figure 50-30). The body part must be measured to determine the proper exposure factors according to a technique chart. At this point, lead shields are positioned for radiation protection. The radiographer then goes to the control booth, consults the technique chart, and sets the x-ray control panel to the desired exposure. Final instructions are given to the patient (typically that the patient must remain still during the x-ray procedure), and the exposure is made. If more than one exposure is needed, the film is changed, the patient is repositioned, and the steps are repeated until the examination is complete.

After the patient’s safety and comfort have been ensured, the film is taken to the darkroom for processing. Film processing usually requires less than 10 minutes before the film can be evaluated. If the film is satisfactory and no further exposures are needed, the patient is returned to an examination room or dressing room. The radiographer or the medical assistant then readies the x-ray room for the next examination and prepares the films for interpretation.

The films are kept together and given to the physician with the appropriate paperwork. Films are kept in large file envelopes...
that may contain more than one set of films for the same patient. These envelopes must be accurately identified for proper filing. When images are added to the file, notations often are added to the envelope. After the films have been read, they are promptly filed so that they can be retrieved quickly when needed for future reference. Radiology reports also must be filed. Usually the original is filed in the patient’s chart; copies may be filed separately or with the films.

**SCHEDULING AND SEQUENCING DIAGNOSTIC IMAGING PROCEDURES**

One of the most important communications between medical assistants and imaging departments involves the scheduling of multiple diagnostic procedures that may all be ordered at one time by the physician. Consultation often is needed to decide how many procedures can be done in one day and to sequence them in such a way that they will not interfere with one another. For example, an UGI series usually results in barium sulfate scattered throughout the intestinal tract for several days. Even tiny amounts of residual barium cause complications in radiographic examinations of the urinary tract and biliary system, where tiny opacifications are diagnostically significant. Residual barium in the digestive tract also causes unacceptable artifacts on abdominal CT scans. For this reason, barium studies are scheduled last in any series of procedures.

Some imaging departments schedule a series of several examinations in one day for patients who are able to tolerate this approach. Radiologists prefer various scheduling practices. For example, some departments schedule gallbladder and upper and lower GI studies on the same day. Others may insist on 2 or 3 days to complete the same examinations. You should become familiar with the practice in the institution where you usually schedule patients.

Scheduling several examinations on the same day may be less stressful for the patient, resulting in a single bowel preparation, a single period of fasting, and a single trip to the imaging center. However, the number of examinations an individual patient can tolerate varies, especially if the patient is elderly or ill. Make sure you discuss scheduling options with the patient and/or family before planning more than one examination per day.

When fiberoptic studies, such as gastroscopy or colonoscopy, are ordered in conjunction with radiographic examinations requiring barium as a contrast medium, the fiberoptic studies are done first. This avoids the possibility that the barium will interfere with visual assessment during the fiberoptic examination. Patients undergoing gastroscopy usually receive sedation and a muscle relaxant before the physician inserts the gastroscope. When an UGI series is to follow, it should be delayed to allow sufficient time for the patient to become responsive and alert before the UGI series, because oral administration of barium to a sedated patient increases the risk that the patient may choke on the barium.

Another study to be considered when sequencing diagnostic procedures is an thyroid assessment test that involves iodine uptake. Because the administration of a contrast medium containing iodine causes inaccurate results in such tests for at least 3 weeks, thyroid assessment tests ($T_3$ or $T_4$) or nuclear medicine thyroid scans must be performed before any contrast medium with iodine is administered.

### SEQUENCING ORDER FOR DIAGNOSTIC STUDIES

1. All x-ray examinations that do not require contrast media
2. Any laboratory studies or nuclear medicine procedures that involve iodine uptake
3. Computed tomography (CT) studies with intravenous (IV) contrast any time after iodine uptake blood studies
4. Radiographic examinations of the urinary tract
5. Radiographic examinations of the biliary system
6. Fiberoptic studies (e.g., gastroscopy, endoscopy, sigmoidoscopy, colonoscopy)
7. CT studies of the abdomen or pelvis (done before barium studies)
8. Lower gastrointestinal (GI) series (barium enema)
9. Upper gastrointestinal (UGI) series (barium swallow)

An additional consideration in patient scheduling involves deciding which patients need early morning appointments and which can be scheduled later in the day. Imaging departments always begin the daily routine with patients who must fast in preparation for examination so that they do not have to go too long without food. When scheduling, request early priority for pediatric and geriatric patients, because they have the most difficulty maintaining nothing by mouth (NPO) status for long periods, and extended fasting may actually interfere with their recovery. Patients with diabetes who must postpone their insulin until their morning meal also need priority in scheduling. Outpatients who are diabetic should be reminded to postpone their morning insulin until the examination is complete, even if they have been scheduled for an early appointment. If an emergency
should cause a delay, the patient who has had insulin may suffer a reaction. Paperwork done in the office for diagnostic studies needs to include information about patients with diabetes so that the radiology staff is aware of their status.

**CRITICAL THINKING APPLICATION 50-1**

Mrs. Pellegrini, a 62-year-old patient with diabetes, calls Metro Urgicenter at 8:30 am to confirm her 10 am appointment for an outpatient imaging procedure that requires fasting. On speaking with her, Sara discovers Mrs. Pellegrini has already taken her morning insulin. Should Mrs. Pellegrini keep her appointment or be rescheduled? Why or why not?

When instructing the patient about preparing for an examination, it is important to have printed instructions prepared in advance. If more than one alternative is printed on any given paper, be sure to indicate, both orally and in writing, which instructions are to be followed. Review the sheet with the patient slowly, explaining any words or procedures that may not be familiar. Have the patient explain back to you what is to be done (remember the importance of feedback in establishing whether the patient understands). If the patient is too young, too ill, confused, or incapable of understanding and following the instructions, give the instructions (oral and written) to the person who will be responsible for assisting the patient. Be sure to include the telephone numbers of your clinical facility and of the imaging department so that the patient or the patient’s family may call if any questions arise after the patient leaves the office.

In preparation for a UGI series, the patient must fast, avoiding water, smoking, and chewing gum. The NPO order is instituted for a limited period, usually 8 to 12 hours, before the procedure. This ensures that the stomach is empty at the time of examination so that an accurate radiographic image of its inner surfaces can be produced. Chewing gum and smoking are avoided because they tend to increase gastric secretions.

The preparation for a barium enema involves the use of a bowel cleansing kit. These kits usually contain one or more types of cathartics, a suppository, a low-volume enema, and illustrated instructions in several languages. Research has demonstrated that increased fluid intake enhances the effectiveness of cathartics and helps minimize the patient’s discomfort. For this reason, instructions for cathartics are accompanied by a fluid intake schedule that suggests at least 8 ounces of water or clear liquid every 2 hours between noon and midnight on the day preceding the examination. The medical assistant should emphasize the importance of fluid intake. The required doses of cathartics have a strong, thorough action that occasionally cause patients to experience painful spasms of the bowel and irritation of the intestinal lining. Persistent diarrhea may last through the night, preventing sleep. Although patients may find this preparation uncomfortable and inconvenient, its effectiveness in cleansing the bowel usually outweighs these considerations. Caution must be exercised in implementing an aggressive preparation for elderly or frail patients who are likely to be adversely affected. A gentler alternative should be available for these debilitated patients. Those with chronic or acute diarrhea may require a lower dose or less active preparation than is usually given. When the routine strength or amount of cathartics is reduced, several days of a low-residue diet and an increased fluid intake become critical to the success of preparation. Patients should always be advised of the nature of the action expected from the cathartic when it is given. Table 50-3 summarizes common diagnostic procedures and the patient preparation required for each.

**CRITICAL THINKING APPLICATION 50-2**

Dr. Roberts, a physician at Metro Urgicenter, has scheduled Mr. Tillman for a barium enema, and David asks Sara to provide Mr. Tillman with the preparation instructions for the procedure. What information should Sara obtain from Mr. Tillman to determine whether the usual bowel preparation is appropriate? If Sara thinks the usual preparation might be too harsh for Mr. Tillman, how should she explain her concern to David and Dr. Roberts? Who should decide whether to implement a variation in protocol: Sara, David, or someone else?

### Radiation Safety

#### Radiation Units

Two systems are used to measure radiation and radiation dose: the conventional (British) system and the international system (Système International [SI]) established in 1981. The conventional system is still the most commonly used in the United States. The reason for the measurement determines which unit is most appropriate.

The roentgen (R) is the conventional unit of radiation exposure. It represents a measurement of radiation intensity and is determined by the interaction of the x-ray beam with air. For example, an x-ray machine might produce 0.01 R during the exposure for a chest radiograph. The corresponding SI unit is coulombs per kilogram (C/kg), which specifies the electrical charge in coulombs produced by the exposure of 1 kg of dry air.

The roentgen is not a useful dose unit because dose varies with the depth of measurement and the amount of radiation energy absorbed in the exposed tissue. The conventional unit used to measure both therapeutic radiation doses and specific tissue doses received in diagnostic applications is the rad, which stands for radiation absorbed dose. It usually is qualified by the specific body part to which it applies. For example, a radiation oncologist may prescribe a treatment involving 150 rad to the pelvis. The SI unit for dose measurement is the Gray (Gy).

The biologic effect of radiation exposure varies according to the type of radiation involved and its energy; equal doses of various types of radiation do not necessarily result in equal biologic effects. To measure occupational dose or other exposure that may involve more than one type of radiation, the dose equivalent unit used is the rem, which stands for roentgen equivalent in man. Dose equivalents usually are assumed to represent whole body dose or the dose to unspecified tissues. The SI unit for dose equivalent is the Sievert (Sv).

Because the radiation quantities involved in diagnostic radiology are so small, units may be used that represent 1000 of the common units: milliroentgen (mR), millirad (mrad), and millirem (mrem). It may be confusing to determine which units
<table>
<thead>
<tr>
<th>STUDY</th>
<th>PURPOSE</th>
<th>PROCEDURE</th>
<th>PATIENT PREPARATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arteriogram</td>
<td>To aid diagnosis of arterial occlusion, aneurysm, hemorrhage, abnormal vessels, and transient ischemic attacks</td>
<td>Catheter is inserted into femoral or brachial artery and advanced under fluoroscopy to site; dye is injected, and x-ray images are taken.</td>
<td>Clear liquids 24 hr before test; nothing by mouth (NPO) 8 hr before test; if abdominal vasculature is to be imaged, patient may need laxative and enemas</td>
</tr>
<tr>
<td>Arthrogram</td>
<td>To detect damage to joint connective tissue and structures</td>
<td>Fluoroscopic and radiographic examination of a joint after injection of air or contrast dye.</td>
<td>NPO 8 hr</td>
</tr>
<tr>
<td>Barium enema</td>
<td>To detect bowel obstruction, celiac sprue, colon cancer, polyps, diverticulitis, irritable bowel syndrome</td>
<td>Fluoroscopic and radiographic examination of the colon after barium enema to find internal structural abnormalities; takes approximately 1 hr.</td>
<td>Bowel must be emptied before procedure; clear liquid diet 24 hr before test; laxatives days before test; enemas morning of test</td>
</tr>
<tr>
<td>Barium swallow</td>
<td>To detect dysphagia, esophageal varices, hiatal hernia, pyloric stenosis, stomach cancer, ulcers</td>
<td>Fluoroscopic and radiographic examination as barium is swallowed to detect abnormalities of the pharynx, esophagus, and stomach; takes about 15 min.</td>
<td>NPO 8 hr</td>
</tr>
<tr>
<td>Bone scan</td>
<td>To detect bone cancer, bone infection, osteoarthritis, osteomyelitis</td>
<td>Nuclear medicine: Radioactive isotope is injected intravenously (IV), body is scanned, and levels of isotope are recorded on film. Areas of high metabolism show as “hot spots”; scan is done 1-3 hr after isotope injection.</td>
<td>NPO 4 hr; must void before scan; radioactive material is excreted in urine within 48 hr and is not harmful to others</td>
</tr>
<tr>
<td>Computed tomography (CT)</td>
<td>Provides detailed, cross-sectional views of all types of tissue; one of the best tools for studying the chest and abdomen</td>
<td>Special x-ray equipment and computers are used to obtain image data from different angles around the body, and multiple cross-sectional views (tomographs) are produced.</td>
<td>NPO after midnight if IV contrast medium used; no metal objects; must lie very still; advise of confined space and possible claustrophobia</td>
</tr>
<tr>
<td>Intravenous urogram (IVU) or intravenous pyelogram (IVP)</td>
<td>To evaluate structure and function of kidneys, ureters, and bladder</td>
<td>IV contrast medium is injected, and x-ray films are taken of renal structures.</td>
<td>Bowel cleansing 24 hr before with laxatives and enema is important to prevent obstruction of views; NPO 8 hr</td>
</tr>
<tr>
<td>Magnetic resonance imaging (MRI)</td>
<td>To aid diagnosis of intracranial and spinal lesions, aneurysms, heart defects, multiple sclerosis, and soft tissue abnormalities throughout the body</td>
<td>Magnetic field and radiofrequency energy are transmitted to a computer, which produces cross-sectional images of soft tissue; it may eliminate the need for angiography and myelography. No radiation exposure is involved. Patient lies on a flat table that moves into a tunnel-shaped scanner; takes 45-90 min.</td>
<td>May have fluid restriction; radioactive contrast dye may be used; must remove all metal; contraindications include any metallic implants with iron (e.g., pacemakers, artificial heart valves, aneurysm clips, material associated with metal-related occupation); patient hears loud tapping noise during test and must remain still</td>
</tr>
<tr>
<td>Myelogram</td>
<td>To aid diagnosis of spinal lesions, ruptured disk, spinal stenosis</td>
<td>Fluoroscopic and radiographic examination of the spinal column after injection of contrast medium into the subarachnoid space; takes about 1 hr.</td>
<td>NPO 8 hr</td>
</tr>
</tbody>
</table>

should be used in a given situation. This is made more difficult by the tendency of many radiographers to use the traditional roentgen, rad, and rem units interchangeably. This practice does not cause serious inaccuracy when speaking only of diagnostic x-ray studies, because exposure to 1 roentgen of x-ray energy results in approximately 1 rad of absorbed dose, which is equal to a dose equivalent of 1 rem.

### Effects of Low-Dose Radiation Exposure

**Cellular Response to Exposure**

Most cellular effects of radiation exposure are extremely short lived, because chemical alterations within the cells are quickly repaired. Even if a cell dies, cell death is an insignificant injury unless the number of cells involved is massive. Some cells may
sustain damage that requires several days for the body to repair. The body produces special enzymes that function to repair DNA protein molecules. Sometimes a cell may be damaged in such a way that its DNA “programming” is changed and the cell no longer behaves normally. This type of injury eventually may result in the runaway production of new, abnormal cells, causing a tumor or malignant blood disease.

The relative sensitivity of different types of cells is summarized in the laws of Bergonié and Tribondeau, which state that cell sensitivity to radiation exposure depends on four characteristics of the cell:

- **Age:** Younger cells are more sensitive than older ones.
- **Differentiation:** Simple cells are more sensitive than highly complex ones.
- **Metabolic rate:** Cells that use energy rapidly are more sensitive than those that have a slower metabolism.
- **Mitotic rate:** Cells that divide and multiply rapidly are more sensitive than those that replicate slowly.

According to these laws, blood cells and blood-producing cells are very sensitive. Cells that are in contact with the environment are quite simple, have relatively short lives, and are quite sensitive. These include the cells of the skin and the mucosal lining of the mouth, nose, and GI tract. Some glandular tissue is also particularly sensitive, especially that of the thyroid gland and the female breast. The tissues of embryos, fetuses, infants, children, and adolescents tend to be more sensitive than those of adults because of their young age and higher metabolic and mitotic rates. Nerve cells, which have a long life and are quite complex, are much less vulnerable to radiation injury.

**Somatic Effects**

Radiation effects can be classified as somatic or genetic. Somatic effects are those that occur to the body of the person who is irradiated. Whereas the effects of relatively high doses of radiation are immediate and predictable, the effects of the very low doses associated with radiography produce long-term effects. They are not easily identified as a result of radiation exposure, because they occur 3 to 30 years after treatment and because the same problems can occur in the absence of radiation exposure. Only extensive research with large populations can demonstrate the role of radiation in causing these effects. In other words, radiation causes increased risk for health problems, but the complications cannot be predicted with respect to any one individual. Although the individual risk is extremely small, increasing exposure to the entire population poses public health risks that require the attention and concern of everyone involved in applying ionizing radiation to human beings.

The documented latent effects of low doses of ionizing radiation include the following:

- **Cataract formation:** This is a risk for radiologists and radiographers who work extensively in fluoroscopy and those who perform other work that involves repeated exposure to the eyes.
- **Carcinogenesis:** Increased risk of malignant disease, particularly cancer of the skin, thyroid, breast, and leukemia.
- **Shortened life span:** A study of the life span of radiologists who died before 1945 showed that they had shorter life spans than physicians who did not use radiation in their practices. This group included radiologists who had used radiation since the early days of x-ray science. More recent studies show that occupational exposure no longer has a measurable effect on the life span of radiologists. Nevertheless, because radiation exposure has been linked to shortening of the life span, it is a public health concern and another reason to practice a high level of radiation safety.

**Radiation and Pregnancy**

Radiation exposure poses risks to the developing embryo or fetus. Research has demonstrated that excessive radiation during pregnancy may result in spontaneous abortion, congenital defects in the child, growth retardation, increased risk of cancer and leukemia in childhood, and an increase in significant genetic abnormalities in the children of parents who were exposed in utero. Studies of women exposed to radiation as a result of diagnostic and therapeutic procedures confirm that radiation to the uterus in excess of 5 rad is cause for concern. This is more exposure than is received with most x-ray examinations, but these levels may be encountered with direct exposure to the pelvis, especially with CT examinations or fluoroscopic studies.

**Genetic Effects**

Genetic effects in the form of changes or mutations in the hereditary material of reproductive cells may occur if the ovaries or testes are exposed to radiation. In the female, all the ova cells the individual will ever produce are present at birth. Because no new egg cells are created as the individual ages, the effect of radiation exposure to the ovaries accumulates over time. In addition, the genetic effects of radiation to the testes may include damage to stem cells that produce sperm, resulting in the production of sperm with a genetic mutation. Most genetic mutations threaten the survival of an individual. Even when these changes are recessive (not apparent in the offspring), they may be passed on to future generations.

**GUIDELINES FOR PEDIATRIC X-RAY EXAMINATIONS**

- Provide age-appropriate explanations about the procedure and instructions for patient compliance.
- Inform the parents about the procedure and answer questions.
- Give the patient or parents written information when needed about preparation for the examination.
- Explain that allowing parents in the x-ray room will be up to the facility.
- When possible, use commercial immobilization devices to position the child (e.g., restraint board with Velcro closures, popoose board, positioning chair [Figure 50-31]).
- Have a parent help the child maintain a particular position when immobilization devices are not available or are ineffective. The parent must wear the appropriate lead shielding equipment.
Radiation Protection

Clearly, exposure to x-rays creates some risk for both patients and radiographers; therefore it is essential that those performing radiographic studies are knowledgeable about and diligently practice radiation safety. All unnecessary radiation exposure to patients, co-workers, and oneself must be prevented.

PERSONNEL SAFETY

In diagnostic x-ray departments, radiation hazards exist from exposure to the primary x-ray beam as well as to scatter radiation caused by an interaction between the primary beam and the patient or other material in its path. Scatter radiation is present throughout the x-ray room during an exposure. X-rays travel at the speed of light. They do not linger in the room after the exposure, and they are not capable of making the objects in the room radioactive. Therefore, the only time a radiation hazard exists is during the x-ray exposure itself.

Because radiographers are considered occupationally exposed individuals, they are prohibited from activities that would result in direct exposure to the primary x-ray beam. This means that they are not allowed to hold patients or cassettes during x-ray exposures and must stand clear of the path of the primary x-ray beam during fluoroscopic and mobile radiographic examinations. Whenever possible, patients should be immobilized without someone holding them. When infants or children must be held, a parent (as long as the parent is not pregnant) usually is the appropriate person to perform this duty, with the required lead covering.

Medical assistants may or may not be considered occupationally exposed persons, depending on their work assignments and the frequency with which they are involved with radiation use. Medical assistants who are not routinely exposed occasionally may assist with procedures by holding patients or cassettes. When this is the case, the medical assistant should wear a lead apron and should avoid direct exposure to the primary x-ray beam if possible (Figure 50-32). If the hands will be in the primary beam, lead gloves should also be worn.

Personnel are not exposed to any significant amount of radiation when standing well behind the protective lead barrier of the control booth. X-rays travel in straight lines and do not turn corners. Scatter radiation is not powerful enough to generate additional radiation of concern when it interacts with matter, so the control booth need not be sealed.

Occupational exposure increases when assisting with fluoroscopic procedures or using mobile x-ray equipment. The three principal methods used to protect personnel from unnecessary radiation exposure are time, distance, and shielding.

Because the amount of exposure received is directly proportional to the time spent in a radiation area, dose is decreased when this time is minimized. For example, you might shorten the time of exposure by stepping into the control booth during fluoroscopic procedures when not required to be near the patient.

The second method involves using distance. Increasing the distance between yourself and a radiation source reduces your exposure in proportion to the square of the distance; therefore, small increases in distance have a relatively large effect. Mobile x-ray units have long cords on the exposure switches, which allows the radiographer to get as far from the radiation source as possible while making an exposure.

The third method, shielding, is the most common type of personnel protection used in outpatient radiography settings. The lead wall of the control booth provides a radiation safety barrier and is the principal defense for personnel. Other types of shielding include lead aprons, gloves, goggles, and thyroid shields. These types of shielding are worn during fluoroscopic procedures and mobile radiographic examinations.

**PRE-EXPOSURE SAFETY CHECK**

Before making an exposure, make sure of the following:
- The x-ray room door is closed; a closed door indicates that an exposure is in progress and no one may enter the room.
- No nonessential persons are in the x-ray room; all essential individuals outside of the lead barrier are appropriately shielded.
- All those in the control booth are completely behind the lead barrier.
- The only cassette in the room is the one in use.

Personnel Monitoring

A device for monitoring radiation exposure to personnel is called a dosimeter. Dosimeters should be worn in the region of the
Exposure reports are sent to the facility for each batch with an annual summary of personnel exposure. The report sent by the laboratory that processes the personnel dosimeters reports occupational dose in rem. Personnel should be advised of the radiation exposure reported from their badges and should be provided with copies of the annual reports for their own records. Employers are required to provide a complete record of an employee’s radiation exposure history to all employees who have radiation exposure records before the individual leaves the employment of that facility.

**Effective Dose Equivalent Limits**
The ALARA principle is the guiding philosophy associated with all radiation use that involves exposure to humans, both patients and workers. It states that all radiation exposure to humans should be limited to levels that are as low as reasonably achievable.

The effective dose equivalent (EDE) limiting system is used to calculate the upper limit of permitted occupational exposure. For occupationally exposed personnel, the EDE limit is 5 rem (50 mSv) per year. This applies to workers over age 18 who are not pregnant and is assumed to be a whole body dose. These limits apply to occupational exposure only and do not include diagnostic imaging exposure that the worker may receive as a result of tests related to their own healthcare.

The established EDE limits ensure that the safety of radiation workers is comparable to that of workers in other, safe occupations. The allowable exposure is considered to be so low as to pose an insignificant risk. The occupational exposure received by radiographers usually is well below the established limit.

**Occupational Precautions During Pregnancy**
Radiation exposure during pregnancy must be closely monitored because of possible complications for the developing fetus. The EDE limit of whole body radiation for the pregnant worker is 0.5 rem over the 9-month course of the pregnancy. The worker first must submit a written document to her employer declaring the pregnancy. The employer then is responsible for providing fetal radiation monitoring and for ensuring that the occupational dose does not exceed the EDE limit for pregnant workers. Here again, the ALARA principle is important. Every effort should be made to minimize exposure, keeping the dose as far below the limit as possible.

For a pregnant radiographer, the safest work assignment would be one in which a permanent lead barrier (control booth) always shields the worker during exposures. Pregnant radiographers, or those of childbearing age who may be pregnant, should pay particular attention to personal safety measures when assisting with fluoroscopy or using mobile x-ray equipment.

**Patient Protection**
Patients must be consistently protected from unnecessary radiation exposure. The following methods are used to minimize the radiation dose to patients:

- Avoid errors. Double-check requisitions and patient identification so that the right patient gets the right examination.
- Establish good routine procedures and follow them strictly so that careless errors do not necessitate repeat exposures.
- Collimate. Use the smallest radiation field needed to fulfill the physician's order. The size of the radiation field should always be less than the size of the film.
- Use the highest kVp consistent with acceptable film quality. This permits use of the least possible mAs to obtain an acceptable exposure.
- Use an SID of at least 40 inches. This limits patient exposure from tube housing leakage and collimator scatter.
- Use the fastest films and screens consistent with the necessary film quality.
- Provide shielding for gonads, eyes, breasts, and thyroid as appropriate.

**Gonad Shielding**

Lead shields that prevent unnecessary radiation exposure to the reproductive organs are required when the patient is of reproductive age or younger, whenever the gonads are within the primary radiation field, and when the shield will not interfere with the examination. This applies to most patients under age 55. A shield device consisting of at least 0.5 mm of lead or equivalent is placed between the x-ray tube and the patient. Shields attached to the collimator (shadow shields) may be positioned by viewing their shadows within the collimator light field. Shields placed on or near the patient's body are referred to as contact shields and are more effective than shadow shields. Both types meet the legal requirements for gonad shielding. The female shield is placed with its lower margin at the level of the pubic symphysis (Figure 50-34). The male shield is positioned with its upper margin about 1 inch below the pubic symphysis (Figure 50-35). It is helpful to note that the pubic symphysis is at about the same level as the greater trochanter of the femur, which prevents the need to palpate the pubic symphysis for proper shield placement.

**Pregnant or Possibly Pregnant Patients**

The greatest risks for spontaneous abortion, fetal death, and significant birth defects exist when significant levels of exposure occur during the first trimester of pregnancy. The embryo is most vulnerable to radiation insult while tissues are in the process of differentiation. Unfortunately, this creates the greatest hazard at a time when a woman may not yet be aware she is pregnant.

The public is generally aware that x-rays should be avoided during pregnancy, and this may lead to irrational fears on the part of pregnant women or their families. The chance is extremely remote that a routine x-ray examination of the chest or an extremity would harm the developing child. On the other hand,
examinations requiring direct radiation to the pelvis, especially relatively high-dose fluoroscopy studies or CT scans of the abdomen or lumbar spine, may be cause for concern.

Radiation control regulations require that female patients of childbearing age be advised of potential radiation hazards before an x-ray examination. This requirement usually is met by posting signs in the radiology department advising women to tell the radiographer before the examination if they may be pregnant. These signs should be written in all languages commonly used in the community.

The medical assistant should ask specific questions to rule out pregnancy when taking a medical history. If pregnancy is a possibility, an early pregnancy test should be done to rule out the possibility. If the patient is pregnant and the proposed x-ray examination involves direct pelvic radiation, the physician must weigh the potential risks and benefits of the examination and discuss them with the patient before proceeding with the study. In the case of minor or chronic complaints, the examination typically is delayed until after the child is born. In practice, however, the possibility of pregnancy may not even be considered. This is especially true with accident or injury, when the patient is being cared for by unfamiliar physicians in an emergency situation. For this reason, it is essential to consider the possibility of pregnancy in any female of childbearing age and to ask specific questions to determine whether the physician has addressed the issue of pregnancy before proceeding with scheduling or assisting with an x-ray examination.

If an x-ray examination of a pregnant patient must be done, modifications in procedure can help minimize the dose to the embryo or fetus. If the part to be examined is not the abdomen or pelvis, this area can be shielded with a lead apron. If the abdomen or pelvis is to be evaluated, the number of views or the size of the radiation field may be minimized, resulting in less radiation exposure than that required for a routine procedure.

**Critical Thinking Application 50-3**

Ingrid White is gowned and ready for a lumbar spine x-ray examination when Sara asks her whether there is any possibility she might be pregnant. Mrs. White confides that she and her husband have been trying to conceive for several months, and she is not sure whether she currently is pregnant. What should Sara do?

**The Role of the Medical Assistant**

Depending on your location, you may or may not be legally permitted to take x-ray films. Most states require some sort of license or permit to practice radiography. Some, such as New York and New Jersey, grant licenses only to professional radiologic technologists who have completed at least a 2-year education program and obtained certification in radiography from the American Registry of Radiologic Technologists (ARRT).

**Limited radiography**, sometimes called **practical radiography**, is practiced primarily in clinics and physicians’ offices. This field developed as nurses, medical assistants, chiropractic assistants, and other health care office personnel were trained to perform basic x-ray procedures in addition to their primary duties. It is called **limited** because the scope of practice is restricted compared with that of registered radiologic technologists. Limited practice does not usually involve the use of contrast media, and additional restrictions may be applied, depending on the scope of practice permitted in the states where limited radiography can be legally practiced.

However, even if you are not qualified as a radiographer, it may be helpful to understand the general procedures involved in an x-ray examination and to identify areas where the medical assistant might be of help to the patient or radiographer, or both. The exact nature of your duties will vary with your qualifications, your place of employment, the size of the staff, and the equipment available.

The process of radiography involves validation of orders, patient preparation, proper selection of cassettes and film, correct positioning of patient and equipment, measurement of the part to be examined, protective shielding, correct setting of the exposure controls, and identification and processing of the film. These basic procedures vary considerably, depending on the body part to be examined.

**Closing Comments**

**Legal And Ethical Issues**

Only licensed health practitioners are permitted to order x-ray examinations. Interpretation of diagnostic images is part of the professional practice of making a diagnosis and is solely the privilege of physicians. Although you may learn to recognize certain conditions represented in diagnostic images, you must never discuss your observations with the patient.

In most states, x-ray machines must be licensed, and personnel operating this equipment must have a current license or permit. In all states that regulate radiography, the practice is defined as more than simply pushing the exposure button. If you position the x-ray equipment, position the patient, or set the exposure controls, even though you do not make the exposure, you are probably practicing radiography as defined by law. Practicing without a valid license or permit or practicing outside the scope of one’s credentials may result in fines, imprisonment, or both. Employers may also be penalized if their employees practice radiography in violation of regulations. Everyone who practices radiography must be aware of the legal standards that apply to them and take care that their practice conforms to these standards. Even if you work in a state that currently has no requirements for practicing radiography, you should be aware that the safe practice of radiography requires additional education and experience beyond that provided in this chapter.

X-ray films and other diagnostic images are the property of the institution or facility where they are taken. Even though the patient may pay for the procedure, this does not mean the patient owns the films. They are considered part of the medical record and are subject to the same kinds of requirements with respect to confidentiality, retention, and availability to the patient. The retention period varies from state to state; usually it is 5 to 7 years. Images may be loaned or transferred to other healthcare providers to assist in the patient’s care. The patient should sign a
SUMMARY OF SCENARIO

David Swain and the physicians at Metro Urgicenter depend on Sara's assistance to keep the x-ray department running smoothly. Today, for example, she instructed four patients to gown and prepare for routine x-ray examinations. Greg Nolan had PA and lateral views of the chest because of a persistent cough and fever. Margaret and Jeff Barge both needed spine x-ray studies to rule out possible fractures from a car accident. Dr. Farnsworth ordered AP and lateral views of Ella Jackson's left hip. Sara processed the films and was proud to see that they had no handling artifacts. This afternoon, Sara made an appointment for Cecile Marsden to have a bone scan at University Imaging Center. She was able to describe the procedure for Ms. Marsden so that she would know exactly what to expect. Sara recognizes that she must remain up-to-date on the current radiologic diagnostic procedures to provide assistance when needed and to answer patients' questions. Sara enjoys her work in the x-ray department and is attending evening classes to become certified as a limited radiographer.

SUMMARY OF LEARNING OBJECTIVES

1. Define, spell, and pronounce the terms listed in the vocabulary.
   Spelling and pronouncing medical terms correctly bolster the medical assistant's credibility. Knowing the definitions of these terms promotes confidence in communication with patients and co-workers.

2. Apply critical thinking skills in performing the patient assessment and patient care.
   Completing the Critical Thinking Application exercises throughout the chapter can help the student medical assistant become more adept at critical analysis of real-life situations.

3. Identify the principal components of an x-ray machine.
   The main component of the x-ray machine is the tube in its barrel-shaped tube housing. The collimator is mounted on the tube housing. The tube housing, with its attachments, is mounted on the tube support. The radiographic table and an upright cassette holder provide support for the patient and the film and incorporate a grid device. At the control console the operator selects the exposure settings and makes the exposure.

4. Describe the cassette and film image receptor system and explain its function in radiography.
   The image receptor system usually consists of a cassette with two intensifying screens that give off light when stimulated by x-ray energy and double-emulsion film that lies between the intensifying screens. The film is exposed on both sides, principally by the light emitted from the screens. This system greatly reduces the amount of radiation and the exposure time compared with direct exposure of film by x-rays.

5. Recognize the precautions to be taken when unloading, loading, and processing radiographic film and cassettes.
   Cassettes are unloaded and reloaded in the darkroom under safelight illumination only. Precautions include ensuring that the door is locked;

6. Distinguish among the three body planes and use these terms correctly when discussing radiographic positions.
   The three body planes are the sagittal plane, which divides the body into right and left parts, the coronal plane, which divides the body into anterior and posterior parts, and the transverse plane, which divides the body into superior and inferior parts. For a frontal projection (AP or PA), the coronal plane is parallel to the film and the sagittal plane is perpendicular to it. For a lateral projection, the sagittal plane is parallel to the film and the coronal plane is perpendicular to it. Neither the sagittal nor the coronal plane is parallel to the film on an oblique projection.

7. Identify anteroposterior (AP), posteroanterior (PA), lateral, oblique, and axial radiographic projections.
   In an AP projection, the patient is supine and facing the x-ray tube. In a PA projection, the patient is facing the film, and the coronal plane is parallel to the film. In a lateral projection, the coronal plane is perpendicular to the film. In an oblique projection, neither the coronal nor the sagittal plane is parallel to the film. In an axial or semiaxial projection, the x-ray beam is angled toward the patient's head or feet along the long axis of the body.

8. Compare and contrast radiography and fluoroscopy and give examples of appropriate applications of each.
   Radiography and fluoroscopy are both x-ray imaging procedures with a wide variety of applications. Radiography produces still images, usually
9. List and describe imaging modalities that do not involve x-rays.
   MRI uses a strong magnetic field and radiofrequency pulses to produce
   images of all parts of the body, including bone, soft tissue, and blood
   vessels. Nuclear medicine studies demonstrate the function of organs
   and tissues by mapping the radiation given off within the body when
   radioactive tracers have been ingested or injected into the patient.
   Sonography is a very safe imaging method that demonstrates soft tissues
   using high-frequency sound waves.

10. Explain the patient preparation guidelines for typical diagnostic
    imaging examinations.
    Table 50-3 summarizes patient preparation.

11. Outline the general procedure for assisting with an x-ray
    examination.
    The patient is prepared with education and appropriate gauzing and
    positioning, lead shields are used as needed. The medical assistant
    assists with film processing if trained to do so. The procedure is docu-
    mented in the medical record, and radiology reports are filed.

12. Summarize the guidelines for scheduling multiple diagnostic
    procedures.
    When possible, several examinations should be scheduled on the same
    day if the patient is strong enough. Diagnostic imaging that does not
    require contrast media or nuclear medicine should be scheduled first.
    Next are examinations of the urinary tract and biliary system. Fiberoptic
    studies (e.g., colonoscopy) and CT studies of the abdomen and pelvis
    should be scheduled before any GI studies that require barium. CT and
    MRI can be scheduled anytime unless they require IV contrast; if iodi-
    ne dye is needed, the procedure is scheduled after examinations that do
    not require visualization. Barium studies are always scheduled last, and
    a UGI series (barium swallow) is the final procedure.

13. Apply patient education principles when providing instructions for
    preparation for diagnostic procedures.
    Table 50-3 summarizes patient preparation guidelines for diagnostic
    imaging procedures. The patient must be informed of the purpose of the
    study, how the procedure will be performed, and any important patient
    preparation steps needed to make sure the examination can be com-
    pleted successfully. The healthcare facility should have instruction sheets
    ready to distribute to patients scheduled for diagnostic studies. The
    medical assistant must understand diagnostic procedures so that the
    patient's questions can be answered and informed consent can be
    obtained. The medical assistant should review instruction sheets with the
    patient to make sure the preparation is done as recommended.

14. Describe the health risks associated with low doses of x-ray ex-
    posure, such as those used in radiography.
    The health risks associated with radiography are extremely small and
    consist of a slightly increased likelihood of developing cataracts, cancer,
    or leukemia. The potential also exists for a minimal decrease in life span
    and for a negative outcome if the abdominal area is exposed to radiation
    during pregnancy. Exposure to the reproductive organs may cause
    genetic changes that can be passed on to future generations.

15. Summarize the steps for ensuring that patients receive the least
    possible exposure during x-ray procedures.
    To ensure that patients receive the least possible exposure during x-ray
    procedures, radiology personnel should avoid errors that could require
    repeat exposures; establish good routine procedures and follow them
    strictly; collimate to the smallest radiation field; use the highest kVp
    possible; use an SID of at least 40 inches; use the fastest films and
    screens consistent with the necessary film quality; and shield the repro-
    ductive organs and other sensitive organs (e.g., eyes, thyroid, and breasts).

16. Describe precautions for ensuring the safety of equipment operators
    and staff members during x-ray procedures.
    The principal safety precaution for x-ray equipment operators and staff
    is to stay completely behind the lead barrier of the control booth during
    exposures. Occupationally exposed individuals must not hold patients or
    cassettes during exposures. Any staff member required to be in the x-ray
    room during an exposure should be shielded by a lead apron, should
    stay at least 10 feet from radiation sources as possible, and should minimize
    the time spent in the room during exposures.

17. Explain the legal responsibilities associated with x-ray procedures
    and the administrative management of diagnostic images.
    Diagnostic images are the property of the facility in which they are made.
    Images may be loaned or transferred to other healthcare providers to
    assist in the patient's care, in which case the patient should sign a
    release, the images should be sent directly to the borrowing provider
    if possible, and a record must be kept of the loan. Only licensed health-
    care practitioners are permitted to order x-ray examinations and/or to
    interpret x-ray images.