OBJECTIVES

On completion of this chapter, you will be able to:

- Define radiology.
- Describe dangers and safety precautions associated with x-rays.
- Describe the positions used in radiography.
- Describe diagnostic imaging.
- Describe nuclear medicine.
- Describe interventional radiology.
- Analyze, build, spell, and pronounce medical words.
- Identify and define selected abbreviations.
- Describe each of the techniques presented in Radiology & Nuclear Medicine Spotlights.
- Review the Medical Vocabulary Checkpoint.
- Complete the Study and Review section, and the Chart Note Analysis.

OUTLINE

I. Overview of Radiology and Nuclear Medicine
   A. Radiology – the science of high-energy radiation; its sources; and the chemical, physical, and biologic effects of such radiation. It is the scientific discipline of medical imaging using radionuclides, ionizing radiation, nuclear magnetic resonance, and ultrasound. It was developed after the discovery of an unknown radiation in the year of 1895, by a German physicist, Wilhelm Conrad Roentgen, who called his discovery an x-ray. An x-ray is produced by the collision of a stream of electrons against a target contained within a vacuum tube. This collision produces electromagnetic rays of short wavelengths and high energy. The physician who specializes in radiology, roentgen diagnosis, and roentgen therapy is called a radiologist.
   1. Characteristics of X-Rays – the characteristics are:
      - X-rays are an invisible form of radiant energy with short wavelengths traveling at 186,000 miles per second. They are able to penetrate different substances to varying degrees.
      - X-rays cause ionization of the substances through which they pass. Ionization is a process resulting in the gain or loss of one or more electrons in neutral atoms. The gain of an electron creates a negative electrical charge, whereas the loss of an electron results in a positively charged particle. These negatively or positively charged particles are called ions.
• X-rays cause fluorescence of certain substances, thus allowing for the process known as fluoroscopy (Fig. 21–1, p. 708). Fluoroscopy is the examination of the tissues and deep structures of the body by x-ray, using the fluoroscope, a device that projects x-ray images in a movielike sequence onto a screen monitor. This process allows the physician an opportunity to visualize internal structures that are in motion and to make permanent records of the examination for future study.

• X-rays travel in a straight line, thus allowing the x-ray beam to be directed at a specific site during radiotherapy or to produce high-quality shadow images on film (radiographs).

• X-rays are able to penetrate substances of different densities. Substances that the radiation passes through easily are said to be radiolucent. Substances that obstruct the passage of radiant energy or absorb radiant energy are called radiopaque. This characteristic allows x-rays to be used as a diagnostic tool:
  o Control of the voltage and amperage applied to the x-ray tube, plus the duration of the exposure, allow images of body structures of varying densities.
  o A contrast medium can be introduced into the body to enhance certain x-ray images.

• X-rays can destroy body cells – this characteristic allows radiation to be used in the treatment of malignant tumors. Care must be exercised in the administration of radiotherapy, as x-rays can destroy healthy as well as abnormal tissue.
  o Radiotherapist – administers the x-ray voltage using radiotherapy machines such as a linear accelerator or the betatron.

2. **Dangers and Safety Precautions** – x-rays are invisible and produce no need to take certain precautions to avoid sound or smell, so those working around and with radiation unnecessary exposure. A list of some of the dangers known to be associated with x-rays and the safety precautions designed to prevent unnecessary exposure include:

a. **Prolonged Exposure** – can cause damage to the gonads and/or depress the hematopoietic system, which can cause leukopenia and/or leukemia. Personnel involved with radiation therapy should spend the minimal amount of time necessary when caring for patients receiving internal radiation therapy. **The farther away an individual is from the source of radiation, the less the degree of exposure.**
b. Secondary Radiation – x-rays scatter from their normal straight paths when they strike radiopaque objects therefore adding unwanted density to the x-ray image.
   - **Grids** – devices positioned between the x-ray machine and the patient to absorb scatter and secondary radiation before it reaches the x-ray film.

c. Safety Precautions – not all scatter or secondary radiation is absorbed by a grid; therefore, those working in areas adjacent to x-ray equipment risk unintentional exposure from this source unless proper safety precautions are observed. Safety precautions include:
   - **Film Badge (Fig. 21–5, p. 719)** – is a device that is worn by a medical worker that is sensitive to ionizing radiation and monitors exposure to beta and gamma rays. A periodic analysis of the film badge reveals the amount of radiation the individual has received.
   - **Lead Barrier** – persons who operate x-ray equipment should do so from behind barriers equipped with a lead-treated window for viewing the patient.
   - **Lead-lined Room** – all x-ray equipment should be housed in an area featuring lead-lined walls, floors, and doors to prevent the escape of radiation from the room.
   - **Protective Clothing** – people who hold or position patients for x-ray examination should wear lead-lined gloves and aprons, especially if they hold a patient, such as a child, while an x-ray is being taken.
   - **Gonad Shield** – the reproductive organs are radiosensitive and must be protected by a lead shield while x-rays are being taken. X-rays can cause damage to the genetic material within the reproductive organs, which could lead to birth defects or cancer

3. Positions Used in Radiography
   a. **Anteroposterior Position (AP)** – the patient is placed with the anterior (front) part of the body facing the x-ray tube and the posterior (back) of the body facing the x-ray film. X-rays will pass through the body from the front to the back in reaching the film.
   b. **Posteroanterior Position (PA)** – the patient is placed with the posterior (back) portion of the body facing the x-ray tube and the anterior (front) of the body facing the film. X-
rays pass through the body from the back to the front to reach the film.

c. **Lateral Position (lat)** – the x-ray beam passes from one side of the patient’s body to the opposite side to reach the film. Placing the patient’s right side next to the film and passing x-rays through the body from left to right is known as the **right lateral position**. Placing the patient’s left side next to the film and passing x-rays through the body from right to left is known as the **left lateral position**.

d. **Supine Position** – the patient rests on the back, face upward, allowing the x-rays to pass through the body from the front to the back.

e. **Prone Position** – the patient is placed lying face down with the head turned to one side. The x-rays pass from the back to the front side of the body.

f. **Oblique** – patient is placed so that the body or body part to be imaged is at an angle to the x-ray beam.

4. **Diagnostic Imaging** – involves the use of x-rays, ultrasound, radiopharmaceuticals, radiopaque media, and computers to provide the radiologist images of internal body organs and processes. These images are used to identify and locate tumors, fractures, hematomas, disease processes, and other abnormalities within the body. Advances in the field of electronics have produced a variety of computer-assisted x-ray machines to enhance the images obtained by the radiologist. These sophisticated machines now make possible noninvasive procedures for the visualization of organs and processes that were previously not accessible or that required exploratory surgical procedures for examination. Special considerations in imaging include:

- **Pregnant Health Care Practitioners** – are permitted to work in and around certain diagnostic imaging machines. Pregnant practitioners are requested not to remain within the room during the actual data acquisition or scanning.

- **Pregnant Patients** – can be accepted to undergo certain scanning if, in the determination of a designated attending radiologist, the risk-benefit ratio for the patient warrants that the study be performed.

a. **Computed Tomography or Computed Axial Tomography (CT/CAT Scan)** (Figs. 21–2, 21–3, pp. 711, 712) – technology that combines an advanced x-ray scanning system with a powerful minicomputer to provide vastly improved imaging quality while making it possible to view parts of the body and abnormalities not previously open to radiography. The CT scanner combines **tomography**, the process of imaging structures by focusing on a specific body plane and blurring all details from other planes, with a
**microprocessor** that provides high-speed analysis of the tissue variances scanned. CT scans reveal both bone and soft tissues, including organs, muscles, and tumors. Image tones can be adjusted to highlight tissues of similar density, and, through graphics software, the data from multiple cross-sections can be assembled into 3-D images. CT aids diagnosis, surgery, and treatment, including radiation therapy, in which effective dosage is highly dependent on the precise density, size, and location of a tumor. The CT scan progresses as follows:

- The patient refrains from eating or drinking for approximately 4 hours.
- All jewelry and metal objects must be removed.
- Imager assures that female patient is not pregnant.
- Patient is instructed to change into an exam gown.
- Patient is placed on the CT table; the table will slide through the opening in a machine that is shaped like a doughnut with a hole in its center called the **gantry**.
- In the gantry, an x-ray tube travels around the individual, creating computer-generated x-ray images.
- Some types of exams require the patient to receive an intravenous injection of **iodinated contrast**, which is a dye that makes some tissues show up better. Scans of the intestines call for the ingestion of diluted iodinated contrast solution prior to the exam.
- After the exam, the technologist will view the pictures. If they are adequate, the person is free to leave.

**b. Magnetic Resonance Imaging (MRI) (Fig. 21–4, p. 713)** – a noninvasive imaging technique used to view organs, bone, and other internal body structures for a variety of purposes. The imaged body part is exposed to radio waves while in a magnetic field. The picture is produced by energy emitted from hydrogen atoms in the human body. The patient is not exposed to radiation during this test. The MRI process is as follows:

- Before the test the patient is assessed for drug or food allergies (especially shellfish or foods with added iodine such as table salt).
- Patient is assessed for claustrophobia or anxiety to enclosed spaces – if this is a problem, mild sedating medication may be given.
- A woman is asked if she is pregnant.
• The person is asked to remove all metal objects such as belts, jewelry, and any pieces of removable dental work. Watches and credit cards are not taken into the MRI scanner.
• Surgical history must be taken – technologist has to be aware of any previous surgery that required placement of metal in the body, such as hip pinning.
• No food restriction unless patient is undergoing MRI guided biopsy.
• Procedure is explained to patient – body part being imaged may feel warm and loud banging and knocking noises will be heard during many stages of the exam. Earplugs are available.
• Patient lies supine and slides into the bore on a special table – the bore is a horizontal tube running through the magnet from front to back. To prevent image distortion on the final images, the person must lie very still for the duration of the test.
• Contrast agent may be administered prior to or during the test – contrast is used to enhance internal structures and improve image quality. Typically, this material is injected into a vein in the arm.

**c. Ultrasound (US) (Figs. 21-11, 21–12, p. 725)** – the term literally means **beyond sound** or a sound whose frequency is beyond the range of human hearing. Ultrasound is used for evaluation of a patient’s internal organs. Its energy is transmitted into the patient and, because various internal organs and structures reflect and scatter sound differently, returning echoes can be used to form an image of a particular structure. These ultrasonic echoes are then recorded as a composite picture of the internal organ and/or structure. Terms associated with ultrasound are:

• **Ultrasonography** – the process of using ultrasound to produce a record of ultrasonic echoes as they strike tissues of different densities.
• **Sonogram or Echogram** – the record produced by ultrasonography.
• **Doppler Echocardiography** – an adaptation of ultrasound technology; a noninvasive technique for determining the blood flow velocity in different locations in the heart. This same technique can be used in determining the uterine artery blood flow
velocity during pregnancy, as well as to determine the fetal heart rate.
The test is done in the ultrasound or radiology department and is performed as follows:

- Preparation for the procedure depends on the body region being examined.
- The patient lies down for the procedure.
- A clear, water-based conducting gel is applied to the skin over the area being examined to help with the transmission of the sound waves – this gel may feel slightly cold and wet.
- The transducer is then moved over the area being examined.
- The patient may be asked to change position so that other areas can be examined.

Results are considered normal if the organs and structures in the area being examined are normal in appearance. The significance of abnormal results will depend on the body region being examined and the nature of the problem.

d. Other Imaging Techniques – these include:

- **Thermography** – detailed images of body parts are developed from data showing the degree of heat and cold present in areas being studied.
- **Scintigraphy** – involves the production of two-dimensional images of tissue areas from the scintillations emitted by an internally administered radiopharmaceutical device that concentrates on a targeted site.

B. **Nuclear Medicine** – subspecialty within the field of radiology that uses radioactive substances to produce images of body anatomy and function. The images are developed based on the detection of energy emitted from the radioactive substance given to the patient either intravenously or by mouth. These images may be used to diagnose disease processes and evaluate organ functioning. Some of the general uses of nuclear medicine include:

- Image blood flow and heart function.
- Scan lungs.
- Evaluate kidney function.
- Identify blockage of the gallbladder.
- Evaluate bones for fracture, infection, arthritis, tumors.
- Identify bleeding into the colon.
- Locate an infection site.
- Measure thyroid function for hyperactivity or hypoactivity.
Certain imaging procedures, including PET scanning, employ radionuclides to provide real-time visuals of biochemical processes. One device, a nuclear imaging machine, employs a scintillation camera that can rotate around the body to pick up radiation emitted by an injected substance. Through computerization, a digitized image of a particular organ is produced.

1. Positron Emission Tomography (PET Scan) (Fig. 21–9, p.724) – a diagnostic procedure that involves the development of biologic images based on the detection of radiation from the emission of positrons. Positrons are tiny particles emitted from a radioactive substance that have been administered to the patient. The subsequent images or views of the human body developed with this technique are used to aid diagnosis and evaluate a range of diseases.

C. Interventional Radiology (IR) (see Table , p. 715) – a branch of medicine in which certain diseases are treated nonoperatively. An interventional radiologist, a physician specially trained in imaging who specializes in treating diseases percutaneously, uses radiologic images to guide catheters, balloons, stents, filters, and other tiny instruments through the body’s vascular system and/or other systems. The procedures and/or surgeries are performed in an interventional suite, generally on an outpatient basis. General anesthesia is usually not necessary and conscious sedation and/or local anesthesia is more commonly used. These procedures are cost effective and are increasingly replacing traditional surgery for certain conditions and procedures.

1. Radiation Therapy, Radiotherapy, X-ray Therapy, or Cobalt Treatment – the aim of this treatment is to deliver a precise, calculated dose of radiation to diseased tissue while causing the least possible damage to surrounding normal tissue. (See Chapter 20, Oncology, on page 676.)

II. Life Span Considerations
A. The Child – Nuclear medicine may be used in the diagnostic workup of childhood disorders that are congenital or acquired later. Most procedures involve an intravenous injection of a radiopharmaceutical based on body weight. If the child is younger than 4 years of age, sedation is usually necessary. During the procedure, the child lies on a scanning table. The previously administered radiopharmaceutical gives off gamma rays that the gamma camera detects. The gamma camera works in conjunction with a computer to develop an image. The gamma camera, which works in conjunction with a computer to develop an image, moves slowly along or around the child to obtain images of the part of the body being examined. Scanning time varies from 20 to 45 minutes. The child is exposed to a small dose of radiation, but there are no known long-term
adverse effects from such low-dose tests. The nuclear medicine physician interprets the images and forwards a report to the referring physician.

B. The Older Adult – About 170,000 people in the United States are diagnosed with lung cancer each year. Most are diagnosed when their disease is advanced, and nearly 90% die within two years. Identifying lung cancer early while surgery is a treatment option improves survival rates; 70% of patients who are diagnosed early survive at least 5 years.
A new study from the National Cancer Institute (NCI) shows that screening for lung cancer with chest x-rays can detect early lung cancer but can also produce false-positive test results, causing needless extra test

III. Building Your Medical Vocabulary
A. Medical Words and Definitions – this section provides the foundation for learning medical terminology. Medical words can be made up of four types of word parts:

1. Prefix (P)
2. Root (R)
3. Combining Forms (CF)
4. Suffixes (S)

By connecting various word parts in an organized sequence, thousands of words can be built and learned. In the text, the word list is alphabetized so one can see the variety of meanings created when common prefixes and suffixes are repeatedly applied to certain word roots and/or combining forms. Words shown in pink are additional words related to the content of this chapter that have not been divided into word parts. Definitions identified with an asterisk icon (*) indicate terms that are covered in the Pathology Spotlights section of the chapter.

IV. Abbreviations (p. 726)

V. Radiology and Nuclear Medicine Spotlights
A. Bone Densitometry or Dual-Energy X-ray Absorptiometry (DEXA) – a noninvasive procedure used to diagnose osteoporosis and to assess the risk of developing fractures. It is also effective in monitoring the effects of treatment for osteoporosis. This test is recommended for postmenopausal women, individuals with a history of hip fracture, people prone to fractures, smokers, men who have clinical conditions associated with bone loss, patients with Type 1 diabetes, liver disease, kidney disease, a family history of osteoporosis, and hyperthyroidism. There are two types of DEXA equipment:

1. Central Device – measures bone density in the hip and spine.
2. Peripheral Device – measures bone density in the wrist, heel or finger. The test takes from 10 to 30 minutes depending on the equipment used and the parts of the body being examined. The bone density exam is interpreted by a radiologist, who sends the results to
the referring physician. The results of the test are in the form of two scores:

- **T Score** – this number shows the amount of bone one has as compared with a young adult of the same gender with peak bone mass. A score above –1 is considered normal. A score between –1 and –2.5 indicates the first stage of osteopenia. A score below –2.5 indicates osteoporosis.
- **Z Score** – this number reflects the amount of bone one has as compared with other people in the same age group and of the same size and gender. If it is unusually high or low further evaluation may be recommended.

### B. Bone Scan (Fig. 21–14, p. 728)

A test used to find cancer, infection, fractures, or injuries in the bone; also used to check a person’s response to treatment for certain bone conditions. The test takes about an hour, not including prescan waiting time. A radioactive substance is injected into a vein in the arm of the person having the scan. Usually, the test begins after a wait of 2 to 3 hours. The procedure is as follows:

- Before the test, the person undresses completely and puts on an exam gown.
- All jewelry and metal objects, including body-piercing jewelry, must be removed so they will not interfere with the exam.
- A woman is asked if she is pregnant.
- When the test starts, the person lies flat on his or her back on a table.
- A special camera is positioned so the entire body can be scanned.
- Rays from the radioactive substance previously injected into the person are detected by the camera, which sends pictures to a computer.

This test can do the following:

1. Show specific areas of irregular bone metabolism, which can suggest certain diseases based on the pattern of abnormality.
2. Detect abnormal blood flow to a particular bony region.
3. Help evaluate metabolic diseases that affect bone, such as certain thyroid conditions.
4. Detect the spread of cancer to the bones and help the physician evaluate results of cancer treatment.
5. Provide information for the physician to diagnose bone changes from a condition called reflex sympathetic dystrophy, a disorder of nerves that causes pain, usually in the hands or feet.

### C. Mammography (Fig. 21-15, p. 729)

A specific type of imaging that uses a low dose x-ray system for examination of the breasts. A mammography exam is called a **mammogram**. Breast cancer screening with mammograms has reduced deaths from breast cancer in women 40 to 69 years of age. A mammogram can detect changes in the breast, such as cancer, often before a lump can be felt. It can also show calcifications, or
mineral deposits, cysts, or fluid-filled masses, leaking breast implants, and noncancerous tumors or growths. There are two types of mammograms:

1. **Screening** – used to detect breast cancer or other changes in the breast tissue in women who do not have symptoms. Screening guidelines endorsed by the American Cancer Society and the National Cancer Institute are:
   a. Practice monthly breast self-examination (BSE).
   b. Between the ages of 40 and 49, have breasts examined by a health professional every year and get a mammogram every 1 or 2 years.
   c. After age 49, have mammogram (along with a manual breast examination) every year.

During a screening mammogram the following occurs:
   - The woman undresses to the waist and puts on a gown that opens from the front.
   - Technologist places one breast on an x-ray film cassette, which resembles a metal shelf.
   - The woman, usually in a standing position, rests her breast on the film cassette.
   - A plastic paddle briefly squeezes the breast from above to flatten it out, allowing a clearer x-ray to be taken.
   - Two views are usually taken of each breast for a screening mammogram.

2. **Diagnostic** – ordered when a screening mammogram shows something abnormal in the breast. A diagnostic mammogram may also be ordered if the woman has symptoms that suggest breast cancer, such as the following:
   - Discharge from the nipple other than breast milk.
   - Lump or swelling in the breast or underarm area.
   - Nipple pain.
   - Redness or scaliness of the nipple or breast skin.
   - Retraction, or turning inward, of the nipple.
   - Skin irritation or dimpling.

A diagnostic mammogram requires more views of the breast and more detail than the screening exam.

3. **Breast Cancer Screening for Men** – approximately 1,300 men a year are diagnosed with breast cancer. When a male is scheduled for a mammogram, he may be embarrassed, as he may feel that breast cancer is strictly a female disease. The male breast generally does not contain as much adipose tissue as the female; therefore, it may be difficult to place the man’s breast onto the film holder and obtain the proper amount of compression.

VI. **Medical Vocabulary Checkpoint**

VII. **Study and Review (pp. 731–734)**
VIII. Practical Application: SOAP: Chart Note Analysis