TENTH EDITION

PATIENT CARE in RADIOGRAPHY

WITH AN INTRODUCTION TO MEDICAL IMAGING





Ruth Ann Ehrlich | Dawn M. Coakes

ELSEVIER

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PREFACE

During the past 35 years, *Patient Care in Radiography* has expanded to meet the changing needs of students and technologists in radiography and other medical imaging modalities. It is a resource that provides an introduction to these professions and an orientation to the hospital environment. First and foremost, however, it is a fundamental text on patient care, designed and written to help radiographers meet patient needs. The reader learns to care for the patient effectively while functioning as a responsible and valuable member of the health care team from the patient introduction, through routine procedures, and the final recording of events in the medical record.

Although the primary goal is centered on patient care, concern for those who provide that care is also an essential focus in this text. Discussions of significant aspects of self-care and professional development are included in the following chapters:

- Chapters 3, 5, 7, and 10 incorporate important self-care concepts.
- Chapter 4 contains discussions on health care delivery, the health care team and career.
- Chapter 5 describes professional attitudes, patient rights, legal considerations, and medical records.
- Chapter 6 includes communication strategies for many situations, including dealing with patients of all ages, patients' families and coworkers, plus transcultural encounters and those who have communication impairments.
- Chapter 9 provides Standard Precautions and additional guidelines for infection control as recommended by the Occupational Safety and Health Administration (OSHA) and the Centers for Disease Control and Prevention (CDC).

Applying these principles is critical to your well-being and your ability to provide good care to others.

NEW TO THIS EDITION

As in previous editions, the tenth edition of *Patient Care in Radiography* contains updated and new information designed to keep student and practicing radiographers current on important topics in this rapidly changing field:

- Every effort has been made to address the content of the American Society of Radiologic Technologists (ASRT) curriculum for radiography that falls within the general scope of the text and to provide both content and learning tools that will aid in implementing the ASRT curriculum guidelines.
- Content has been updated to reflect current information and infection control guidelines from the CDC and to be consistent with Occupational Safety and Health Administration (OSHA) recommendations. This information will help to ensure the well-being of radiographers by raising practice standards in the workplace and by minimizing risks of exposure to blood-borne pathogens.
- Chapter 2 has new information about digital radiography, which has replaced film-screen technology.
- Chapter 21 has new information on surgical laparoscopic cholecystectomy.
- Chapter 5 has two new tables with information on crimes and torts that help to clarify this content for students.
- Chapter 9 has new information on enteric contact precautions.
- The Answer Key (now printed in the text) helps students evaluate learning.

KEY FEATURES

The reading level is comfortable for the student radiographer without being overly simplistic. Again, we have done our best to retain the features that readers have appreciated in previous editions:

- Content outlines accompany each chapter.
- Smaller chapters segregate material and facilitate readability.
- Callout boxes are used to indicate key items for learning, and warning boxes alert students to issues of safety.
- Step-by-step procedures are shown in photo essays, and patient care is integrated with procedural skills.
- Additional pedagogical elements, such as learning objectives, key terms, illustrations, tables, boxes, comprehensive summaries, review questions, and critical thinking exercises, have been retained and improved.

These features can be incorporated into classroom objectives and activities and will also enhance the effectiveness of individual study.

The chapters of this text were designed to be used consecutively; each section builds on the preceding information. A basic glossary is included for quick reference, but please note that it is not intended to replace the more detailed definitions and discussions in a good medical dictionary.

We hope that this book proves to be a valuable resource to you as you care for patients in the challenging field of medical imaging.

EVOLVE: ONLINE RESOURCES

The instructor resources for *Patient Care in Radiography* are available online on Evolve and consist of:

- A test bank offering more than 450 questions
- An image collection with all the images from the text
- PowerPoint slides

The student Evolve site includes an image collection, as well as check-off forms for students to use for documentation of clinical objectives related to patient care. For more information, visit http://evolve.elsevier.com/Ehrlich/radiography/ or contact an Elsevier sales representative.

ACKNOWLEDGMENTS

Suggestions by students, instructors, colleagues, and reviewers have contributed greatly to this edition and are acknowledged with our thanks. In addition to their suggestions, many students in the Portland Community College Radiologic Technology program assisted by serving as models for photography. Many thanks also to models Leslie Danford, Gregg Norman, Kay Coakes, Noah Coakes, Charlie Coakes, Sara Breithaupt, and Ron Kizziar, MD.

We are especially grateful to Dr. Ly Huynh, a radiologist with Radiology Specialists of the Northwest, for his consultation in reviewing several chapters. His expertise, insight, and suggestions have helped beyond measure. Thank you to Providence Portland Medical Center and the medical imaging staff for allowing us access to their facility when we created color illustrations. In addition, they have been an excellent and most welcome resource when questions arose about hospital policies and procedures.

We have been privileged to benefit from the photographic expertise of Jeff Watson; his technical ability is top notch, and it is applied with a sharp eye, a deep understanding of clinical practice, and a delightful sense of humor.

As always, it has been a pleasure to work with the professionals at Elsevier: Jamie Blum, Senior Content Strategist; Luke Held, Senior Content Development Manager; Umarani Natarajan, Senior Project Manager; and the fine staff at Elsevier. Our sincere gratitude to all of you!

Ruth Ann Ehrlich and Dawn M. Coakes

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PART 3 Patient Care in Specific Procedures and Environments

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1

Introduction to Radiography

OBJECTIVES

At the conclusion of this chapter, the student will be able to:

- Name the discoverer of x-rays, state the place and date of the discovery, and describe the discovery.
- Name four other pioneers in the development of radiography and describe their contributions.
- Summarize the history and development of radiography education.
- List four essentials for the production of x-rays.
- Draw a diagram of a simple x-ray tube and label the parts.
- Briefly describe the process by which x-rays are produced in the tube.
- List five different types of electromagnetic wave radiation and identify those that are ionizing.
- List six characteristics of x-radiation.
- Define *wavelength*, *frequency*, and *velocity* with respect to a sine wave and state which of these factors is a constant.
- Describe the differences between primary radiation, scatter radiation, and remnant radiation.
- Correctly identify the essential devices found in a typical radiographic room and state the purpose of each.
- Demonstrate the vertical, horizontal, and angulation motions of an x-ray tube.

CHAPTER OUTLINE

KEY TERMS

- amplitude
- anode
- attenuation
- bucky
- cathode
- collimator
- detent
- electromagnetic energy
- electron stream
- filament
- fluoresce
- fluoroscope
- focal spot
- frequency
- grid
- grid cap
- image intensifier
- image receptor (IR)
- latent image
- photon
- photostimulable p hosphor
- quantum (*pl.* quanta)
- remnant radiation
- scatter radiation
- sine wave
- space charge
- target
- Trendelenburg position
- wavelength

The study of radiography includes many topics, and each topic is best understood when a host of others have already been mastered. Obviously, something has to come first. As you progress in your radiography education, you will discover that learning occurs somewhat like the peeling of an onion—one layer at a time will be revealed. You will visit topics again and again, each time building a broader understanding based on your previous learning and experience. The subject matter in this section is treated on an introductory level to provide a starting place for your radiography education. All these topics will be presented in depth at a later time in your program; some are the subjects of entire courses in the radiography curriculum. Eventually, this information will be woven together to provide a sound basis for clinical practice and decision making. Have patience and confidence in yourself as you take the first steps in your new profession.

Some radiography programs combine the topics of patient care with an introduction to medical imaging, and instructors find that the five chapters of Part I provide a suitable beginning. The curriculum designs of other schools may include this introductory material under a different course heading. Regardless of whether the content of this chapter is a part of your current course, it may serve as a useful resource.

Entering a hospital radiology department as a student for the first time can be both exciting and bewildering. The equipment, language, and activities unique to this environment require some guidance for comprehension. A good way to introduce you to radiography might be to guide you through a medical imaging department, exploring and pointing things out. Think of this chapter as the textbook version of such a tour. But before we enter the modern world of radiology, let's take a moment to see how it all began more than a century ago.

HISTORY

Discovery of X-Rays

In the 1870s and 1880s, research involving electricity was the cutting edge of physical science, and many physicists were experimenting with a device called a *Crookes tube* (Fig. 1.1), a cathode ray tube that was the forerunner of the fluorescent lamp and the neon sign. Although Crookes tubes also produced x-rays, no one detected them.

Then, on November 8, 1895, Wilhelm Conrad Roentgen, a German physicist (Fig. 1.2), was working with a Crookes tube at the University of Würzburg. In his darkened laboratory, he enclosed the tube with black photographic paper so that no light could escape. Across the room, a plate coated with barium platinocyanide crystals (a fluorescent material) began to glow. Roentgen noted that the plate fluoresced in relation to its distance from the tube, becoming brighter when the plate was moved closer. He placed various materials, such as wood, aluminum, and his hand, between the plate and

Fig. 1.1 Pear-shaped Hittorf–Crookes tube used in Roentgen's initial experiments. (Courtesy of Eastman Kodak, Rochester, New York.)

the tube, noting variations in the effect on the plate. He spent the next few weeks investigating this mysterious energy that he called "x ray," *x* being the symbol for the unknown. By the end of the year, Roentgen had identified nearly all the properties of x-rays known today. He was awarded the first Nobel Prize in Physics in 1901 in recognition of his discovery.

> In November of 1895, Wilhelm Conrad Roentgen discovered x-rays while working with a Crookes tube in his laboratory at the University of Würzburg in Germany.

X-Ray Pioneers

Early radiography often required as long as 30 minutes to create a visible image. Over the years, many advances in this technology have reduced the time and radiation exposure involved in radiography. The early sources of electricity were not powerful enough to be efficient and could not be easily adjusted until H.C. Snook, working with an alternating current generator, developed the interrupterless transformer. William Coolidge designed the hot cathode x-ray tube to work with Snook's improved electrical supply. The *Coolidge tube* (Fig. 1.3), introduced in 1910, was the prototype for the x-ray tubes of today.

Roentgen used a glass plate coated with a photographic emulsion to create the first radiograph. Soon after Roentgen's discovery was published, Michael Idvorsky Pupin demonstrated the radiographic use of fluorescent screens, now called *intensifying screens*. He used light emitted by fluorescent materials when activated by x-rays to expose photographic plates.

Fig. 1.2 Photograph of W.C. Roentgen, the discoverer of x-rays, taken in 1906. (Courtesy Wellcome Library, London.)

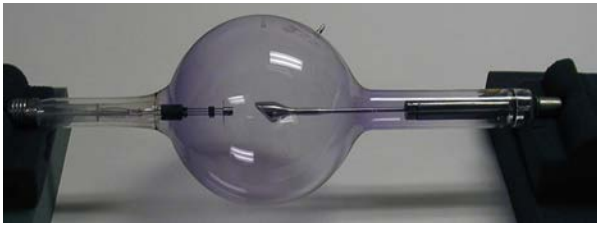

Fig. 1.3 The Coolidge "hot cathode" x-ray tube, prototype of modern tubes, was introduced in 1910.

In 1898, Thomas Edison began experiments with more than 1800 materials to investigate their fluorescent properties. He invented the first fluoroscope and discovered many of the fluorescent chemicals used in radiography over the intervening years. Edison abandoned his research when his assistant and long-time friend, Clarence Dally, became severely burned on his arms as a result of serving as a subject for many of Edison's x-ray experiments. Dally's arms had to be amputated, and in 1904 he died from his exposure. His death was the first recorded x-ray fatality in the United States.

Until World War I, glass photographic plates were used as a base for x-ray images. During the war, manufacturers of photographic plates for radiography could not obtain high-quality glass from suppliers in Belgium, and the U.S. government turned to George Eastman, founder of the Eastman Kodak Company, for help. Eastman had invented photographic film using cellulose nitrate, a new plastic material, as a substitute for glass. He produced the first radiographic film in 1914.

Early in the 20th century, radiation injuries, such as skin burns, hair loss, and anemia, began to appear in both doctors and patients. Measures were taken to monitor and reduce exposures; this process is still ongoing. Lead apparel, protective barriers, and exposure limitations have substantially decreased the amount of radiation received by those involved in the use of x-rays.

> Today, because of improved technology and safety precautions, x-ray examinations are much safer for patients, and radiography is considered to be a very safe occupation.

Early Radiographers

During his early experimentation with x-rays, Roentgen produced the first anatomic radiograph—an image of his wife's hand. The first documented medical application of x-rays in the United States was an examination performed at Dartmouth College in February 1896 of a young boy's fractured wrist.

The first radiographers were physicists familiar with the operation of the Crookes tube. As equipment for generating x-rays was installed in hospitals and physicians' offices, physicians learned to take radiographs and soon developed techniques to demonstrate many different anatomic structures. These physicians began to train their assistants to develop the photographic plates and to assist with x-ray examinations. In time, many of these assistants became skilled in radiography and were called *x-ray technicians*.

Radiography Education

On-the-job training of x-ray technicians in hospitals evolved into hospital-based educational programs. Formal classes and clinical experience were combined to provide students with the knowledge and skills needed to take radiographs and to assist with radiation therapy (x-ray treatments). As the fields of diagnostic and therapeutic radiology became more complex and specialized in the decade of the 1950s, education for radiation therapy technologists was separated from that for radiographers.

Colleges were first involved in radiography education because hospital-based radiography programs took advantage of the academic offerings at local colleges. Radiography students often attended college part-time to learn basic science subjects such as anatomy and physiology.

After World War II, with many returning soldiers wanting to attend college with the financial assistance provided by the GI Bill, junior colleges were developed to provide the first 2 years of academic education for university-bound students. In the 1960s, these institutions expanded and multiplied into the community college system that is currently a significant part of national public education in the United States. In the process of this expansion, more emphasis was placed on vocational education. Community colleges formed effective partnerships with companies and institutions that provided on-the-job training. Following this trend, many hospital-based radiography programs became affiliated with community colleges to provide the necessary academic courses. Some 4-year colleges and universities also began to offer educational programs in radiologic technology.

As the requirements for accreditation of educational programs in radiography have increased over the years (see Chapter 4), the organizational structure of colleges has proved to be well suited to the management of these programs. Today, colleges and hospitals still cooperate to provide education in radiography.

> Although many outstanding hospital-based programs exist, the majority of radiography programs are based in colleges.

OVERVIEW OF RADIOGRAPHIC PROCEDURE

Educational preparation provides the radiographer with the necessary knowledge and skills to confidently obtain a patient's radiographic images. To do this, the radiographer positions the patient's anatomic area of interest over the **image receptor (IR)** (Fig. 1.4A). The IR is placed on the tabletop to image small body parts, such as extremities. For larger anatomic areas, it can be placed in a tray beneath the table surface, or some digital tables have built-in IRs (see Chapter 2). The x-ray tube

Fig. 1.4 A, A radiographer aligns patient anatomy to an image receptor in a bucky tray. B, A radiographer aligns an x-ray tube to the patient and image receptor.

position is adjusted to align the x-ray beam to the IR (see Fig. 1.4B). The radiographer then goes to the control booth, sets the exposure factors on the control console, and activates the exposure switch.

During the exposure, x-rays from the tube pass through the patient. Different types of tissue absorb different amounts of the radiation, resulting in a pattern of varying intensity in the x-ray beam that exits on the opposite side of the patient. The radiation then passes to the IR and exposes it. The IR then has a pattern of exposure that is referred to as the **latent image.** Depending on the type of IR, a digital image may appear immediately on a monitor or the photostimulable IR plate may be scanned by a laser in a special processor to produce a digital image. Processing converts the latent image into a visible one. All imaging systems include methods for identifying images with the patient's name, the date, and the name of the facility.

As you may have suspected, many details were omitted from the previous paragraphs. This is only a brief introduction to the radiographic process. Next, we consider how x-rays are produced, their physical nature, and how their various characteristics relate to the process of radiography.

X-RAY PRODUCTION

Our tour will include a close look at a number of pieces of x-ray equipment. To better appreciate their purposes, it will be helpful to understand how x-rays are produced. There are four basic requirements for the production of x-rays:

1. A vacuum
2. A source of electrons
3. A target for the electrons
4. A high potential difference (voltage) between the electron source and the target

The container for the vacuum is the x-ray tube itself (Fig. 1.5), sometimes referred to as a *glass envelope*. It is made of borosilicate glass to withstand heat and is fitted on both ends with connections for the electrical supply. All the air is removed from the tube so that gas molecules will not interfere with the process of x-ray production.

The source of electrons is a wire **filament** at the electrically negative **cathode** end of the tube. It is made of the element tungsten, a large atom with 74 electrons orbiting around its nucleus. An electric current flows through the filament to heat it; this accelerates the movement of the electrons and increases their distance from the nucleus. Electrons in the outermost orbital shells get so far from the nucleus that they are no longer held in orbit; instead, they are flung out of the atom, forming an "electron cloud" around the filament. These free electrons, called a **space charge,** provide the needed electrons for x-ray production.

The **target** is at the electrically positive **anode** end of the tube, the end opposite the filament. The smooth, hard surface of the target is the site to which the electrons travel and is the place where the x-rays are generated. The target is also made of tungsten, which has a high melting point and withstands the heat produced at the anode during x-ray exposure.

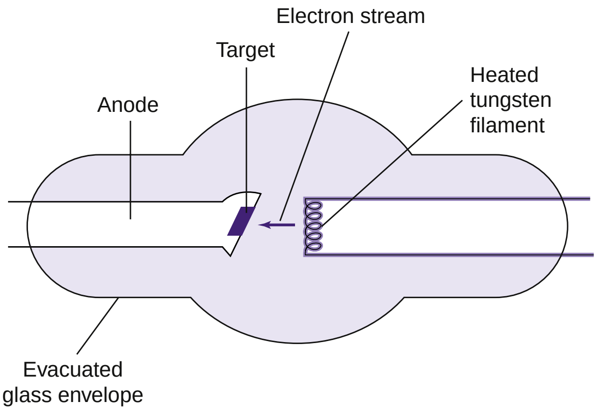

Fig. 1.5 Diagram of Coolidge tube simplifies understanding of x-ray production.

The voltage required for x-ray production is provided by a high-voltage transformer. The two ends of the x-ray tube are connected in the transformer circuit so that, during an exposure, the filament or cathode end is negative and the target or anode end is positive. The high positive electrical potential at the target attracts the negatively charged electrons of the space charge, which move rapidly across the tube, forming an **electron stream.** When these fast-moving electrons collide with the target, the kinetic energy of their motion must be converted into a different form of energy. The great majority of this kinetic energy is converted into heat (>99%), but a small amount is converted into the energy form known as *x-rays.*

> When fast-moving electrons collide with the target of an x-ray tube, the kinetic energy of their motion is converted into other forms of energy: heat and x-rays.

ELECTROMAGNETIC ENERGY

X-rays are among several types of energy described as **electromagnetic energy,** or electromagnetic wave radiation. They have both electrical and magnetic properties, changing the field through which they pass both electrically and magnetically. These changes in the field occur in the form of a repeating wave, a pattern that scientists call a *sinusoidal form* or **sine wave.**

Several characteristics of this waveform are significant. The distance between the crest and valley of the wave (its height) is called the **amplitude** (Fig. 1.6). More important to radiographers is the distance from one crest to the next, or **wavelength** (Fig. 1.7). The **frequency** of the wave is the number of times per second that a crest passes a given point.

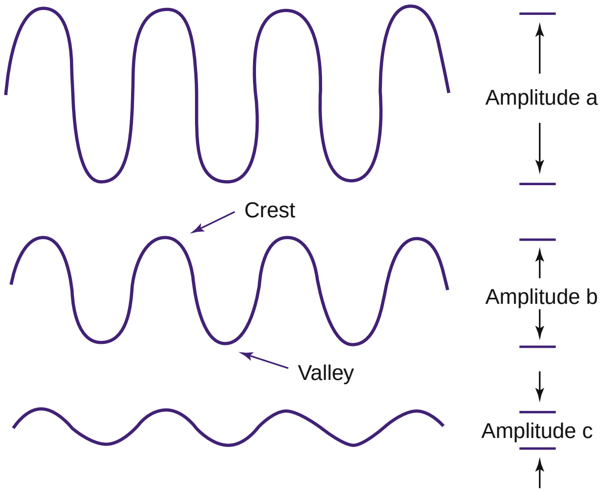

Fig. 1.6 These three sine waves are identical except for their amplitudes. (From Bushong SC: *Radiologic science for technologists*, ed 11, St Louis, 2017, Elsevier.)

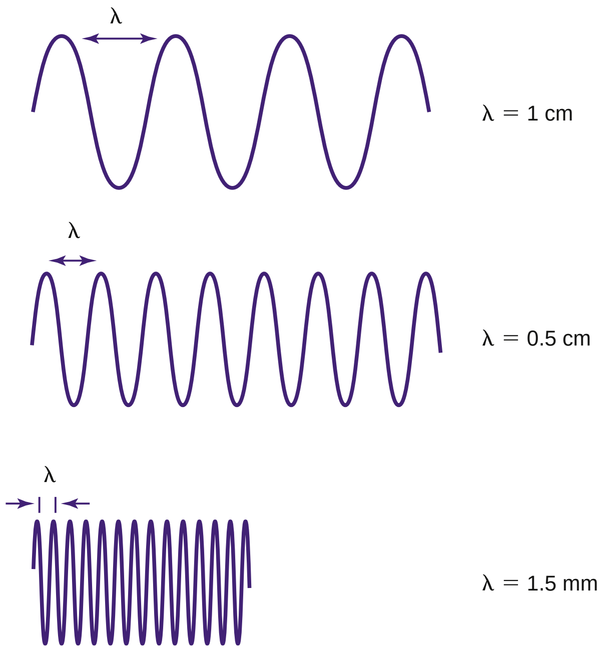

Fig. 1.7 These three sine waves have different wavelengths. The shorter the wavelength, the higher the frequency. (Note that the symbol for wavelength is the Greek letter lambda: λ.) (From Bushong SC: *Radiologic science for technologists*, ed 11, St Louis, 2017, Elsevier)

Because all electromagnetic energy moves through space at the same velocity—approximately 186,000 miles/sec, which is 30 billion (3×10^{10}) cm/sec—it is apparent that a relationship exists between wavelength and frequency. When the wavelength is short, the crests are closer together; therefore more of them will pass a given point each second, resulting in a higher frequency. Longer wavelengths will have a lower frequency; this can be expressed mathematically as follows:

$$\text{Velocity } (v) = \text{Wavelength } (\lambda) \times \text{Frequency } (f)$$

The more energy the wave has, the greater will be its frequency and the shorter its wavelength. We can therefore use either wavelength or frequency to describe the energy of the wave. In radiologic science, wavelength is more often used to describe the energy of the x-ray beam. The average wavelength of a diagnostic x-ray beam is approximately 0.1 nanometer (nm), which is 10^{-10} (0.0000000001) m, or approximately one-billionth of 1 inch.

The wavelength of electromagnetic radiation varies from exceedingly short (shorter than that of diagnostic x-rays) to very long (more than 5 miles). This range of energies is known as the *electromagnetic spectrum;* it includes x-rays, gamma rays, visible light, microwaves, and radio waves (Fig. 1.8). Radiation with a wavelength shorter than 1 nm (10^{-9} m) is said to be *ionizing radiation* because it has sufficient energy to remove an electron from an atomic orbit. X-rays are one type of ionizing radiation.

The smallest possible unit of electromagnetic energy (analogous to the atom with respect to matter) is the **photon,** which can be thought of as a minute "bullet" of energy. Photons occur in groups or bundles called **quanta** (singular, **quantum**).

> The smallest possible unit of electromagnetic energy is the photon, which can be thought of as a minute "bullet" of energy.

CHARACTERISTICS OF RADIATION

Because x-rays and visible light are both forms of electromagnetic energy, they share some similar characteristics. Both travel in straight lines, and both have a photographic effect. It is also important to remember because accidental exposure can occur when image receptors are placed near x-ray sources.

Both x-rays and light have a biologic effect; that is, they can cause changes in living organisms. Because of their greater energy, x-rays are capable of producing more harmful effects than light. Unlike light, x-rays cannot be refracted by a lens. The x-ray beam diverges into space from its source until it is absorbed by matter.

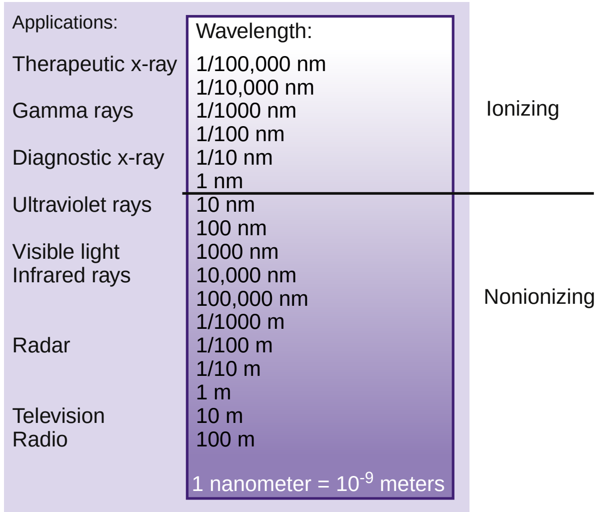

Fig. 1.8 Electromagnetic spectrum.

Unlike light, x-rays cannot be detected by the human senses. This fact may seem obvious, but it is important to consider. If x-rays could be seen, felt, or heard, we would have an increased awareness of their presence and radiation safety might be much simpler. Because they are undetectable, however, safety requires that you learn to know when and where x-rays are present without being able to perceive them.

X-rays can penetrate matter that is opaque to light. This penetration is differential, depending on the density and thickness of the matter. For example, x-rays penetrate air readily. There is less penetration of fat or oil, even less of water, which is approximately the same density as muscle tissue, and still less of bone. The effect on the x-ray beam caused by passing through matter is called **attenuation.** X-rays that have passed through the body are referred to as **remnant radiation** or exit radiation. Attenuation results in the absorption of a portion of the radiation and produces a pattern of intensity in the remnant radiation. This pattern reflects the absorption characteristics of the body through which it has passed; this pattern is recorded to form the image.

X-rays cause certain crystals to **fluoresce,** giving off light when they are exposed. Among crystals that respond in this way are barium platinocyanide, barium lead sulfate, calcium tungstate, and several salts consisting of rare earth elements. These crystals are used to convert the x-ray pattern into a visible image that can be viewed directly, as in fluoroscopy, or recorded on photographic film. The use of fluorescent intensifying screens to expose radiographs greatly reduced the quantity of radiation needed to produce images compared with that required for direct exposure of film. The combination of film and intensifying screens was the conventional IR for decades, but is now largely replaced by filmless technology that produces digital images. This topic is explored further in Chapter 2.

THE PRIMARY X-RAY BEAM

X-rays are formed within a very small area on the target (anode) called a **focal spot.** The actual size of the largest focal spot is no more than a few millimeters in diameter. From the focal spot, the x-rays diverge into space, forming the cone-shaped *primary x-ray beam* (Fig. 1.9). The cross section of the x-ray beam at the point where it is used is called the *radiation field*. A photon in the center of the primary beam and perpendicular to the long axis of the x-ray tube is called the *central ray*.

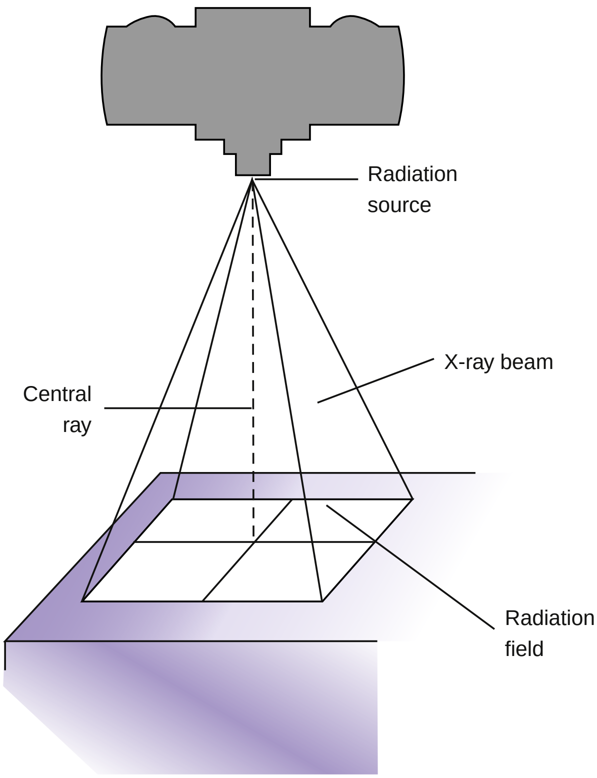

Fig. 1.9 A cross section of the x-ray beam is called the *radiation field;* an imaginary perpendicular ray at its center is called the *central ray*.

The x-ray beam size is restricted by the size of the port, the opening in the tube housing. Attached to the housing is the **collimator,** a device that enables the radiographer to further control the size of the radiation field.

SCATTER RADIATION

When the primary x-ray beam is attenuated by any solid matter, such as the patient or the x-ray table, a portion of its energy is absorbed. This results in the production of **scatter radiation** (Fig. 1.10). Scatter radiation generally has less energy than the primary x-ray beam, but it is not as easily controlled. It emanates from the source (usually the patient) in all directions, causing unwanted exposure to the IR and posing a radiation hazard to anyone in the room.

> Scatter radiation is the principal source of occupational exposure to radiographers.

The characteristics of primary radiation, scatter radiation, and remnant radiation are summarized for comparison in Table 1.1.

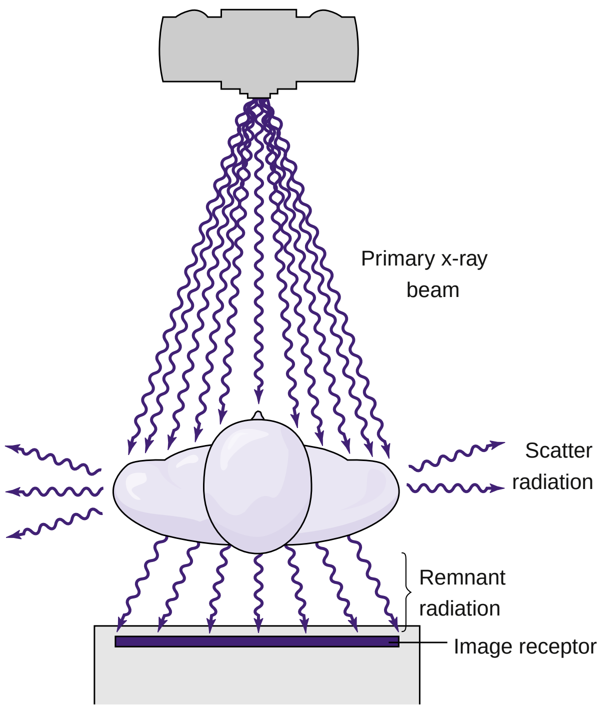

Fig. 1.10 Scatter radiation forms when the primary x-ray beam interacts with matter. (From Bushong SC: *Radiologic science for technologists*, ed 11, St Louis, 2017, Elsevier)

RADIOGRAPHIC EQUIPMENT

X-ray rooms vary in design, depending on their purpose. For example, a room dedicated to upright chest radiography might not have an x-ray table because the patients in this room would be standing for their examinations, not lying down. A room designed for gastrointestinal examinations would be equipped for both radiography and fluoroscopy. This dual-purpose equipment is described later in this chapter. A typical room designed for general radiography (Fig. 1.11) is suitable for many different types of x-ray examinations. In a hospital setting, the room will be fairly large, perhaps 18 × 20 feet in size, with wide doors to accommodate hospital beds and stretchers. Physical features will include the radiographic table, the x-ray tube and its support system, an upright IR cabinet against one wall, and a shielded control booth that contains the control console.

The X-Ray Tube

The x-ray tube is the source of the radiation. Modern multipurpose x-ray tubes (Fig. 1.12) are dual focus tubes. Their cathode assemblies contain two filaments, one large and one small (Fig. 1.13). Each is situated in a focusing cup that directs its electrons toward the same general area on the target portion of the anode. When the small filament is activated, its electrons are directed to a tiny focal spot on the target. The small filament and focal spot provide finer image detail when a relatively small exposure is appropriate—for example, when imaging a small body part such as a toe or wrist.

The large filament provides more electrons and is aimed at a somewhat larger target area. The combination of large filament and large focal spot is used when a large exposure is required, such as for radiographs of the lumbar spine or the abdomen, because the greater number of electrons meets the exposure requirements of the larger body part and the large focal spot can better handle the resulting heat at the anode. The anode is disk-shaped and rotates during the exposure (Fig. 1.14), distributing the anode heat over a larger area than the focal spot itself and increasing the heat capacity of the tube. It is the rotation of the anode that causes the whirring sound heard just before and after the exposure.

X-Ray Tube Housing

The x-ray tube is located inside a protective barrel-shaped housing (Fig. 1.15). The housing incorporates shielding that absorbs radiation that is not a part of the useful x-ray beam. The housing protects and insulates the x-ray tube while providing a base for the attachments that allow the radiographer to manipulate the x-ray tube and to control the size and shape of the x-ray beam.

TABLE 1.1 X-Ray Beam Attenuation

Type of Radiation	Definition	Travel Pattern	Energy Level
Primary radiation	The x-ray beam that leaves the tube and is not attenuated, except by air.	It originates at the tube target and expands in a cone-shaped beam that is perpendicular to the axis of the tube. Its direction and location are predictable and controllable.	Its energy is controlled by the kilovoltage setting.
Scatter radiation	Radiation scattered or created as a result of the attenuation of the primary x-ray beam by matter.	It travels in all directions from the scattering medium and is difficult to control.	Generally, it has less energy than the primary beam.
Remnant (exit) radiation	What remains of the primary beam after it has been attenuated by matter.	Its travel pattern is a continuation of the pattern of the primary beam.	Because the pattern of densities in the matter results in differential absorption, this pattern is inherent in remnant radiation. The pattern of intensity of remnant radiation creates the radiographic image.

Fig. 1.11 A typical room designed for general radiography.

X-Ray Tube Support

The tube housing can either be attached to a ceiling-mounted tube hanger or mounted on a tube stand. Both types of mountings provide support and mobility for the tube. A tube hanger (Fig. 1.16) is suspended from the ceiling on a system of tracks to allow positioning of the tube at locations throughout the room. This ceiling mount is useful when positioning the tube over a stretcher or when moving the tube for use in different locations. A tube stand is a vertical support with a horizontal arm that supports the tube over the radiographic table. The tube stand rolls along a track that is secured to the floor (and sometimes also the ceiling or wall), permitting horizontal motion.

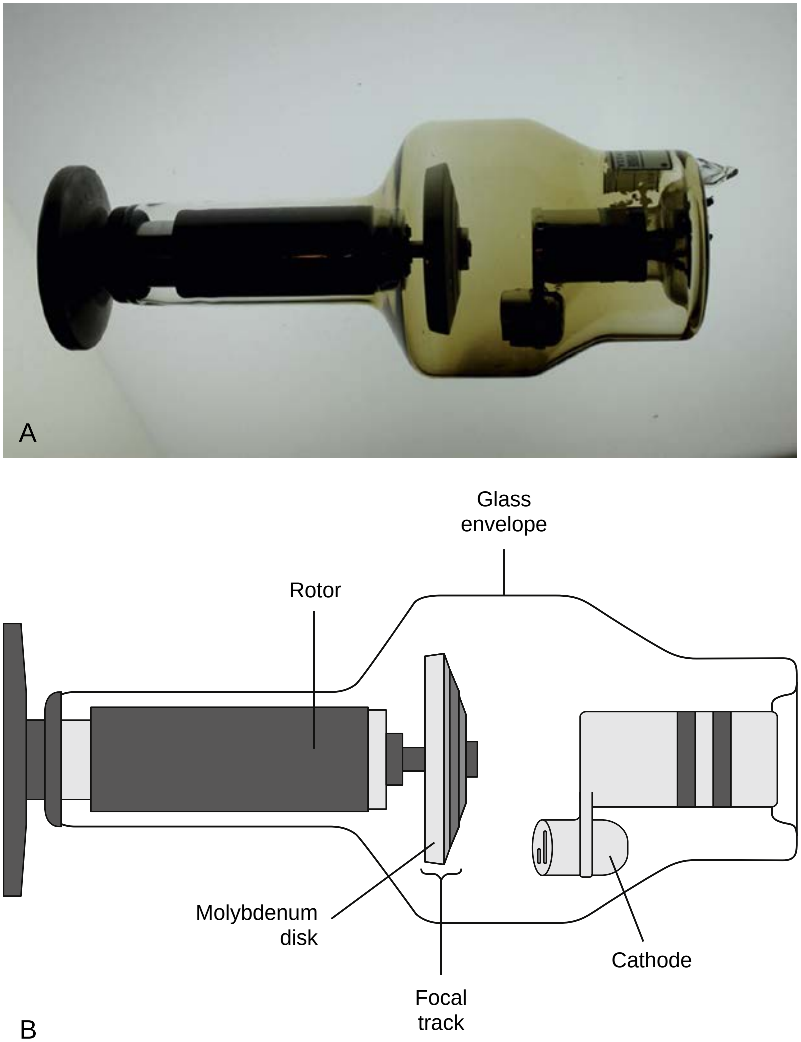

Fig. 1.12 A, Modern rotating-anode x-ray tube. B, Diagram of typical x-ray rube with key parts labeled.

A system of electric locks holds the tube support in position. The control system for all, or most, of these locks is an attachment on the front of the tube housing. To move the tube in any direction, the locking device must be released. Moving the tube without first releasing the lock can damage the lock, making it impossible to secure the tube in position.

> Do not attempt to move the x-ray tube without first releasing the appropriate lock.

Typical tube motions (Fig. 1.17) include the following:

- Longitudinal—along the long axis of the table
- Transverse—across the table, at right angles to longitudinal
- Vertical—up and down, increasing or decreasing the distance between the tube and the table

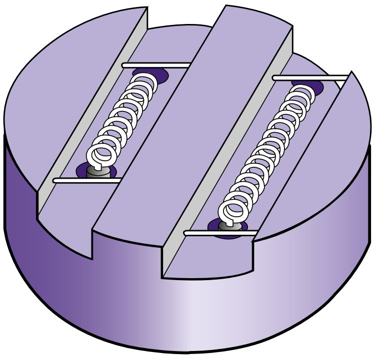

Fig. 1.13 Dual focus x-ray tube has focusing cups with large and small filaments. (From Long B, Frank E, Ehrlich RA: *Radiography essentials for limited practice,* ed 5, St Louis, 2017, Elsevier.)

- Rotation—allows the entire tube support to turn on its axis, changing the direction in which the tube arm is extended
- Roll (tilt, angle)—permits angulation of the tube along the longitudinal axis and allows the tube to be aimed at the wall rather than the table

A **detent** is a special mechanism that tends to stop a moving part in a specific location. Detents are built into tube supports to facilitate placement at standard locations. For example, a vertical detent will indicate when the distance from tube to IR is 40 or 48 inches, common standard distances. Other detents provide "stops" when the transverse tube position is centered to the table and when the tilt motion is such that the central ray is perpendicular to the table or to the upright IR cabinet.

Collimator

Another attachment to the tube housing is the collimator, a boxlike device mounted beneath the port. 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 (Fig. 1.18) There is usually also a centering light that helps to align the IR. Controls on the front of the collimator allow the radiographer to adjust the size of each dimension of the radiation field. The collimator has a scale that indicates each dimension of the field at specific source-image distances. A timer controls the collimator light, turning it off after a certain length of time—usually 15 to 30 seconds. This helps to avoid accidental overheating of the unit by prolonged use of its high-intensity light.

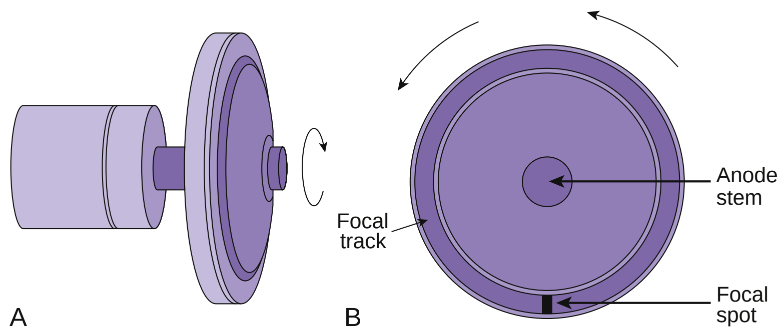

Fig. 1.14 Rotating anode. Electrons strike the anode in the tiny focal spot area, but the heat is spread around the entire focal track of the spinning anode face. A, Side view. B, View from cathode. (From Long B, Frank E, Ehrlich RA: *Radiography essentials for limited practice,* 5th ed, St Louis, 2017, Elsevier.)

Fig. 1.15 The tube housing *(arrow)* shields the tube and provides mounting for tube motion controls and collimator.

Fig. 1.16 Ceiling-mounted tube support.

Radiographic Table

The radiographic table (Fig. 1.19) is a specialized unit that is more than just a support for the patient. Although the table is usually secured to the floor, it may be capable of several types of motion: vertical, tilt, and "floating" tabletop.

For vertical table motion, a hydraulic motor, activated by a hand, foot, or knee switch, raises or lowers the height of the table. This motion allows the lowering of the table so that the patient can sit on it easily and permits the table to rise to a comfortable working height for the radiographer. Adjustments to exact stretcher height can be made to facilitate patient transfers. There will be a detent at the standard height for routine radiography. This standard table position corresponds to indicated distances from the x-ray tube. Because it is important that standard tube–IR distances be used, it is necessary to return the table to the detent position after lowering it for patient access. Not all tables are capable of vertical motion.

A tilting table (Fig. 1.20) also uses a hydraulic motor to change position. In this case, the table turns on a central axis to attain a vertical position; this allows the patient to be placed in a horizontal or vertical position or at any angle in between. The table can also tilt in the opposite direction, allowing the patient's head to be lowered at least 15 degrees into the **Trendelenburg position.** A detent stops the table in the horizontal position. Tilting is an essential feature of fluoroscopic tables and may also be a feature of a radiographic unit.

Special attachments for the tilting table include a footboard and a shoulder guard system to provide safety for the patient when tilting the table (Fig. 1.21). Pay particular attention to the attachment mechanisms so that you will be able to apply these devices correctly when needed.

> Before tilting a patient on the table, always test the footboard and shoulder guards to be certain that they are securely attached.

The motor that tilts the table is powerful and can overcome the resistance of obstacles placed in the way. Many step stools and other pieces of movable equipment have been damaged because they were under the end of the table and out of view when the table motor was activated. Such a collision can also damage the table motor.

> **!**
>
> Be certain that the spaces under the head and foot of the table are clear before activating the tilt motor.

A floating tabletop allows the top of the table to move independently of the remainder of the table for ease in aligning the patient to the x-ray tube and the IR. This motion may involve a mechanical release, allowing the radiographer to shift the position of the tabletop manually, or it may be power-assisted, activated by a small control pad with directional switches. Power-assisted movement is usual for fluoroscopic tables.

Grids and Buckys

You will recall from an earlier part of this chapter that when primary radiation encounters matter, such as the patient or the x-ray table, the resulting interaction

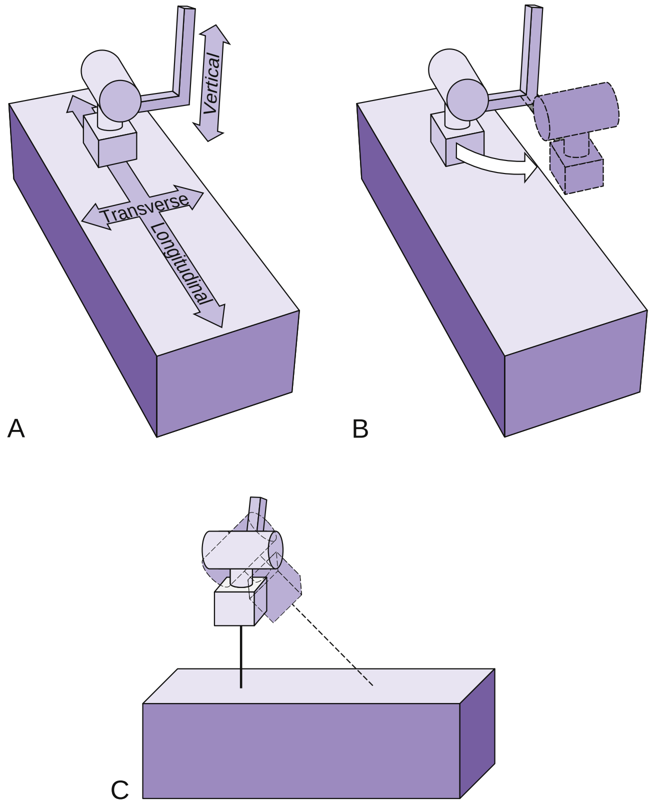

Fig. 1.17 Tube motions. A, Longitudinal, transverse, and vertical. B, Rotation. C, Angulation. (From Long B, Frank E, Ehrlich RA: *Radiography essentials for limited practice,* ed 5, St Louis, 2017, Elsevier.)

Fig. 1.18 Collimator light defines the radiation field and aids in the alignment of the bucky tray.

Fig. 1.19 Radiographic table.

produces scatter radiation. Most of the scatter produced during an exposure originates within the patient. This scatter radiation causes fog on the radiographic image, a generalized exposure that compromises the visibility of the anatomic structures. **Grids** and **buckys** are devices to prevent scatter radiation from reaching the IR.

> Grids and buckys prevent scatter radiation from reaching the IR and producing fog that degrades the image.

A bucky is usually located beneath the table surface; it is a moving grid device that incorporates a tray to hold the IR (Fig. 1.22). The entire unit can be moved along the length of the table and locked into position where desired. The grid that is incorporated into the bucky device is situated between the tabletop and the IR (Fig. 1.23). It is a plate made of tissue-thin lead strips, mounted on edge, with radiolucent interspacing material (Fig. 1.24). The strips must be carefully aligned to the path of the primary x-ray beam, so precise alignment of the x-ray tube is essential. In most radiographic units, the grid moves during the exposure. The purpose of moving the grid is to blur the image of the thin lead strips so that they are not visible on the radiograph. When the table has a floating tabletop, the bucky mechanism and IR tray do not move with the tabletop.

Fig. 1.20 The hydraulic fluoroscopic table tilts to change the patient's position. A, Semi-upright position. B, Trendelenburg position.

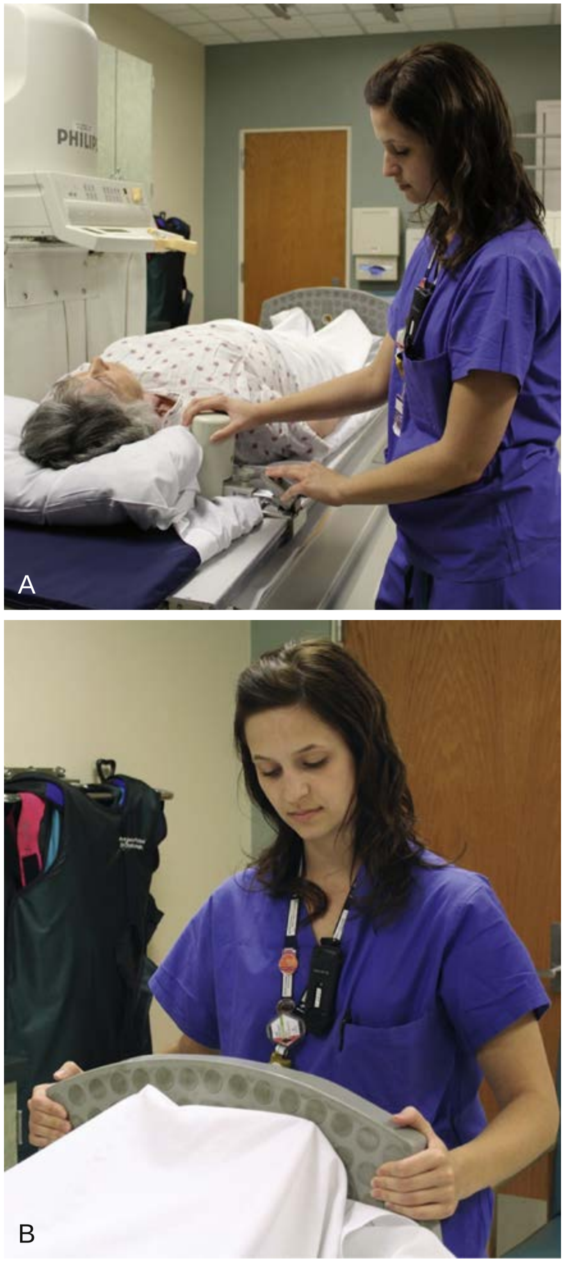

Fig. 1.21 Table attachments must be secured carefully for patient safety before tilting the table. A, Footboard. B, Shoulder guard.

Stationary grids that do not move during the exposure serve the same purpose as a bucky. A grid can also be incorporated into a device called a **grid cap,** which is a grid mounted in a frame that can be attached to the front of an IR for mobile radiography and other special applications.

Grids or buckys are generally used only for body parts that measure more than 10 to 12 cm in thickness. (The average adult's neck or knee measures 12 cm.) When a grid is not needed, the IR is placed on the tabletop.

> Grids or buckys are generally used only for body parts that measure more than 10 to 12 cm in thickness.

Fig. 1.22 The bucky tray holds the image receptor within the x-ray table.

Upright Image Receptor Units

An upright device holds the IR in position for upright radiography (Fig. 1.25). It is adjustable in height and can incorporate a grid. Even if the table tilts to the upright position, it is common to have a separate upright unit for some examinations, such as those of the cervical spine and the chest. When the patient is sitting or standing at the upright device, the tube is angled to direct the x-ray beam toward the IR. The distance may be adjusted to 40, 48, or 72 inches, depending on the requirements of the procedure.

Transformer

Cables from the tube housing connect the x-ray tube to the transformer, which provides the high voltage necessary for x-ray production. Some transformers look like a large box or cabinet, which may be located within the x-ray room. Newer transformer designs are much smaller and may be incorporated into the control console.

Control Console

The control console, located in the control booth, is the access point for the radiographer to determine the exposure factors and to initiate the exposure (Fig. 1.26). 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; determines the focal spot size

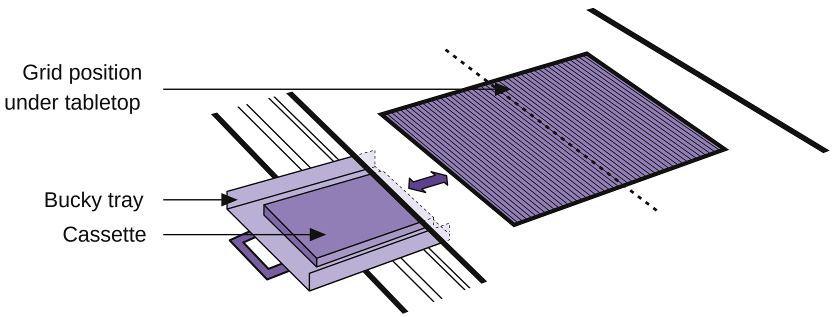

Fig. 1.23 The bucky device for scatter radiation control incorporates a tray for the image receptor and is mounted under the tabletop. Note that the lead strips are parallel to the long axis of the table. (From Long B, Frank E, Ehrlich RA: *Radiography essentials for limited practice,* ed 5, St Louis, 2017, Elsevier.)

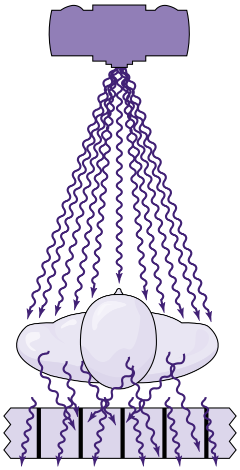

Fig. 1.24 Lead strips in the grid absorb scatter radiation emitted from the patient; remnant radiation passes through the grid and exposes the image receptor. (From Bushong SC: *Radiologic science for technologists*, ed 11, St Louis, 2017, Elsevier.)

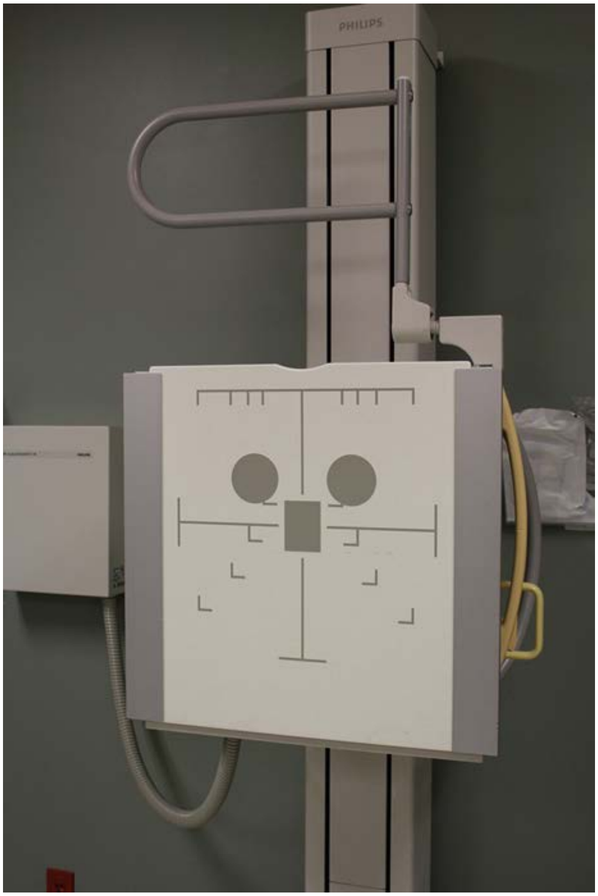

Fig. 1.25 Upright image receptor device.

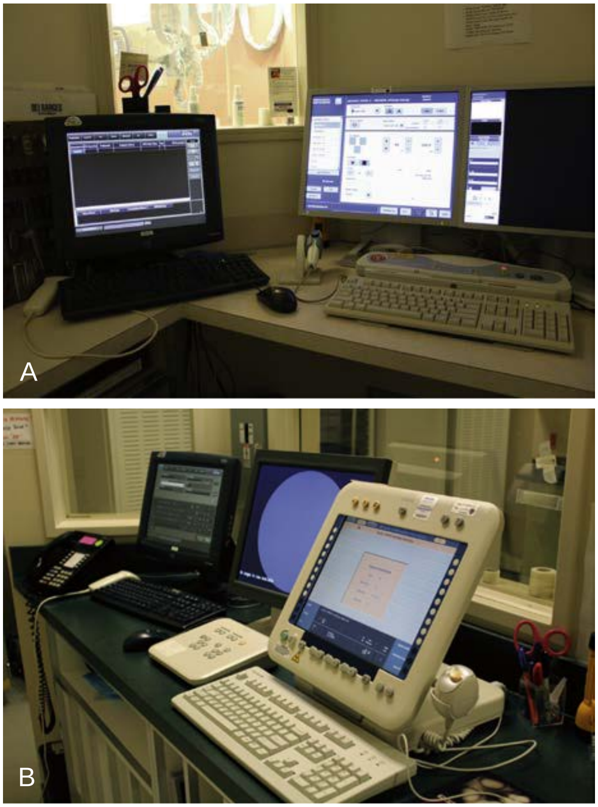

Fig. 1.26 Examples of x-ray control consoles. (A) Simple computerized radiographic controls. (B) Controls for filmless radiography with digital fluoroscopy.

- kVp—controls the kilovoltage, and thereby the wavelength and 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; the mAs (the product of mA and time) determines the total quantity of radiation produced during an exposure
- Bucky—activates the motor control of the bucky device so that the grid will move during the exposure
- Automatic exposure controls—special settings available on units that allow termination of exposure when a certain quantity of radiation has reached the IR
- Meters or digital readouts to indicate the status of the settings
- Prep (ready or rotor) switch—prepares the tube for exposure and must be continuously activated until exposure is complete