Connecticut Podiatric Medical Association

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FOOT & ANKLE SPECIALISTS

RADIOLOGY CERTIFICATION COURSE

Discovery of X-rays

In 1895, German physicist Wilhelm Konrad Roentgen was operating a vacuum tube at high voltage when he noticed a glow coming from cardboard coated with a chemical, several feet away from the tube. He realized that this glow, or fluorescence, was caused by the invisible radiation leaving the vacuum tube. Since the rays were new and without a name, they were called X (for unknown) rays, and sometimes Roentgen rays, after their discoverer.

Properties of X-rays

X-rays are a form of **electromagnetic radiation**[1] similar to **gamma radiation.**[2] To understand how such radiation behaves, imagine a person throwing a stone into a lake. The water moves in all directions away from the stone. Radiation moves away from its source in a wavelike motion similar to the movement of the water. Although x-rays are the same type of radiation as radio, or visible light waves, they have higher energy photons and a much **shorter wavelength**. For example, the wavelengths used in television are approximately six feet, whereas the average wavelength of medical x-rays is about one-billionth of an inch.

Because x-rays have such short wavelengths, they can penetrate matter, whereas other types of electromagnetic radiation, such as visible light, are absorbed or reflected. When x-rays are produced, they travel in straight lines at an extremely fast speed--186,000 miles per second, the speed of light. Although invisible, they can cause certain substances to fluoresce, or glow. They produce an image on a photographic film that can be made visible by processing. X-rays are electrically neutral; in other words, they are neither positive nor negative.

Some of the properties of x-rays are listed below.

X-rays:

- are a form of electromagnetic radiation like gamma radiation
- have higher-energy photons and shorter wavelength than visible light
- penetrate most forms of matter
  NOTE: X-rays do not readily penetrate certain dense materials such as lead.
- travel at the speed of light (186,000 miles per second)
- affect photographic film very much as light rays do
- make certain chemicals emit light (fluorescence)
- can ionize matter, including living tissue
  NOTE: This property of x-rays can produce biological changes and cause damage to the human body.
- cannot be seen, heard, or felt
- travel in a straight line from their source, though they may be deflected by atoms they meet
- obey the inverse square law (This law is discussed in Section C of this unit.)
- cannot be reflected

Interaction of X-rays with Matter

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[1] electromagnetic radiation: the transmission of energy via **photons*** at the speed of light
* **photon**: a very small bundle of electromagnetic energy
[2] gamma radiation: electromagnetic radiation spontaneously emitted from radioactive materials

When x-rays enter an object, some of the x-ray photons interact with the object's atoms and some do not. When they do, radiant energy is transferred from the x-rays to the atoms. This transfer of energy is called absorption. The remaining x-ray photons, those that do not interact with atoms, travel in straight lines and can produce an image on a film showing the size, shape, and internal composition of the object. When the object is the human body, this image on a radiographic film is used for diagnosis.

Types of Radiation

As the electrons interact with the atoms of the target, photons of various energies emerge from the target. Most of these photons are directed toward the object being radiographed, and a few of them are not. Those photons directed toward the object are called **primary radiation**, and those which are not are called **leakage radiation**. The primary radiation is then divided into **remnant** and **attenuated radiation**. The primary photons that pass through the object being radiographed and reach the film are the **useful x-ray beam**, and they are called remnant radiation. The primary photons that interact with atoms of the object are called attenuated radiation (see Figure I). When it interacts with the object, the attenuated radiation is divided into **scatter radiation** and **absorption**. Since scatter radiation and leakage radiation are not useful for radiographic procedures, they are categorized as **secondary** radiation. These different types of radiation can be depicted as follows:

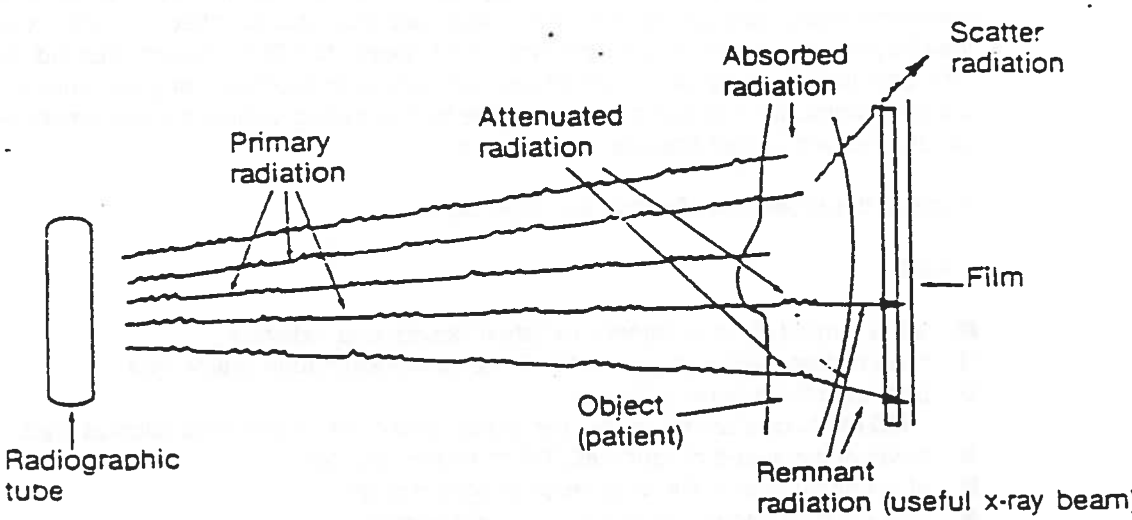

Figure I
Types of Radiation

The **exposure rate** is the number of roentgens produced by the x-ray machine per second. In other words, it is the intensity of radiation. Exposure rate can be expressed, for example, as R/min (roentgens per minute) or R/hr (roentgens per hour).

Rad--Unit of Absorbed Dose (D). The absorbed dose of radiation, known as D, is the amount of energy absorbed by a substance or object. A **rad** refers to a unit of the absorbed dose. As the amount of exposure (R) increases, so does the absorbed dose (D). The higher the quantity of the absorbed dose in the human body, the greater the chance of biological damage occurring.

Rem--Unit of Dose Equivalent (H). The dose equivalent, known as H, takes into account the fact that the biological effects of ionizing radiation on human body tissue are dependent not only on the absorbed dose, but also on other factors. The **rem** is the unit used to measure dose equivalent.

The following table lists the ionizing radiation quantities with their units of measure, the media, and the effects measured.

QUANTITY	UNIT OF MEASURE	MEDIUM	EFFECT MEASURED
exposure	roentgen (R)	air	ionization of air
absorbed dose (D)	rad	any object	amount of energy absorbed by the object
dose equivalent (H)	rem	human body tissue	biological effects

Summary

X-rays are a form of electromagnetic radiation (like gamma radiation) that can penetrate and ionize matter, including human tissue. Ionizing radiation has both natural and man-made sources. X-rays, a type of ionizing radiation, are produced when electrons are made to strike a positively charged target in the radiographic tube and to interact with the atoms of the target. Radiation can be categorized into two main types: primary radiation and secondary radiation. Primary radiation is the useful x-ray beam, and secondary radiation consists of leakage and scatter radiation. Three units of measurement are used in determining the amount of ionizing radiation: roentgen for radiation exposure, rad for absorbed dose, and rem for dose equivalent.

The Cells and Their Radiosensitivity

The human body is composed of various types of cells that perform many different functions. Every mature human cell is highly specialized, having a specific function to perform. The cell's specialized function is determined by the structure of the cell's molecules. Most of these cells can be damaged by ionizing radiation, because ionization can change the structure and chemical balance of the cell's constituent molecules. This molecular change, then, changes the cellular functions.

Different types of cells can be exposed to different amounts of radiation before damage occurs, since the degree of their radiosensitivity differs. The lower the cells' degree of specialization and the faster their division, the greater their radiosensitivity.

Immature cells, which are nonspecialized and which undergo rapid cell division, **are more radiosensitive than mature cells**, which are specialized in function and which divide slowly or have ceased to divide.

Lymphocytes (white blood cells) are among the most radiosensitive of the blood cells. Female and male reproductive cells (ova and spermatogonia) are very radiosensitive. The cells that become the linings and covers of body organs (epithelial cells) have moderately high sensitivity. Muscle and nerve cells, which are highly specialized and do not divide, have low sensitivity.

Two Categories of Biological Effects

The biological effects of ionizing radiation can be considered in two categories: genetic effects and somatic effects.

Genetic Effects. Molecular damage to DNA molecules in the sperm or ova can cause biological damage in offspring. Though these effects may not show up for years or for generations after the exposure is received, they may be passed on from one generation to another. Because the radiation dose at the gonads (ovaries and testes--where egg and sperm, respectively, are manufactured and stored) is genetically significant, it is called the genetically significant dose (GSD). Gonadal shielding (discussed in the next section) is important to minimize the amount of radiation received by the male or female gonads.

NOTE: Symptoms of genetic effects are also called genetic dose indicators.

Somatic Effects. Forms of biological damage that affect the individual but that are not passed on to the offspring are called somatic effects. These effects can be either short-term or long-term depending upon the length of time between the exposure and the appearance of symptoms of the damage.

NOTE: Symptoms of somatic effects are also called somatic dose indicators.

Embryological effects are the effects of radiation on the embryo or fetus during its development. These effects vary in severity during each of the three major periods, or trimesters, of gestation. As the pregnancy progresses, radiosensitivity decreases.

The most severe effects occur during the **first trimester**. Exposure to x-radiation during the first six weeks often causes death or abnormalities. Between the second and sixth week of the first trimester, during **organogenesis** (when major organs are developing), the fetus is extremely susceptible to radiation-caused abnormalities.

Radiation sensitivity decreases during the second and third trimesters. Even at these stages, however, abnormalities and disorders can result from radiation exposure.

Protection of X-Ray Machine Operators

As a basic x-ray machine operator, you will be exposed to radiation from several sources:

- radiation from accidental exposure to the primary x-ray beam when, for example, you hold a patient
- scatter radiation from patients
- scatter radiation from other surfaces, such as walls, floor, and x-ray table
- leakage radiation from the radiographic tube

Three Basic Protection Measures

The radiation exposure you receive as a result of your occupation is called **occupational exposure**. You can minimize occupational exposure by practicing basic radiation protection measures. These measures involve time, distance, and shielding accessories.

Time. Keep the time of exposures short as possible. The quantity of radiation received by an individual is directly related to the amount of exposure time. If the exposure time is doubled, the dose is doubled. By the same accounting, cutting the time in half will cause the exposure to be reduced by 50 percent.

Distance. Maintain a considerable distance between yourself and the radiographic tube, the source of radiation. As the distance from the source of the x-ray beam increases, the **intensity of the radiation** (also called **exposure rate**) beam decreases. Thus, the greater the distance, the smaller the radiation intensity. **If the distance is doubled, the intensity is decreased** to 1/4 the original exposure. A distance increased by three times will reduce the radiation intensity to 1/9 the original exposure. This relationship is known as the **inverse square law,** which states that the radiation intensity is inversely proportional to the square of the distance.

As Figure II and this example show, when the original distance (D_1)is doubled (D_2), the radiation is spread over an area four times larger, but the exposure rate, or radiation intensity, is reduced, to 1/4 of the original exposure.

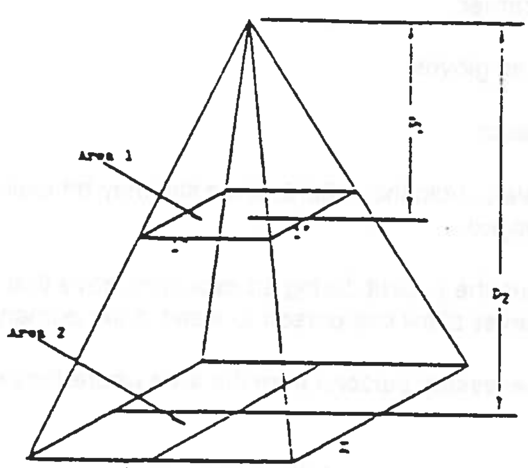

Figure II
Inverse Square Law

NOTE: The distance from the source of radiation to the film is called target to film distance (TFD), source to image detector (SID), or focal film distance (FFD). These three terms are used interchangeably.

Shielding Accessories. Use protective shielding routinely. Shielding refers to **radiopaque**[8] materials inserted between the source of radiation and the individual. Shielding accessories such as protective barriers, aprons, and gloves are generally made of lead.

While activating radiographic equipment, you should stand behind the protective lead barrier or wear a protective lead apron or gloves.

NOTE: The National Council on Radiation Protection and Measurements (NCRP) recommends that the thickness of the lead in shielding accessories be as follows:

lead aprons	.5 mm Pb (lead or equivalent)
lead gloves	.25mm Pb (lead or equivalent)
Bucky slot cover	.25mm Pb (lead or equivalent)

1.5 mm Pb (1/16 inch lead)

Summary

The basic measures that the x-ray machine operator can take to protect against occupational exposure to radiation involve three factors: time, distance, and shielding. Even with the proper exposure time, TFD, shielding accessories, and protective barriers, you and other persons can be exposed to radiation unnecessarily if you are not careful.

- The following state what you should and should not do when making an exposure:
- Stand behind the protective barrier.
- Wear protective lead apron and gloves.
- **Never** stand in the primary beam.
- **Never** allow a pregnant female to hold the patient, since she may be exposed to radiation and the embryo or fetus may be damaged.
- When another person restrains the patient during an exposure, have that person wear protective lead apron and gloves and **never** allow that person to stand in the primary beam.
- Make sure to remove all unnecessary persons from the area where they can be exposed to radiation.
- **Never** hold the patient or touch accessories during exposure.
- Keep the time of exposure as short as possible.
- Keep as great a distance as possible between you and the source of radiation.

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[8] radiopaque: having the capacity to absorb (rather than transmit) a relatively large amount of the x-rays passing through

Patient Protection

The overexposure of the patient to radiation during a radiographic examination can be reduced by several means: by preparing and positioning the patient properly, by restricting the primary beam (collimation), by using a filter in front of the radiographic tube opening, by providing gonadal shields, by selecting appropriate exposure factors, and by using radiographic accessories.

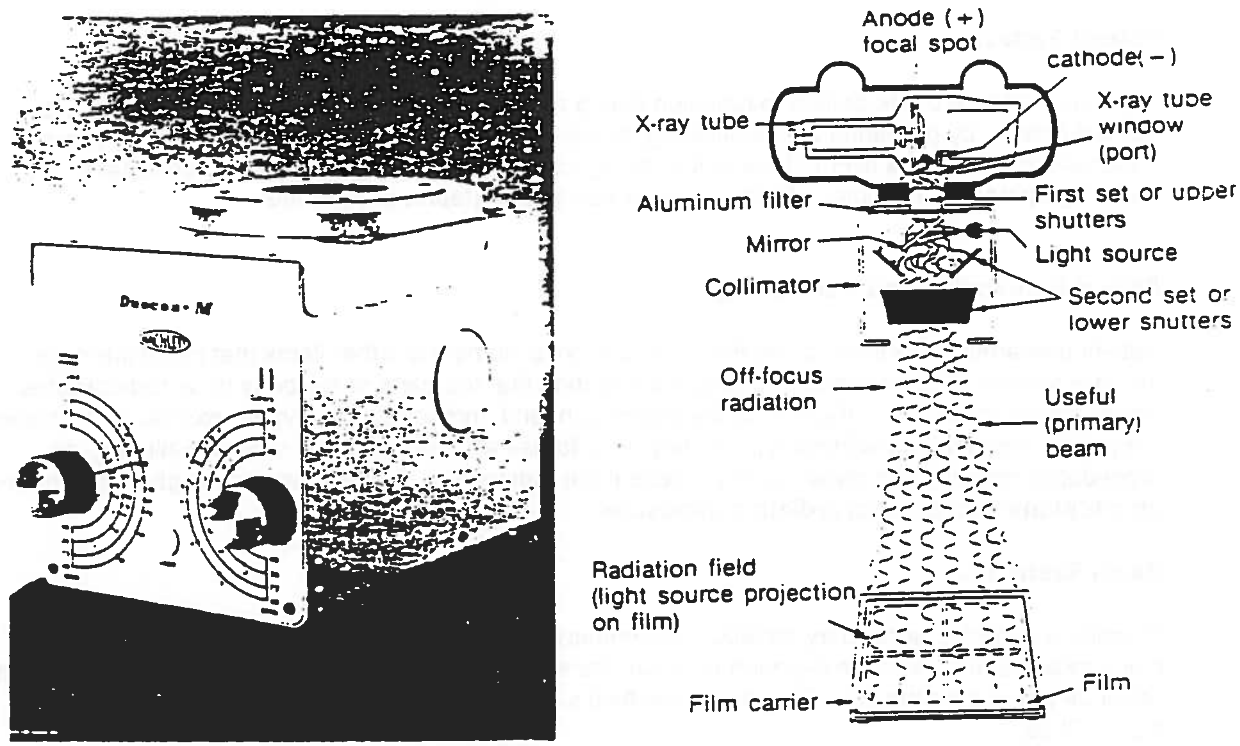
Patient Preparation and Positioning

Patient preparation requires having the patient remove clothing or other items that might interfere with the examination. Patient positioning requires ensuring that the parts of the body to be radiographed are clearly visible, centered in the field of the radiograph, and immobilized during the exposure. To prevent the patient from moving voluntarily, you may need to use an immobilization device. Failure to do procedures correctly can mean having to repeat the radiograph. **A needless repeat gives the patient an additional 100 percent radiation exposure.**

Beam Restriction

In order to minimize secondary radiation, the primary x-ray beam should be limited to the body part being radiographed, and the radiation field size (size of the beam or size of the field exposed) should never be larger than the film. The smaller the field size, the smaller the amount of scatter radiation there will be.

Collimators. A collimator is the best device for restricting the primary beam. The collimator is attached to the tube housing of the x-ray machine. It has two sets of lead shutters that can be adjusted to restrict the size of the radiation field to no larger than the film size (see Figure III).



A B

Figure III
Exterior (A) and Interior (B) of Collimator

A: Courtesy of Machlett Labs, Ins., Stamford, Connecticut.

B: Reproduced by permission from Statkiewicz, M.A., and Ritenour, E.R.: *Radiation Protection for Student Radiographers*, Denver, 1983, Multi-Media Publishing Co.; copyrighted by the C.V. Mosby Co., St. Louis.

One set of shutters is adjusted to reduce the amount of off-focus radiation coming from the primary beam and exiting from the radiographic tube housing. The other set of shutters is adjusted to confine the radiographic beam to the body part radiographed. For protection against exposure, the surface of the patient's skin should be at least 15 centimeters below the collimator. Most x-ray machines manufactured before August 1974 had manually adjusted collimators. By manually adjusting the collimator, an x-ray machine operator can use a radiation field smaller than the size of the cassette, thus reducing unnecessary radiation to the patient.

Since 1974, the federal government has required that every radiographic machine have a positive beam limitation (PBL) device. The PBL device automatically adjusts the collimator so that the radiation field size is no larger than the film. Figure I-C-5 shows a properly collimated radiographic beam, which minimizes scattered radiation, and an improperly collimated radiographic beam, which results in extra scattered radiation.

Collimators are equipped with a light and mirror assembly, known as the **light localizer**, which projects a light field through the collimator opening onto the patient's body and shows the size and location of the x-ray beam. Because the light localizer enables the machine operator to see the actual location of the x-ray beam prior to making the exposure, the operator can project the light source onto the film and accurately place the radiation field.

Shielding for Patients

Gonadal Shields. A gonadal shield is a radiopaque material placed between the x-ray source and the gonads (female ovaries or male testes) to reduce the radiation dose. Its main purpose is to protect the gonads from exposure to the primary x-ray beam when the gonads are within range of the properly collimated beam. Gonadal shielding should be used in addition to and not instead of proper beam limitation for all patients--adults and children--with reproductive potential.

Techniques for testicular shielding are better established than for ovarian shielding. The anatomical location of the testes is such that covering them with a shield usually does not obscure needed clinical information. On the other hand, the location of the ovaries often interferes with the visualization of other structures.

The **contact shield**, also made of radiopaque material (usually containing lead), is placed directly on the patient. The most common kind is the **flat contact shield.** These shields are pieces of lead-impregnated rubber in various shapes. A contact shield is placed on the patient above the gonads. Since flat contact shields are difficult to secure in place, they are best suited to recumbent projections and to anteroposterior (AP) or posteroanterior (PA) views.

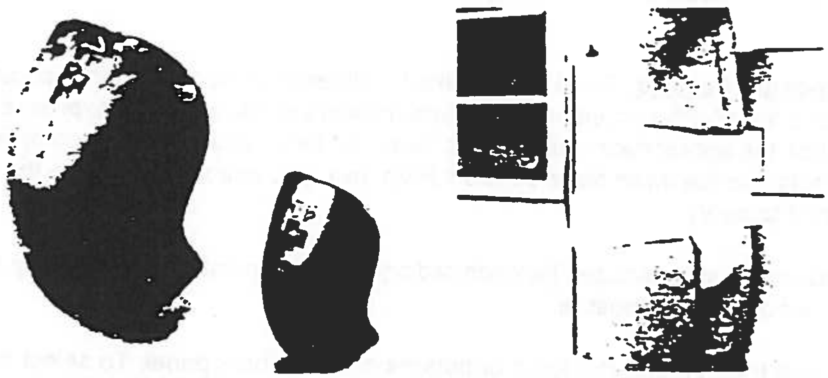


Figure IV
Shaped Contact Shields

Courtesy: Nuclear Associates, Carle Place, New York.

Exposure Factors

Other techniques for exposure reduction are related to technical factors, which fall into two groups: exposure factors and radiographic accessories.

Three Primary Exposure Factors. The factors that control the quantity and quality (penetrating power) of the radiation produced are called primary exposure factors. These factors affect how much radiation will reach the film and how energetic the radiation will be to penetrate the patient and reach the film. The three primary factors are kilovoltage peak (kVp), milliamperage (mA), and exposure time (s).

The **kilovoltage peak (kVp)** is the energy of the electron beam inside the radiographic tube at its peak value. The amount of kVp selected affects radiation exposure by determining the energy of the x-ray photons, which in turn determines the penetrating power of the x-ray beam. That is, the amount of kVp selected determines the amount of force that will be used to accelerate the electrons from the filament to the target. With a higher kVp, the force with which the electrons strike the target will be greater. The greater the force, the more penetrating the energy of the x-rays will be. In other words, the higher the kVp, the higher the quality of the beam.

The amount of **milliamperage (mA)** selected controls the rate at which electrons are emitted from the heated filament. The higher the mA, the hotter the filament and the more electrons omitted. Therefore, the amount of mA selected controls the quantity of radiation produced.

The **length of exposure time (s)** selected also affects the quantity of radiation. The longer the exposure time, the higher the quantity of radiation produced. The combination of these two exposure factors, exposure time and mA, is known as **milliamperes per second (mAs).**

With all other factors remaining constant, an increase in the TFD will result in a decrease in the quantity of x-rays striking the film, while a decrease in the TFD will result in an increase in quantity. As discussed in the previous section, this is the principle of the inverse square law.

Selection of Exposure Factors. Since each patient is different in size and condition and since different body parts are of different sizes, the operator must be able to adjust exposure factors on the machine to produce the appropriate radiographic beam for every situation. In accomplishing this purpose, you should use the three basic controls (kVp, mA, and exposure time) on the x-ray machine control panel (see Figure V).

NOTE: Since distance is standardized for each radiographic examination, you usually do not adjust distance to alter radiographic exposure.

To set the kVp, use the kVp selector knob or buttons on the control panel. To select the appropriate kVp, take into consideration how much penetration the body part being radiographed requires. For example, the femur is much heavier than the bones of the hand; therefore, the kVp required to radiograph the femur is higher than that required for the hand.

To select the appropriate mA, adjust the mA control knob or buttons for the particular radiographic examination, as shown on the technique chart you are using. By doubling the mA, you double the amount of x-rays produced.

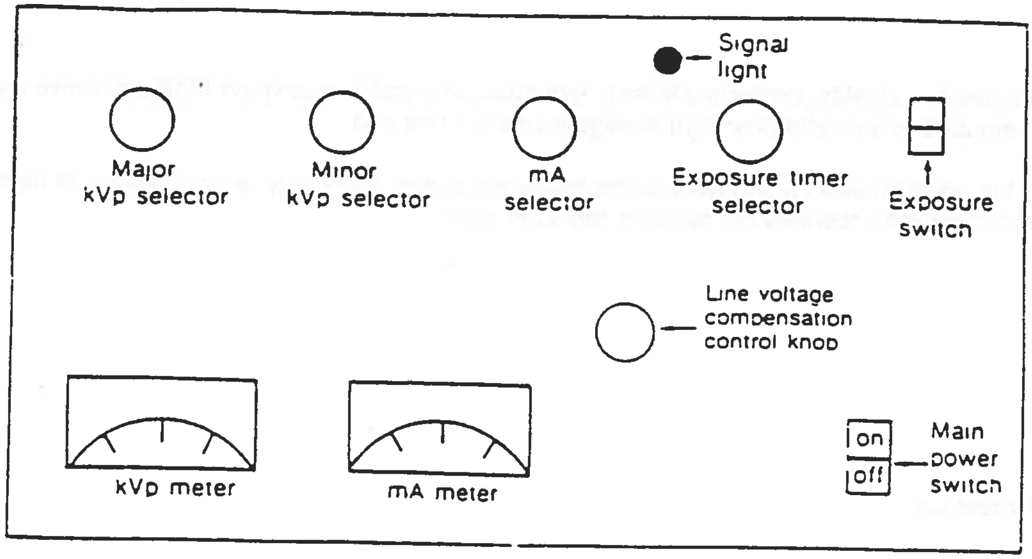


Figure V
The X-ray Control Panel

Since a high kVp produces a more penetrating x-ray beam and a high mAs produces more radiation, a **combination of higher kVp and lower mAs reduces the patient's radiation dose.** For the proper selection of these exposure factors, use the standardized technique charts.

To determine how long x-ray production will take place, set the timer on the control panel. Through the selection of time and mA (mAs), you can control the quantity of x-rays, and you can select the fastest time possible without changing the quantity.

For example:

- If you use 100 mA for 1 second, you are using 100 mAs, because 100 mA x 1 second = 100 mAs.
- If you use 200 mA for 1/2 second, you are still using 100 mAs, because 200 mA x 1/2 second = 100 mAs.

Summary

- To protect patients from overexposure to radiation, you should do the following:
- Instruct patients to remove clothing and jewelry before the exposure and to breathe properly and remain immobile during the exposures.
- Use a collimator to restrict the beam to the area to be radiographed. (Remember, the smaller the field size, the less scatter radiation produced.)
- Adjust filter.
- Use gonadal shields over male and female reproductive organs prior to taking radiographs, when Indicated.

- Place protective shields (protective lenses, eye cups, or thyroid collars) over radiosensitive organs when repeated examinations or high dosage levels are required.

- Select the appropriate kVp and mAs, using technique charts. Generally, a combination of higher kVp and lower mAs reduces the patient's radiation dose.

Patient Protection

Radiographic Accessories

When taking a radiograph, you will need to use radiographic accessories such as radiographic film, screen, patient immobilization devices, and phototimer. By using the right combination of these, you can reduce the amount of exposure to the patient and yourself while producing a high-quality radiograph.

Radiographic Film. Radiographic film is similar to photographic film. Each type consists of two components, the film **base** and the **emulsion**.

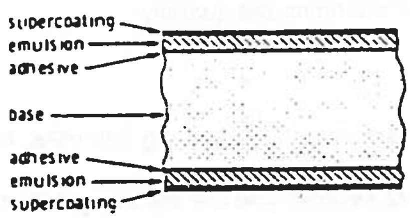


Figure VI
Cross Section of Radiographic Film

Reproduced by permission from: Bushong, Stewart C.: Radiologic Science for Technologists, ed. e, St. Louis, 1984, The C.V.Mosby Co.

Film base. A blue-tinted, transparent sheet of polyester plastic, about 0.008 inch thick, makes up the base of radiographic film. The main purpose of the film base is to provide a support for the emulsion. It also provides a certain degree of stiffness needed for handling. The polyester base is excellent for automatic processing because it is easily transported through the rollers of automatic processors.

Emulsion. Radiographic film emulsion (which covers both sides of the film base) consists of a mixture of **gelatin** and **silver halide** crystals. The mixture transmits light and allows the absorption of chemicals during the development process. Gelatin provides support for the silver halide crystals. A thin layer of adhesive subcoating attaches the emulsion to the film base.

Silver halide crystal is comprised of 95 percent silver bromide and 5 percent silver iodine. When x-rays and light photons interact with the silver halide, it is transformed into irregular clumps and strands of black metallic silver, and produces the image on the radiograph.

Before the radiographic film is developed, the image, which cannot yet be seen, is known as the **latent image**. The actual radiographic image that is visualized after the film is processed is called the **manifest image**, or the visible image.

Types of radiographic film. The type of radiographic film used for an examination will in part determine the amount of radiation exposure required. Radiographic film, like other photographic film, is available in a wide range of speeds and latitudes. **The speed of the film determines the quantity of radiation** required to produce a given density on the film. Latitude refers to the exposure range that will produce approximately the same density.

Two types of radiographic film are used: nonscreen (or direct exposure) film and screen film.

Nonscreen film is especially sensitive to the direct action of x-rays and is used only in special applications. The thicker emulsion of nonscreen film has a higher silver content than the emulsion of screen film. Nonscreen film is used in a cardboard holder; this type of film and holder combination is not currently recommended for use in Florida.

Screen film, manufactured to be sensitive to the fluorescent light of the intensifying screen, is designed for use with intensifying screens. A high-speed screen film used with a high-speed intensifying screen will require as little as 1/40 of the radiation exposure required for a nonscreen film. Thus, **selection of the proper film can significantly affect patient exposure.**

Film Holders. Since radiographic film is sensitive to light, it is protected by a **light-tight** film holder until it is exposed and processed. A film holder must also be **radiolucent**, so that radiation can pass through to expose the film emulsion.

Film holders are available in sizes to match standard film sizes: 14" x 17", 11" x 14", 10" x 12", 8" x 10", 9 1/2" x 9 1/2", 5" x 7", 7" x 17", and corresponding metric sizes.

The **cassette** is a light-tight film holder that contains intensifying screens and film. Cassettes are far more durable than cardboard holders. The front of a cassette is usually constructed from plastic or radiolucent material such as bakelite. The frame and back are constructed of aluminum or stainless steel. Attached to the front and back inside covers of the cassette are the intensifying screens. A layer of felt or sponge ensures the proper film-screen contact. The film is sandwiched between the two intensifying screens (see Figure VII).

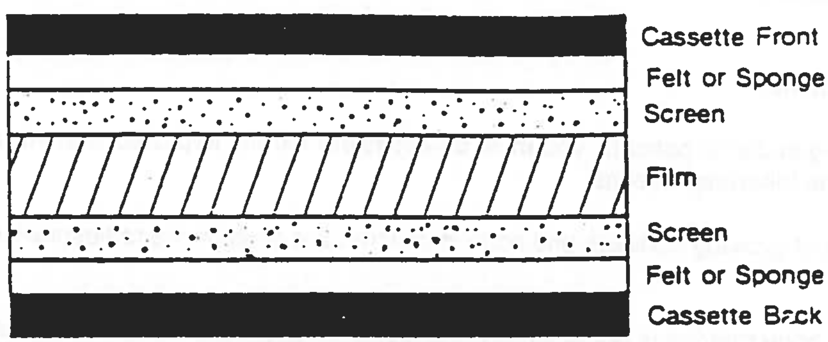


Figure VII
Cross Section of a Cassette (front to back)

Reproduced by permission from: Bushong, Stewart C.: *Radiologic Science for Technologists*, ed. 3, St. Louis, 1984, The C.V. Mosby Co.

Intensifying Screens. Intensifying screens are thin, fluorescent sheets of plastic or cardboard inside the cassette. They are used in the production of nearly all medical radiographs to reduce the amount of radiation needed to make an exposure. Screen film is held between two intensifying screens that emit visible light when struck by x-rays.

Although radiographic film is highly sensitive to light, its sensitivity to direct x-ray exposure is very low. Therefore, if light is added to the radiation, less radiation is required. Intensifying screens help accomplish this purpose, because they convert the x-ray photons to visible light, which then exposes the film. This conversion is done by phosphor crystals, which make up the active layer of an intensifying screen. As you can tell, although some of the screen film's exposure is the result of direct interaction with x-rays, most of the exposure is due to the visible light produced by the screens.

A screen has a specially processed cardboard or plastic base, coated on one side with an emulsion of finely powdered phosphor crystals suspended in a bonding agent. Each time a phosphor crystal absorbs an x-ray photon, it emits a flash of light. Try to picture thousands of these flashes occurring on the screen during an exposure. The screen film is highly sensitive to the light emitted from the phosphor crystals. These crystals are responsible for about 99 percent of the latent image; only the remaining I percent results from the direct action of x-ray photons in the film emulsion.

Summary

The various kinds of radiographic accessories are used to reduce unnecessary exposure and produce high-quality radiographs. Thus, in addition to using the measures discussed in the previous part and listed in the summary, you should also do the following to protect patients:

- Choose the correct combination of radiographic film and intensifying screens.
- Use radiographic accessories such as patient immobilization devices.

Patient Protection

Pediatric Patients

When x-raying pediatric patients, you must be especially careful to protect them from overexposure, because of the following reasons:

- The cells of growing cartilage and bone in children are much more radiosensitive than those in adults.
- A child's bone marrow is rather evenly distributed throughout the skeleton. Irradiation of the blood-forming organs can produce a depression in the normal blood cells as an early response to radiation.

- While the cells of an adult's central nervous system are insensitive to radiation damage, the opposite is true of those of the very young pediatric patient. The nerve cells start to lose their radiosensitivity about the age of two years.
- Radiation to the chest, which includes the breast buds of young girls, can prevent normal breast development. Irradiation of the ovarian area can cause atrophy (reduction) in ovary size. The testes, like the ovaries, will atrophy after high doses of radiation. **Gonadal shielding is thus required for all pediatric patients.**

Female Patients

The short-term and long-term somatic effects of radiation apply to all patients: pediatric, male, female, and geriatric patients. Genetic effects of radiation, however, are significant only for male and female patients of reproductive potential. Because ionizing radiation can damage chromosomes in male or female germ cells and the damaged chromosomes can cause mutations to occur in offspring, both male and female patients with reproductive potential must be protected with gonadal shields. It is especially important to protect female patients of childbearing age, since exposure to ionizing radiation can cause permanent sterility.

You should take special precaution when radiographing pregnant women. Because there is always a chance that a female patient may be pregnant, the importance of preventing unnecessary radiation exposure to a fetus cannot be overemphasized. Most authorities recommend that radiographs be scheduled only during the first 10 days after the beginning of menstruation, because it is unlikely that a woman will be pregnant during this period. (See Section B if you need to review embryological effects.) This is known as the **10-day rule**.

To implement the 10-day rule, you should do the following:

- Ask all female patients of childbearing age about the onset of their last menstrual period. This can be done verbally or with a written questionnaire. Keep this information in the patient's permanent files at your facility.
- Notify the referring physician if the patient might be pregnant.
- If pregnancy cannot be ruled out with certainty and the radiograph must be completed, confine the area exposed to the area of interest. The use of a lead apron is imperative.

Summary

Becausė the cells of children are highly radiosensitive and irradiation of their ovarian areas and testes can prevent normal development, you should use gonadal shielding for all pediatric patients.

You should also use gonadal shielding for both male and female patient with reproductive potential. But you must be especially concerned with female patients of childbearing age. Question each female about her last menstrual cycle and/or possible pregnancy and then alert the radiologist and/or the referring physician if there is a possibility that she may be pregnant. Following the 10-day rule for female patients of child-bearing age is a good safety precaution.

Radiation Monitoring

Occupational Exposure

The Nuclear Regulatory Commission along with other groups has established radiation dose limits for radiation workers. These annual occupational dose limits set the amount of ionizing radiation that a person is allowed to be exposed to in one year. Occupational dose means the dose received on a job where the individual's duties involve exposure to sources of radiation. Occupational dose does not include any dose received from background radiation, as a patient from medical practices, from voluntary participation in medical research programs, or as a member of the public. The occupational dose limit units are expressed in roentgen-equivalent-man or rem.

Basic x-ray machine operators - podiatry must keep their occupational exposures As Low As Reasonably Achievable or **ALARA** They accomplish ALARA by establishing and following sound radiation protection practices to maintain. radiation exposures much lower than the occupational dose limits. The expectation of very low doses is why basic x-ray machine operators - podiatry are not required to have formal, written, radiation protection programs like other x-ray registrants.

Figure VIII describes the occupational dose limits that typically apply to podiatry. The list is not a complete list of all exposure limits. It does not contain limits associated with the use of radioactive material or planned special exposures. Consult the Florida Administrative Code for limits addressing these activities.

Annual Occupational Dose Limits for External Exposure

	Adults (rem)	Minors (rem)	Embryo or Fetus (rem)
Total Effective Dose Equivalent (Deep Dose Equivalent)	5	0.5	none
Eye Dose Equivalent	15	1.5	none
Shallow Dose Equivalent to skin or extremity	50	5	none
Gestation	none	none	0.5

Figure VIII
Occupational Exposure MPDs

Reproduced by permission from: Bushong, Stewart C.: *Radiologic Science for Technologists*, ed. 3, St. Louis, 1984, The C.V. Mosby Co.

Monitoring Occupational Exposure

Monitoring of individual exposure for adults and minors is required if the body is likely to receive in 1 year a dose in excess of 10 percent of the limits above.

Occupationally exposed women who become pregnant may declare their pregnancy if they wish. Once the pregnancy is declared, the woman is a 'declared pregnant woman', which means she has voluntarily informed her employer in writing of her pregnancy and the estimated date of conception. Monitoring of individual exposure for a declared pregnant woman is required if the body is likely to receive in 1 year a dose in excess of 0.05 rem. Each woman who has declared pregnancy must wear a radiation monitor at waist level at all times at work. The waist level monitor is used to estimate the fetal deep dose equivalent. When the declared pregnant worker wears protective clothing, this monitor must be worn under the protective clothing. Each declared pregnant worker whose duties require protective clothing also must wear a radiation monitor outside the protective clothing to estimate the dose to the worker.

Monitoring Methods

Two types of monitoring devices are commonly used - film and TLDs.

Film monitors Most film monitors contain two small pieces of x-ray film that have been sealed in a light-and-moisture-proof package. This package is then placed in a holder - either a plastic badge, a wristband, or a ring. Each of these holders has a metal filter (see Figure IX). The filter makes it possible to determine the type of radiation, if any, the wearer has been exposed to. The amount of radiation that reaches the film is shown by how black the film is in different places. The monitors are usually changed every 4 weeks.

A film monitor is used to estimate the dose the body has received during the period the operator has worn it. A film badge should be worn at the collar during work hours. When wearing a lead apron, the operator should wear the film badge outside the apron at the level of the collar. These badges monitor radiation to the eyes and thyroid, organs that are about 10 times more sensitive to radiation than other organs.

Film monitors are the most popular monitoring devices because they are convenient and reliable (see Figure IX). After being worn, they are sent back to the dosimetry company for processing. Then a dosimetry report, like the one shown in Figure X, is sent to the employer.

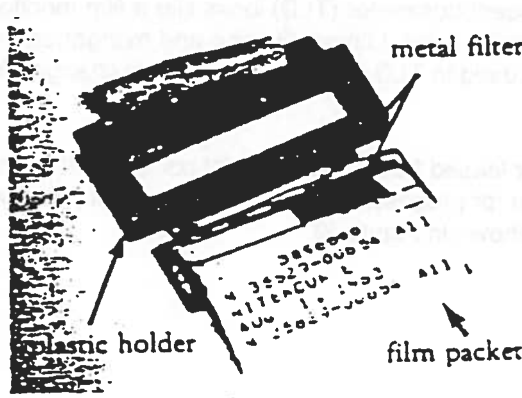
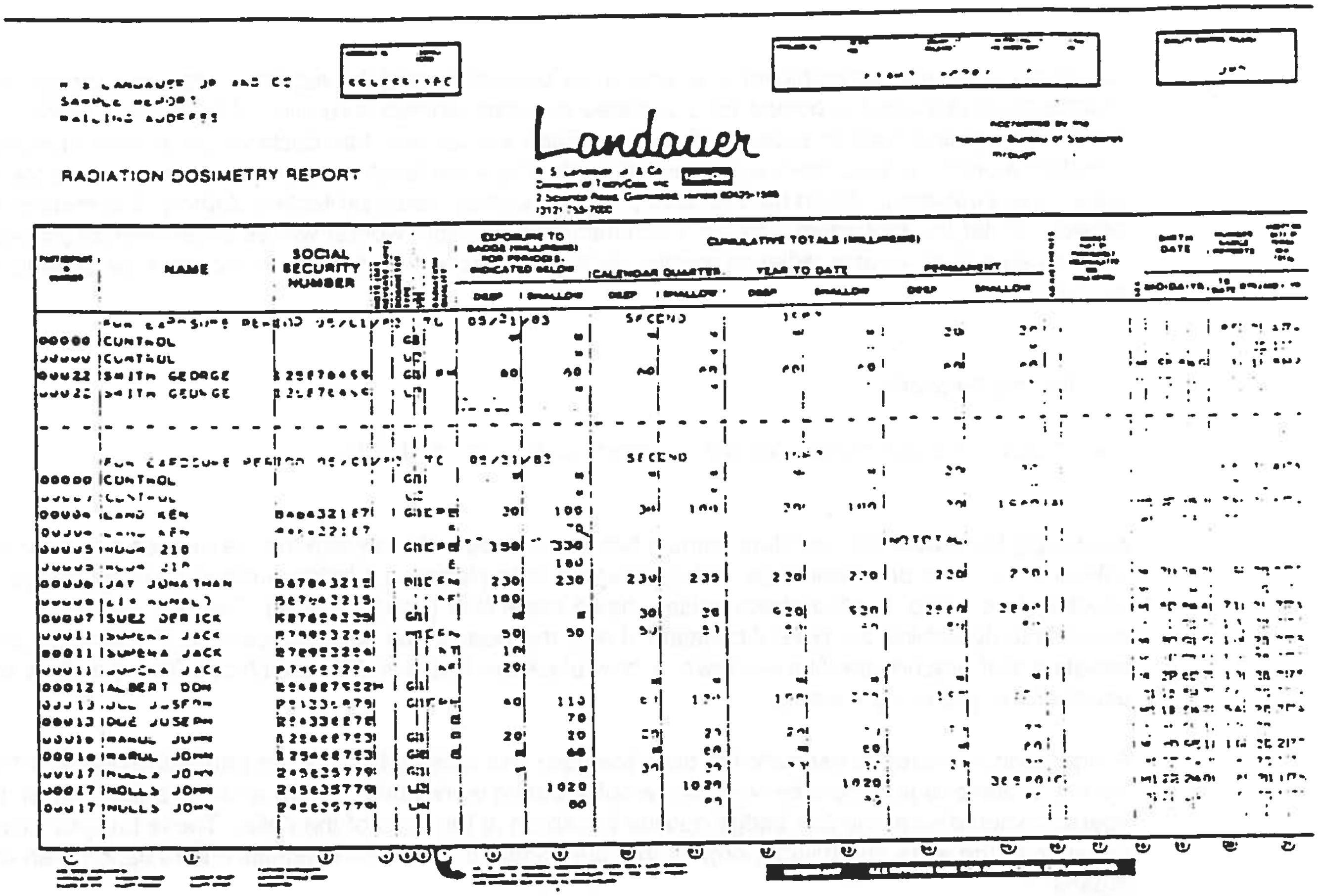


Figure IX
Film Monitors
Courtesy: R.S. Landauer, Jr., and Co., Glenwood, Illinois.


Landauer

RADIATION DOSIMETRY REPORT

PARTICIPANT NUMBER	NAME	SOCIAL SECURITY NUMBER		EXPOSURE TO BADGE (MILLIREMS) FOR PERIODS INDICATED BELOW DEEP	SHALLOW	CUMULATIVE TOTALS (MILLIREMS) CALENDAR QUARTER DEEP	SHALLOW	YEAR TO DATE DEEP	SHALLOW	PERMANENT DEEP	SHALLOW	BIRTH DATE
00000	CONTROL											
	CONTROL											
00022	SMITH GEORGE			80								
	SMITH GEORGE											
00000	CONTROL											
	CONTROL											
	LAND KEN			30	100							
	LAND KEN											
				150	330							
					180							
00006	JAY JONATHAN	B67843215		230	230	230	230	230	230	230		
		867843215		100								
00007	SUEZ DERRICK	K87682423				30		620				
	SUPENA JACK			50	50							
00011	SUPENA JACK	878953228										
	SUPENA JACK			20								
00012	ALBERT DON	824887922										
	DUE JOSEPH			40	110							
00013	DUE JOSEPH				70							
	MARUL JOHN			20	20							
00016	MARUL JOHN	825488753										
	INOLLS JOHN	245835779										
00017	INOLLS JOHN	245835779			1020		1020		1020			
	INOLLS JOHN	245835779			80							

Figure X

Sample Dosimetry Report Form

Courtesy: R.S. Landauer, Jr., and Co., Glenwood, Illinois.

<u>TLD monitors</u> A thermoluminescent dosimeter (TLD) looks like a film monitor; however, instead of pieces of x-ray film, a small crystal is used. Lithium fluoride and manganese-activated calcium fluoride are the crystals most commonly used in TLD systems. The crystal changes from exposure to ionizing radiation.

The TLD usually is purchased or leased from a commercial company. It normally is worn for 1 month like the film monitor and returned for processing to the dosimeter company, which sends the employer a dosimetry report like the one shown in Figure XI.

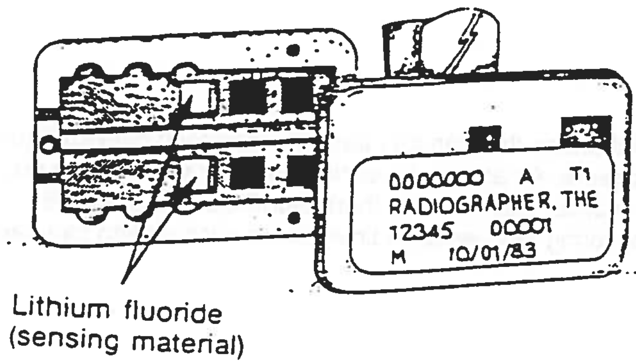


Figure XI
Thermoluminescent Dosimeter (TLD)
Courtesy: R.S. Landauer, Jr., and Co., Glenwood, Illinois.

As an x-ray machine operator, you must be allowed to review the dosimetry report. If a reading is abnormally high, you must report it to the Department of Health, Bureau of Radiation Control, 1317 Winewood Boulevard, Tallahassee, FL 32399-0700.

Since radiation effects are cumulative, you should maintain accurate records of your occupational exposure. **Both Florida and federal regulations require your employer to give you your readings when you leave a job where your radiation exposure was monitored. You must take a copy of that reading to the next employer who will monitor your exposure to ionizing radiation.**

As a basic x-ray machine operator-podiatry, you are responsible for handling your film monitor or TLD badge properly. You should leave monitors at work at the end of each work day. If a badge is washed and dried with a uniform or left in an automobile in the Florida sun, a false reading may result. If you take a monitor home, place it in a room where there is no television or microwave oven. Contact with such electronic equipment can damage the film in the holder.

Monitoring Devices
Characteristics of Monitoring Devices

These two types of monitoring devices have certain common characteristics:

- They are light, easy to carry, durable, and inexpensive.
- They detect and record radiation exposure in a consistent and reliable manner.
- Each contains a strip of metal.
- They are not resistant to heat, humidity, and mechanical shock

Summary

Because of the severe biological damage that can be caused by radiation overexposure, it is important to keep track of occupational exposure. As an x-ray machine operator you may be required to have a monitoring device such as a film monitor dosimeter or thermoluminescent dosimeter. It is extremely important to safeguard these monitoring devices at all times since mishandling can cause damage that will result in inaccurate readings.

Electronics of X-Ray Generation

When radiographing a patient, you follow these steps:

1. Identify the patient.
2. Position the patient.
3. Position the radiographic tube and the film.
4. Set the control selectors for exposure factors on the control panel.
5. Press the exposure button to make the exposure.
6. Process the film.
7. Evaluate the quality of the processed radiograph.

Control Panel

As this process indicates, you should be familiar with the control panel, since you will need to adjust exposure factors to produce the appropriate radiographic beam: you should set the **kVp selector(s)** for the quality (penetrating power) of the beam, the **mA selector** for the quantity of electrons used, and the **timer** for the length of the exposure. These three basic controls and their meters are found on all radiographic machine control panels.

The higher the **kVp** setting, the faster the electrons travel across the radiographic tube, and the more powerful and penetrating the x rays produced. The higher the **mA** setting, the hotter the filament and the more electrons emitted. By doubling the mA, you double the quantity of x rays produced when the exposure switch is activated. Length of **exposure time** also affects the quantity of x rays.

In addition, there are the **main power switch,** which supplies power to the machine, and the **exposure switch,** which starts and stops the x-ray exposure. As shown in Figure XIII, the control panel has a major kVpselector and a minor kVp selector. Whereas the major kVp control changes the kVp in steps of 10 kVp, the minor control changes the kVp in steps of 2 kVp.

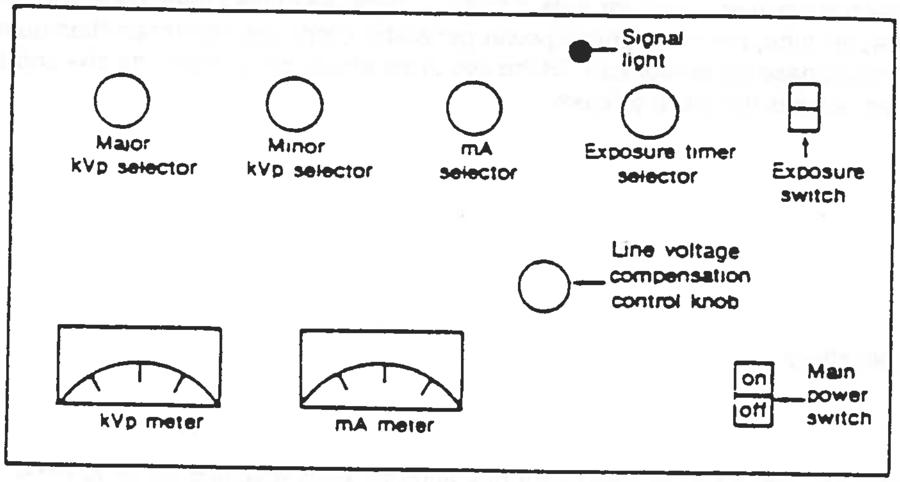


Figure XII
Radiographic Control Panel

<u>Timing Circuit for Exposure Timer</u>. When you push the exposure switch, the autotransformer supplies the power to the timing circuit that operates thc exposure timer. Then a switching device in the primary side of the high-voltage circuit starts activating (closing and opening) to switch on and off the kVp applied to the radiographic tube. The exposure timer determines the length of time this circuit is activated, thus affecting the quantity of x rays produced.

In most radiographic equipment, two different types of timers are used: impulse and electronic. An impulse timer operates on an electric impulse, which starts and stops at or near the zero point of an alternating current. The electronic timer circuit is commonly designed with a back-up relay that limits the exposure (usually to 10 percent more than the time set) if the timer fails.

In podiatric radiography, time must be closely controlled. In some podiatric radiographic equipment, exposures can vary from milliseconds up to a second or more. Most techniques demand that the timing of exposures be accurately controlled within very narrow limits.

Single-Phase and Three-Phase Radiographic Equipment

Several different types of power generators are used for x-ray machines: single-phase, three-phase, falling-load, and constant-potential. Only single- and three-phase generators are discussed here, however, since falling-load and constant-potential types are rarely used.

The single-phase power generator consists of either a one- or a two-pulse voltage pattern, whereas the three-phase power generator consists of either a six- or a twelve-pulse voltage pattern. The single-phase power generator contains only a single phase of electricity that lasts for 1/60 second. The three-phase power generator, however, contains three single phases produced within 1/60 second. The main advantage of the three-phase power generator is its efficiency; because of the nearly constant voltage supplied to the radiographic tube, the three-phase power generator produces higher radiation quantity and quality than the single-phase generator can. Of the two three-phase generators, the six- and the twelve-pulse, the twelve-pulse is the more efficient.

Operating an X-Ray Machine

The following provides a general, basic procedure for operating an x-ray machine by using the control knobs on the control panel.

STEP 1: Turn on the main power switch.

STEP 2: Look at the kVp meter to see whether the incoming line voltage is sufficient to operate the machine.

- If the meter reading is too high or too low, adjust the line voltage by turning the line voltage compensator control knob.

STEP 3: Select the primary exposure factors (kVp, mA, and time), using the technique charts; and set them, using the selector for each.

STEP 4: Press the exposure switch.

STEP 5: Listen for an audible tone or watch for the signal light to go off. One of these indicates the termination of the exposure.

Summary

The control panel that you may need to be most familiar with has the exposure factor selectors, main power switch, exposure switch, and line voltage compensator control knob. When the main power switch is turned on, electrical power is supplied to the autotransformer, which in turn energizes the filament circuit, the high-voltage circuit, and the timing circuit. The filament circuit controls the mA of the radiographic tube by heating the filament until it glows; the step-up transformer in the high-voltage circuit increases the low voltage to the kilovoltage level which was set by the kVp selector; and the timing circuit operates the exposure timer.

In order to generate the power that radiographic equipment needs, single-phase and three-phase power generators are most commonly used. A single-phase power generator consists of either a one- or a two-pulse voltage pattern, and the three-phase power generator consists of either a six- or a twelve-pulse voltage pattern. Of these different types of power generators, the twelve-pulse, three-phase power generator is most efficient.

Warm Up Procedure

The radiographic tube can be damaged not only by allowing excessive heat within the tube, but also by using it without warming it up. You should warm up the tube before its first use of the day and after lack of use for three or four hours. Since tremendous strain is placed on radiograpic tubes during exposures, all tube manufacturers recommend a warm-up procedure. You will need to follow the manufacturer's instructions. The following warm-up procedure is a sample.

STEP 1: Turn the main switch on.

STEP 2: Select the three exposure factors on the control panel as follows.

100 mA
.5 seconds
70 kVp

STEP 3: Press the exposure button.

STEP 4: Wait 3-4 seconds and then repeat STEP 3.

STEP 5: Wait another 3-4 seconds and again repeat STEP 3.

NOTE: You will be making three exposures in all.

Summary

The radiographic tube consists of three major components: the glass envelope; the cathode, which includes the filament; and the anode, which includdcs the target. The cathode is the negatively charged electrode, and the anode is the positive terminal.

Since early in the development of radiographic tubes, tungsten has been used for the target because of its high melting point and good heat conductivity. Despite tungsten's high melting point, target overheating can be a problem. So the tungsten is embedded in copper for better heat dissipation. Also, a rotating anode is used to reduce heat buildup within the tube.

Even with the use of tungsten embedded in copper and a rotating anode, excessive heat can be generated if the exposure factors are set improperly. In order to help x-ray machine operators avoid overheating the tube, tube manufacturers provide tube-rating charts and tube housing-cooling charts. Tube- rating charts help you identify the maximum permissible exposure time, mA, or kVp. In order to use tube-rating charts, you should know the type of x-ray machine you are using, the size of the focal spot, and two of the three exposure factors.

The anode-cooling and the tube-housing-cooling charts help you to identify the amount of time required for the anode and the tube housing to cool down before the tube can be safely used again.

Not only excessive heat but also use of the tube without a warm-up period can damage the tube. Therefore, you should warm up the tube before its first use of the day and after its lack of use for three or four hours, following the manufacturer's recommended warm-up procedures.

Identifying Equipment Failures

Causes of Poor-Quality Radiographs

If a radiograph is too light or too dark or if exposure has not been made at all, the radiograph is not of diagnostic quality. The poor quality may be caused by operator error, patient movement, or equipment failure. Improper film development, which will be covered in Unit III, is also a cause of poor-quality radiographs.

Avoiding Operator Errors

The following are the most common operator errors:

- failure to set the exposure factors correctly for the particular body part being radiographed
- failure to position the patient correctly
- failure to observe the patient for possible movement (You, as the operator, cannot stop the movement, but if you note the patient beginning to move, you can sometimes stop the procedure before making the exposure.)
- failure to process the film correctly

Checking for Equipment Failure

Other causes of poor-quality diagnostic film may be equipment failure either electrical or mechanical. Electrical failures usually occur within the electrical systems of timers, rectifiers, and kVp and mA controls; whereas mechanical failures usually occur in the beam-restriction devices (collimators), and cassettes.

Cassettes. If a radiograph shows an **artifact**[13], this problem may mean that a foreign particle is on or in the cassette. You should, therefore, check the cassette for foreign particles and clean it properly.

NOTE: A misaligned central ray can distort the radiographic image. Therefore, the accuracy of the central ray (center portion of the x-ray beam) should be checked by a person who is skilled in quality-assurance procedures and who has access to the required testing equipment. The United States Department of Health and Human Services publishes a book entitled *Quality Assurance for Radiographic X-ray Units and Associated Equipment*, which explains in-depth procedures for various other quality-assurance tests.

Cleaning the Cassette

As in all phases of medical care, cleanliness is essential in radiography. You should keep the tabletop and all accessories with which the patient has contact scrupulously clean. You should also clean the cassette to prevent any foreign particle from blocking a portion of the film during exposure. The following is a general guideline for cleaning the cassette.

STEP 1: Unload the cassette so that the cleaning procedure can be conducted in good light.

STEP 2: Stand the open cassette on its end.

STEP 3: Carefully brush the entire inside of the cassette, using a camel's hair brush. Start at the top edge to remove all large particles, and work down.

STEP 4: Lay the opened cassette down so that the inside is facing up.

STEP 5: Wet a piece of absorbent cotton or a soft, lint-free cloth with a commercial screen cleaner (available from your local radiographic-film supplier), and gently wash the inside surfaces.

> **CAUTION:** Use only the screen cleaner that is recommended for your brand of screen. Otherwise, you may stain the screens, and stains affect the radiographic images.

STEP 6: Wipe the inside of the cassette with a dry piece of cotton.

STEP 7: Place the opened cassette on its end and allow it to air dry.

STEP 8: Record the date of cleaning for future reference.

---

[13] artifact: a foreign or unwanted mark that appears on a radiograph because of faulty equipment, improper film handling, or processing

Summary

Whenever a diagnostic radiograph is of poor quality, you will need to make another exposure. To avoid unnecessary repeats, you should avoid common operator errors, which usually occur in the following activities:

- setting the exposure factors
- positioning the patient
- processing the film
- noticing patient movement

Since equipment failure can also cause a poor-quality radiograph, you should be able to identify possible equipment failures by checking for abnormal meter fluctuations and for improper radiographic density.

- Abnormal mA meter fluctuations can indicate that the radiographic tube has lost its vacuum.
- Abnormal meter fluctuations and a too-dark radiograph can mean a defective electronic timer or a defective impulse timer.
- Abnormal meter fluctuations and a too-light radiograph may indicate a defective rectifier or a defective impulse timer.
- Artifacts in the radiograph can mean that foreign particles are on or in the cassette.

To check for electrical-system failures in radiographic equipment, you may need to conduct an mAs reciprocity test or a kVp stability test.

If an mAs reciprocity test shows different densities among the radiographs, the tube-current control may be defective. If a kVp stability test shows a reversal or a jump in density between two successive trials, the autotransformer may be defective.

Whenever you identify equipment malfunctions, you should notify your supervisor.

Characteristics of a High-Quality Radiograph

As you know, x-rays passing through a patient's body and interacting with radiographic film produce an image of that body part on the film. This image comprises the outlines and densities of the body part it represents. Thus, when the developed film, called the radiograph, is placed on an illuminated light source, a physician can identify the organs and structures on the radiograph. To be useful, it must be a high-quality radiograph that accurately reproduces an image of the structures and tissues. A high-quality radiograph should have **adequate density** (blackness or opacity), **good contrast** (a range of intermediate shades of gray), **clear detail and sharpness** (good definition and resolution), and **no distortion of size and shape.** The evaluation of a radiograph's quality is based upon these four properties, which can be categorized into two: density and contrast as photographic properties and the recorded detail and absence of distortion as geometric properties.

Photographic Property: Density

Radiographic film density is a measure of the amount of black, metallic silver deposited on the emulsion of the x-ray film as a result of radiographic exposure and development.

It is also a measure of the quantity of radiation absorbed by the film. Density is **controlled by mA, time, and distance** and is **influenced** by kVp, film-screen combination, filtration, tissue thickness of the body part x-rayed, anode heel effect, processing, fog, and artifacts.

Anatomical and pathological characteristics of the patient, especially the thickness of the body part and its density, have the greatest influence on radiographic density, because they influence the absorption of x-radiation in tissue. Generally, when a thick body part is radiographed, more scatter radiation reaches the film and, therefore, the density is increased. **Tissue thickness** of body parts is affected by such factors as physique (body frame), age, and pathology. Various pathological conditions require more or less radiation for penetration. A rule of thumb is that the thicker (denser) the body part, the higher the exposure factors should be.

Film fog is unwanted density which makes it difficult to visualize structures on the radiograph. Film fog may be caused by exposure of the film to light or to secondary radiation, or by improper film development. In order to prevent or reduce film fog, therefore, the darkroom must be lightproof, the safelight should be well maintained, the film must be processed properly, and unused film should be kept in a lead container such as a pass box.

Artifacts are foreign or unwanted marks that show up on a radiograph because of improper film handling, improper processing, or faulty equipment. Artifacts can result in either an increase or a decrease in film density. (Artifacts are further discussed in Section B.)

NOTE: If the other technical factors remain the same, a larger field size will produce lower density because of the inverse square law.

Photographic Property: Contrast

<u>Radiographic Contrast</u>. The distribution of black metallic silver over the film is called radiographic contrast. It refers to the degree of difference between light and dark areas.

A film that has been exposed to room light and then developed will be solid black. Thus it has only one density and no contrast. For contrast to be present, there must be at least two densities. Consequently, contrast can be defined as the visible differences in density shown by the various areas or structures on a radiograph.

Motion is the most significant factor in reducing clarity, increasing distortion, and thereby producing a blurred radiograph. For example, if a patient moves his or her hand while you are taking a radiograph of it, the image of the hand will be spread over a larger area and the edges of the hand on the developed radiograph will appear to be fuzzy. This fuzziness of the edges is known as **penumbra.** With a shortened **exposure time**, the patient has less time to move accidentally, and the radiograph will exhibit better recorded detail. Therefore, short exposure time is important, especially when body parts that move involuntarily, like a beating heart or the digestive system during peristalsis, are radiographed.

The size of the x-ray target **focal spot** has a significant effect on the detail of the image. **The smaller the focal-spot size, the better the detail.** The size of the focal spot depends on the mA selected. The small focal spot, used for 100 mA and below, provides excellent detail. This is one reason that 100 mA is chosen for radiographing the skeletal system. The large focal spot is chosen for techniques requiring 200 mA and up. The use of 200 mA or more generates more heat during the production of x-rays than the use of 100 mA, and the larger focal spot dissipates heat more efficiently, causing more penumbra, which results in a loss in detail .

Angling the tube or central ray (CR), the body part, or the film causes **shape distortion**. Depending on the angulation, the recorded image will appear to be longer or shorter than the actual length of the object. The shape of the object or body part radiographed can also affect the amount of shape distortion.

Summary

The following factors contribute to **high density:**

- high mAs
- short target film distance (TFD)
- ortho film and rare-earth-screen (fast-screen) combination
- small field size

In addition, you should place the anode side of the tube over the thinner body part to be radiographed and the cathode side over the thicker body part in order to utilize the anode heel effect for even density. The following factors contribute to **long-scale (low) contrast:**

- a high kVp with a low mAs or a large field size

The following factors contribute to **good recorded detail** (clear definition and sharp image):

- short object film distance (OFD)
- long target film distance (TFD)
- short exposure time (to minimize patient movement)
- film with small crystals
- slow-speed (or detail) screen

- close and thorough film-screen contact
  small focal-spot size (for 100 mA or below)

The following factors contribute to the **least amount of magnification:**

- a short object film distance (OFD) and a long target film distance (TFD). The angulation should be correct to minimize shape distortion.

Selection of Exposure Factors

Radiographic Consistency

Radiographic consistency describes the property of radiographs when those radiographs--taken at different times but of the same person and body part--have uniform contrast and density. For example, when two podiatric radiographs of the same patient are produced three months apart, they are said to have radiographic consistency if both have the same contrast and density. Consistency is especially important in cases where follow-up radiographs are used to check the progression or regression of pathological conditions. To prevent unnecessary repeats, the exposure system must produce consistent results.

To produce high-quality radiographs that have radiographic consistency, you should follow certain procedures correctly.

- Position the patient properly.
- Prevent voluntary or involuntary motion by the patient.
- Select correct exposure factors.
- Use radiographic equipment and accessories correctly.
- Maintain radiographic equipment.
- Process film correctly and make sure it is free of artifacts.

The most common reasons for repeated radiographs are incorrect positioning of the patient and the selection of incorrect exposure factors. (Positioning is discussed in Unit IV.) By accurately applying the guide-lines set forth in your departmental technique chart, you should be able to select the correct technical factors.

Technique Charts

You will need to refer to a technique chart to select technical factors (exposure factors and accessories). Technique charts usually list the following:

- the body part to be radiographed
- target film distance (TFD)
- the name of the projection (lateral, oblique, etc.)
- thickness (anatomical density) of the body part
- kVp
- mA and time (mAs)

Most technique charts are based on either variable or fixed kVp settings.

Fixed kVp Technique. The fixed kVp technique is also known as the optimum kVp technique or the variable mAs technique. The kVp remains constant, and the mAs is used to compensate for the size of the body part. The kVp needs to be adequate to penetrate the body part and to achieve a suitable scale of contrast. For this technique, you can categorize patients as small, medium, and large. Each of these three categories includes a range of sizes in centimeters. Once the base mAs has been established for a medium patient, **you divide the base mAs by 2 to calculate the mAs for the small patient, but multiply it by 2 to calculate the mAs for a large patient.**

NOTE: With the fixed technique, some anatomical parts will require more exact measurements to ensure proper density and contrast.

Selection of Technical Factors with the Use of a Technique Chart. The following is a general, basic guideline for using a technique chart in selecting technical factors:

STEP 1: Look in the technique chart for the body part to be radiographed.

STEP 2: Identify the technical factors according to either the fixed or the variable kVp technique chart. These factors should include mA, time, kVp, TFD, film-screen combination, use of Bucky, and the name of the projection.

STEP 3: Adjust exposure factors on the basis of the patient's pathological condition and age.

- If the patient is unable to cooperate, increase the mA and decrease the exposure time without changing the mAs. For example, 100 mA at 1 second is equal to 200 mA at the reduced time of 1/2 second.
- If the patient has a dry cast covering the body part to be radiographed, double the mAs or add 10 kVp. If the cast is wet plaster-of-paris cast, multiply mAs by 3.5 or add 15kVp.
- If the patient's age is between 1 and 12, adjust the mAs as follows:

birth to 1 year	use 30% of the adult mAs
2 to 5 years	use 60% of the adult mAs
6 to 9 years	use 70% of the adult mAs
10 to 12 years	use 90% of the adult mAs

- If the patient is 55 years or older, or has been bedridden for more than 6 months, use 75 percent of the adult mAs.

- As a basic rule, increase the mAs for pathological conditions requiring above-normal penetration and decrease the mAs for conditions requiring below-normal penetration. Some conditions that require an increased mAs are osteomyelitis, lung cancer, Paget's disease, and pneumonia. Some conditions that require a decreased mAs are Parkinson's disease, pneumothorax, atrophy, bone cancer (lytic), emphysema, arthritis, and osteoporosis.

STEP 4: If you change from one screen type to another, adjust the exposure factors, as follows.

- Divide the screen-speed value of the new screen by 100.

- Multiply the result by the exposure time (the number of seconds) used in the original exposure. This will be your exposure time for the new type of screen.

Summary

The consistent production of high-quality radiographs will help reduce the need for repeats. The correct selection of technical factors, which include exposure factors and accessories, plus the correct use of the phototimer, will help you achieve this goal of producing high-quality radiographs consistently. To select the correct technical factors, you should use technique charts.

Film Handling and Manual Processing

The frequent need to repeat radiographs is, in part, the result of the careless handling of the film at some point between the time it arrives in the department and the time it is filed as a radiograph. Therefore, proper storage, handling, and processing of radiographic film are extremely important. Since you perform most of these activities in the processing room, commonly called the darkroom, let's discuss the processing room first, and then film storage.

The Processing Room (Darkroom)

Radiography begins and ends in the processing room. This is the place where unexposed film is placed in cassettes and then later removed and processed.

Arrangement. The darkroom is usually arranged in accordance with the standard film-processing route. The room has a wet station and a dry station. The wet station consists of a sink, manual-processing tanks, and/or an automatic processor. The dry station includes the film bins for film storage and the pass boxes (transfer cabinets) for transferring the cassettes. Manual-processing darkrooms have film hangers grouped by size and hung above the bench on racks projecting from the wall.

NOTE: An opened supply of film is stored in the darkroom in the **film bin**, which is a specially leaded, lightproof cabinet located under the work counter. The film bin is divided into compartments, each appropriate for a different standard-sized film. The opened boxes of film should be placed in an upright position. **You must close** the **film bin tightly after each use;** otherwise, the white light will ruin all the film.

Lighting. The darkroom should have both a white light and a safelight. The white light can be used during cleaning activities and while chemicals are mixed. The safelight must be used while the film is being processed so that it won't be exposed. Film accidentally exposed to white light appears solid black upon development; therefore, you must allow no unwanted light to enter the darkroom through holes or cracks around the passbox, doorway, or automatic processor. While developing film and when opening the film bin, you must secure the darkroom door and use the safelights. You should check the cassette regularly to make certain that the hinges and latches are not sprung or broken and that the felt seals are firmly in place.

Since most x-ray film is sensitive to the blue-violet portion of the light spectrum and relatively insensitive to the red-yellow portion, the safelight is usually amber. The safelight consists of a light fixture, a light bulb of no more than 15 watts and a special filter, known as a Written 6 B filter, which allows passage of only the amber portion of the spectrum. Even a safelight is not totally safe, as the film will become fogged if exposed to it for too long. Therefore, **expose film no longer than one minute at a distance of three feet from the safelight.**

Some fast films designed for use with rare-earth screens are sensitive to the safelight, especially after exposure to x-rays and before development.

Film Storage

Radiographic film emulsion is extremely sensitive to light and x-radiation, but it is also sensitive to many other agents, including pressure, temperature, humidity, chemicals, fumes, and static electricity. To protect film from these agents, manufacturers usually package it in quantities of 25, 50, or 100 sheets in a moisture-proof plastic wrapper, then seal it in airtight, metal-foil bags for extra protection. Plastic, which keeps out moisture, and foil, which reflects the heat to a certain degree, are used to prevent fog caused by heat and moisture even before the film is opened. The package is placed in a cardboard box.

For proper film storage, you should pay special attention to the following:

Pressure. Extreme pressure from wrinkling or bending can cause the emulsion to change. Then, after the film is developed, artifacts will appear on the radiograph. To avoid pressure markings and smudges, store packages of unexposed films on edge, and never stack one box on top of another. Even the pressure from one stacked box lying flat can cause crescent marks (half-moon-shaped densities) on the radiograph.

Temperature and Humidity. The temperature at which film is stored determines its maximum storage time. The cooler the temperature the longer the storage period can be. Unexposed film stored at 90°-

110° F will be fogged and unusable after 14 days. Unexposed film may be stored at 75° F for two months, at 60° F for six months, and at 50° F for one year.

The **ideal storage conditions are a temperature of 60°-75° and a relative humidity of 50-60 percent.** Low humidity, cold temperatures, rough handling, or ungrounded electrical equipment can cause **static marks.** High temperatures and excessive humidity can cause **mottling** (uniform fogging). When film is subjected to a drastic change from extreme cold to a warm, humid environment, it will "sweat," causing artifacts, and the emulsions may stick together. Since the containers do not protect against high temperature, even a relatively brief period of excessive heat may ruin the film. Do not store film in a dry, humid, or hot area.

Radiation. Film must be protected from unwanted radiation; stored film should be shielded by lead (or an equivalent) to prevent fog caused by radiation exposure during storage. Film bins located in the processing room should be protected by lead.

Chemical Fumes. Certain chemical fumes, including vapors from household ammonia, sewer gases, hydrochloric acid, and nitric acid, will cause the emulsion to become fogged. Do not store film in any place containing chemical fumes.

Age. Either mottled or uniform fogging can result from using outdated film. Always use film before the expiration date indicated on the end of the box.

Light/Safelight. Fog may occur with any of the following conditions: the darkroom is not lightproof; the safelight contains too large a bulb; the safelight housing or filter is cracked; the safelight filter series is incorrect; the exposure of the film to the safelight is prolonged, especially at short distances.

Radiographic Identification

Since the radiograph is a legal document, admissible in court as evidence, you have a legal as well as an occupational responsibility to make certain that all necessary information is properly imaged on every radiograph. Evidence of collimation on all radiographs is also required by law.

Therefore, before processing the film, you must make sure that the film has on it information that properly identifies the patient. This information includes the following:

- patient's name, date of birth, and social security number
- date of the examination
- physician's name (and address, if different from that of the institution)
- name and address of institution (hospital, government or private health care facility) where the examination was performed

Manual Processing

Although most health care facilities are using automatic film processors, some still use manual processing. For manual processing, you need the processing chemicals: developer, stop bath, and fixer.

Developer. The developer is an alkaline solution composed of reducing agents, a restrainer, an activator, and a preserver. Its function is to **convert the latent image to a visible** (manifest) **image.**

All developers begin to process the unexposed parts after a period of time, thus producing a chemical fog. Therefore, **developing time** is important, as is the **temperature of the developer** solution.

These two factors have an inverse relationship. As the temperature of the chemicals increases, the time required to develop the film decreases. To achieve maximum contrast, the best time and temperature combination for developing is **five minutes at 68°F.** At 75° F, development time is 3 1/2 minutes, while at 60° F development time is 6 1/2 minutes. In short, the higher the temperature, the briefer the developing time, and vice versa. If overdevelopment, contaminated developer, or a too-high temperature of the developer has been allowed, film fog will result, and both radiographic density and contrast will be decreased.

Stop Bath. Stop bath is a mixture of clean water and 1-5 percent acetic acid. Its function is to **stop the action of the developer** by rinsing off most of the chemicals and by neutralizing the alkaline developer. Sometimes, however, you can rinse the developer chemicals off the film by placing it under running water for about 30 seconds.

Fixer. The fixer is composed of a fixing agent, acidifier, hardener, preserver, and water. Its function is to neutralize the developer, remove undeveloped silver, and harden the emulsion **to make the manifest image permanent.** Because of its acidifier, the fixer further neutralizes any developer that might remain after the acid stop bath or water rinse.

Fixing time usually depends on the age of the fixer. It generally takes **about 10 minutes.** A satisfactory fixer requires about one to four minutes to remove the unexposed silver. It takes twice as long to harden the emulsion so that the image is permanent. Prolonged action, however, may dissolve some of the silver and thus cause the film to fade.

Water Wash. The effectiveness of the final wash depends on the temperature of the water, the water-flow rate in the wash tank, and the number of film sheets being washed at one time. Generally, with water **flowing rapidly** through the tank, **20 minutes at 68° F** is adequate. A longer period of time is required when the temperature is lower, when the water flow is slower, or when many film sheets are being processed at one time.

CAUTION: Since hot water softens the film emulsion, be sure to use warm water.

Film Drying. You can dry the film either by placing the film hangers on a special rack, which is normally mounted on the wall, or by using a film dryer, which consists of a special rack, a fan for air circulation, and a source of heat.

Replenisher Solution. When you use the developer continually, the chemicals become exhausted and the level in the developing tank drops because some solution is carried out with each processed film. To make up for this loss of strength and volume, you should periodically add new developer solution, called replenisher solution, to the tank. Then, you may be able to use the developer for about three months. You can also replenish the fixer by adding fresh fixer after discarding an equal volume of older fixer. Replenishment can prolong the useful life of the fixer and maintain its strength.

Cleaning Tanks

Periodically you need to empty the developing, stop bath, and fixing tanks, thoroughly scrub and rinse them, and fill them with fresh developer or fixer. Following is a basic procedure for cleaning the manual-processing tanks.

STEP 1: Remove drain plugs and allow tanks to drain.

STEP 2: Using a soft, plastic scrub brush, scour the tank walls.

STEP 3: Rinse the empty tanks completely with water.

STEP 4: Replace drain plugs. Mix new chemicals in developing and fixing tanks according to the manufacturer's directions. Be careful not to cross-contaminate them.

STEP 5: Fill rinse and wash tanks with water.

Processing Film Manually

These five stages of the manual processing of film can be described in a step-by-step procedure, as follows. You should remember, however, that this is a general guideline only.

STEP 1: Have all necessary supplies and equipment ready.

- film hanger
- timer
- thermometers
- stirring paddles (three, if you use stop bath; two, if you use running water for rinsing the film after the developer)
- processing tanks for developer, stop bath, and fixer
- processing chemicals developer, stop bath, and fixer
- film in the cassette

STEP 2: Secure the darkroom by closing and locking the door.

STEP 3: Mix the developer in a developing tank, as follows.

- Check the water temperature, using the thermometer. When it is 68°F, mix the developer in the water, following the instructions packaged with the developer.
- Stir with a clean paddle until the developer is completely dissolved.
- Make sure the developer solution is deep enough to fully cover the film to be processed.

STEP 4: Mix the stop-bath solution in a stop-bath tank with clean water, according to package instructions (usually 1/2 ounce of stop bath to I quart of water). Stir with a clean paddle.

NOTE: You may skip this step if you are using running water instead of a stop bath.

STEP 5: Mix the fixer with water in a fixer tank, according to the instructions packaged with it (usually one package of fixer to a gallon of water). Stir with a clean paddle.

CAUTION: Do **not** use the same paddle you used for mixing the developer or the stop bath.

NOTE: You must mix the chemicals just before use, since chemicals stratify after sitting more than three hours.

STEP 6: Determine the developing time (usually five minutes for 68°F developer). You may need to use a chart that lists developing times for different types of film.

STEP 7: Determine the fixing time (usually about 10 minutes).

STEP 8: Set the timer for developing, but do not start it.

STEP 9: Turn off all lights except the safelight.

CAUTION: Make sure **not** to expose the film to the safelight for too long a time.

NOTE: By this step, you must have made sure that the patient-identification information is placed on the film.

STEP 10: Unload the cassette (see Figure XIII), as follows.

- Remove the cassette through the inside door of the pass box.
- Place the cassette tube-side down on a dry surface.
- Unlock the cassette.
- Gently open the lid carrying the back intensifying screen.
- Remove the film from the bottom of the opened cassette.
- Close the cassette.

CAUTION: Handle the film by its sides or at the extreme edges. Do not drag the film across the cassette or scrape or slide the film over the surface of the intensifying screen.

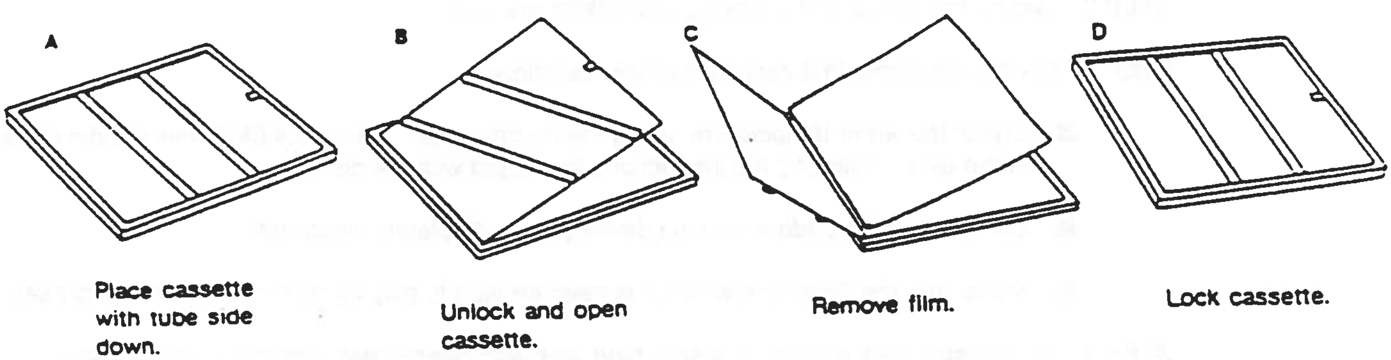


Figure XIII
Unloading the Cassette

STEP 11: Place the film on the film hanger, as follows.

- Select a hanger that is the correct size for the film being processed.

- Starting with the two fixed clips and then using the two movable clips, attach the film to the hanger.
- Make sure the film is securely clamped to the hanger (see Figure XIV).

CAUTION: Never allow the film to touch the sides or ends of the hanger.

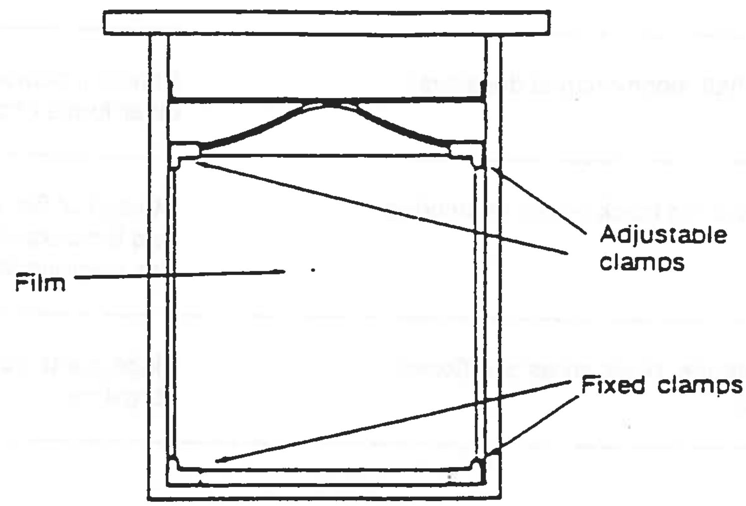


Figure XIV
Film on the Hanger

STEP 12: Start the timer. Immerse the film on the hanger in the developer. Agitate the suspended film as you immerse it.

NOTE: Agitation helps ensure even, speedy development and prevents spotting or staining.

STEP 13: When the timer goes off, remove the hanger from the developer

STEP 14: Rinse the suspended film either in a running-water bath for 30 seconds or in an acid stop bath for 20 seconds. Agitate it. Allow the excess water to drain off the film.

STEP 15: Place the hanger in the fixer and start the timer clock. Agitate the film gently to keep bubbles from remaining in on place on the film surface.

STEP 16: When the timer goes off, remove the hanger and rinse the film in running water for about 20 to 30 minutes, depending upon the force of the water flow.

STEP 17: Place the hanger in the drying area or in a dryer.

STEP 18: Remove the film from the dryer and hanger. Clip the corners to prevent the accidental scratching of other radiographs.

STEP 19: Examine the processed film--the radiograph--for artifacts. Artifacts on radiographs can be signs of improper film handling, improper processing, or a faulty cassette.

NOTE: Since accurate film examination takes some experience, you may need help at first. Before going on to STEP 20, study the following charts, which list some signs of artifacts and the probable causes of each.

Artifacts Probably Caused by Improper Handling of Film

Signs	**Probable Causes**
Crescent marks (half-moon-shaped densities)	Bending, creasing, folding of film; other forms of pressure on film
Static marks (branching black marks or smudge patterns)	Storage of film in low humidity or at cold temperatures; rough handling of film; ungrounded equipment
Smudge marks (dense, black areas of different sizes and shapes)	Fingerprints from wet hands or finger abrasions
Scratches (thin, clear areas)	Accidental removal of the emulsion, from film scraping against either a sharp object, the side of a processing tank, or a film-hanger clip
Chemical fog (overall grayish density)	Overdevelopment; contaminated grayish density) solutions; high temperatures during development
Streaks (dark or light lines)	Uneven development resulting from insufficient agitation, pressure, or solution splashed directly on film

Artifacts Probably Caused by Improper Manual Processing

Signs	Probable Causes
Filling (curly or wavy appearance)	Exhausted fixer and water; solution temperature too high
Spotty, fingermark stains	Handling of film during removal from wash by unwashed hands
Kiss marks (clear areas of greenish-white blemishes)	Film touching other film while in the solution
Drying marks (white, patchy blemishes)	Inadequate film drainage between washing and drying; overheated dryer
Light fog (a black or gray haze on the film)	Loose hinges or worn springs or felt on cassettes;improper folding of envelope in cardboard holder
White specks (pinhead-size white dots)	Dust or dirt on intensifying screens of cassettes
Fuzzy image	Poor screen-film contact or defective screens
Clear film	Contrast media spilled on the cassette or x-ray table

STEP 20: Dry your hands. Reload the cassette for the next radiograph, as follows.

- Place the cassette on the loading table.
- Lift the back of the cassette.
- Place unexposed film in the bottom of the opened cassette.
- Superimpose it on the front intensifying screen.
- Gently close the lid that holds the back intensifying screen.

■ Lock the cassette (see Figure XV).

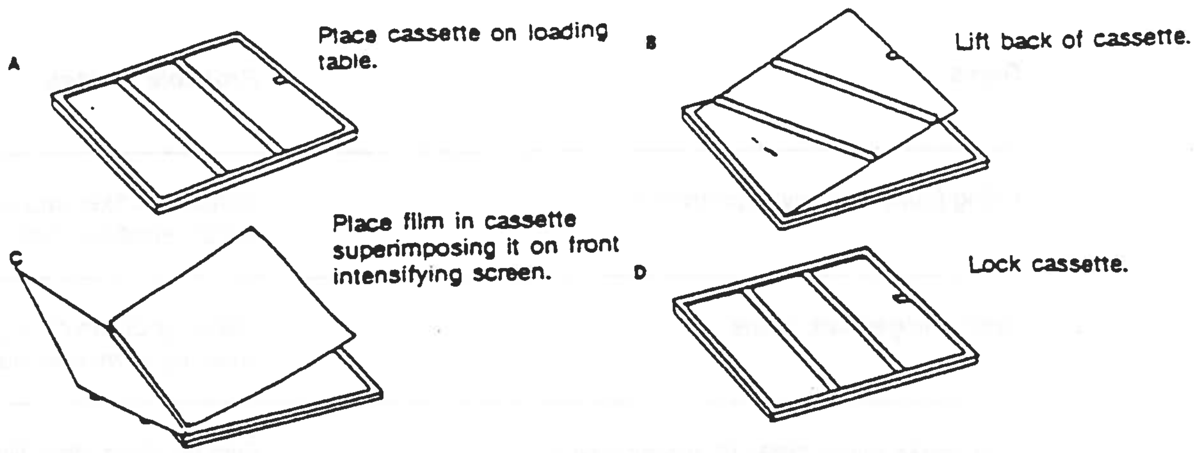


Figure XV
Loading the Cassette

NOTE: When loading and unloading film, you must have clean, dry hands, as hands with lotion or dampness will leave artifacts on the film, and you must be gentle with the film, as the emulsion is easily damaged.

Summary

Radiographic film is sensitive to pressure, heat, radiation, chemicals, and light. It is sensitive even to the safelight if exposed to it too long, especially after its exposure to x-rays and before its development. Therefore, care in handling and storing film is important.

Exposed film can be processed by means of either a manual or an automatic procedure. Either way, there are five basic, distinct steps: developing, stopping developer action, fixing, rinsing, and drying.

After development, the radiograph should bc evaluated for its quality. Poor quality is often indicated by the presence of various artifacts. Although some are caused by improper technical factors (incorrect exposure factors, patient motion, poor patient positioning, an improper screen-film combination, poor screen contact, or double exposure), other types of artifacts may be traced to the improper handling, storage, or processing of the film.

Automatic Film Processing and Quality Control

Automatic Processor

Many health facilities use an automatic processor for film processing. This machine continually feeds the film from one chemical solution to another and through a drying cycle, until it emerges as a finished radiograph. Automatic processing has many advantages over manual processing:

- Processing time is shorter than for manual processing (about 90 seconds as compared with 1 hour).
- It gives more uniform processing and allows better quality control than the manual method.
- It improves and helps to standardize the radiographic technique in the radiology department or office.
- It improves patient care by improving efficiency in radiograph production.
- It facilitates departmental work flow.

An automatic processor is composed of six basic systems:

1. transport system
2. replenishment system
3. temperature-regulation system
4. recirculation system
5. water system
6. dryer system

A cross-sectional view of an automatic processor is shown in Figure XVI.

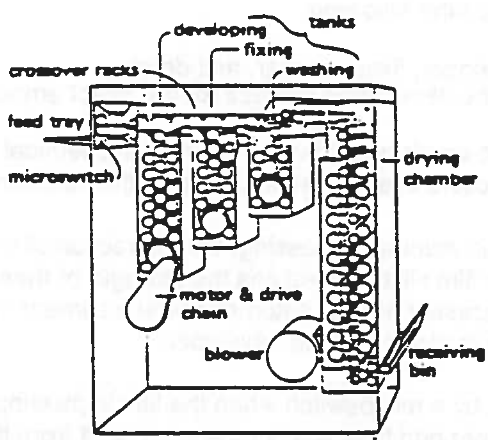


Figure XVI
Cross-sectional view of an Automatic Processor
Reproduced by permission from: Bushong, Stewart C.: *Radiologic Science for Technologists*, ed. 3, St. Louis, 1984, The C.V. Mosby Co.

The Transport System. The transport system is composed of a **feed** tray, rollers, and a main drive motor. Energy from the drive motor is transferred to a drive shaft that activates a series of cog wheels and gears that, in turn, move the rollers of the crossovers and racks.

When film is placed lengthwise into the feed tray, two rollers draw the film into the processor. As the film passes in, a microswitch is activated and an audible tone is given or a safelight comes on to indicate that it is safe to place a second film in the feed tray. If the second film is fed in before the first film has passed through the first two feed rollers, the edges of the two sheets of film could overlap and **both would be ruined**.

Crossover rollers and racks move the film through a crossover and then downward into the developer. The film continues through the roller transport system and then upward to the next crossover rollers (see Figure XVII).

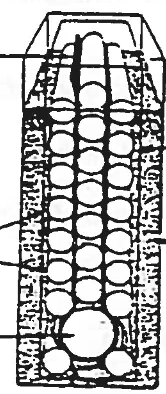


Figure XVII
Rollers Transporting the Film

Reproduced by permission from: Bushong, Stewart C.: *Radiologic Science for Technologists*, ed. 3, St. Louis, 1984, The C.V. Mosby Co.

the rollers in the transport system do the following:

- move the film through the developer, fixer, washer, and dryer
- hold the film at each stage of the developing process for the exact amount of time required
- agitate the film
- squeegee the solution from the emulsion of the film to prevent chemical contamination during the next stage (Only the last few rollers in each section perform this function.)

The Replenishment System. As in manual processing, the interaction of the developing and fixing chemicals with the emulsion of the film slightly weakens the strength of these solutions. To replenish these chemicals, an automatic processor has an automatic replenishment system that is composed of two replenisher tanks, which store the fixer and the developer.

The replenisher pump is activated by a microswitch when the film is passing through the entrance roller assembly. The replenisher developer and fixer solutions are pumped from the tanks each time the microswitch is activated, and for the length of time it takes the film to pass through the feeder rollers. Therefore, the amount of replenisher solutions added has a direct relationship to the length of the film. The **size of the film and the manner in which it is fed into the processor affect the amount of replenisher solution added.** For example, a 7" x 17" film should be fed with the 17" side entering the processor. If the 7" side is fed, too much replenisher will be added. This is known as overreplenishment. **Overreplenishment of developer can cause lower contrast and density.** Therefore, **you should always feed the film into the feed tray crosswise.**

Failure of the microswitch, low solution levels in the tanks, pump failure, and clogged filters can cause underreplenishment. This condition appears as a loss of density on the finished radiograph.

Temperature Regulation System. The speed at which the developer and fixer chemicals act upon the film emulsion is regulated and controlled by the temperature of the solutions. When the temperature is higher and the chemicals are more active, less time is required. The faster the processing time of the automatic processors, the higher the temperature of the chemicals. A device with an automatic thermostat heats the water as it passes through; the water then, by the process of heat exchange, controls the temperature of the replenisher solutions. The chemical temperatures should vary no more than 2° F.

The wash water temperature is controlled by a mixing valve that mixes hot and cold water. A thermostat gauge is located between the mixing valve and the automatic processor. A shut-off valve is usually located between the thermostat and the mixing valve so that the mixing valve does not have to be readjusted each time the water flow is turned on.

The Recirculation System. The recirculation system consists of processor tanks, filters, pumps, and drains. It provides the necessary agitation by continually mixing the replenisher solutions. This process helps keep the solutions at a constant temperature and in constant contact with the film. The solutions arc pumped from the processor tanks and passed through filters, which filter out extraneous particles and by-products of film development. The solutions are then returned to the processing tanks.

The Water System. The water system circulates water through the wash tank to remove all residual processing chemicals from the film. It is an "open system," in that fresh tap water is piped into the tank at the bottom and overflows directly into the sewer system.

The Dryer System. This system is composed of a blower, ventilation ducts, drying tubes, and an exhaust system. The dryer system can dry the film in a very short time under the following conditions:

- Film must be properly developed by the developer and fixer.
- Rollers must have removed surface moisture before the film enters the dryer section.
- An adequate supply of warm air from the dryer must strike both sides of the radiograph.
- The temperature of the air in the dryer section must be 120°-130° F.
- The exhaust system must remove the warm, moist air so that only the hot, dry air moves over the surface of the film.
- The holes at the ends and the slits along the sides of the air tubes that direct air onto the films must be clean.

Operating an Automatic Processor

Before using any automatic processor, you must consult the manufacturer's operating manual. The following is a general, basic procedure for operating a processor.

STEP 1: Check the level of the replenishment solutions in the covered plastic tanks.

STEP 2: Secure the darkroom.

STEP 3: Secure the cover on the automatic processor so that light will not expose the film.

STEP 4: Turn on the automatic processor as follows.

- Turn the circuit breaker to ON.
- Turn the water control knob to ON.
- Turn the processor switch to ON.

STEP 5: After the solutions and dryer are at operating temperature, run an unexposed film for quality control. If quality is acceptable, go on to STEP 6. If not, run unexposed film until quality is acceptable.

STEP 6: Feed an exposed film into the processor.

STEP 7: Pick up the finished radiograph.

STEP 8: Examine the radiograph for any artifacts and determine the probable cause(s).

NOTE: Some of the artifacts that result from **improper automatic processing** and their probable causes are listed on the following page.

Artifacts	**Probable Causes**
Uneven spots	Poor squeegee action of first two or three pairs of rollers in dryer
Small clear spots	Dirt on the screen
Drying streaks	Dirty air tubes; air tubes out of position
Scratch	Improperly seated rollers or other restriction in lines; faulty thermocouple in heat exchanger; faulty thermostat
Fog	Light leaking into darkroom; improperly fastened cover on wet section of processor; contamination of developer with fixer; chemical imbalance

Streaking or insufficient density	Weak developer (low developer concentration); developer temperature too low
Mottling	Concentrations of developer too high
Yellow smudges	Exhausted fixer
Lack of clarity	Concentration of fixer too high

Evaluation of Radiographs

If you do not successfully produce a high-quality radiograph with the first exposure, you should be able to identify the cause of the poor quality and make the appropriate corrections. As you know, a high-quality radiograph is the result of proper patient positioning, patient immobilization (lack of movement during exposure), well-coordinated technical factors, and optimum processing. Consequently, criteria for radiographic evaluation are based on these factors. Since artifacts resulting from improper manual and automatic processing have been covered already, other general signs of poor quality are discussed here.

Criteria for Diagnostic Radiographs. When evaluating a radiograph, you should place it on the view box and look for the four characteristics of a high-quality radiograph--sharp, clear recorded detail; minimal or no distortion of shape and size; adequate density; and good contrast--and the following:

- All of the necessary identification information is shown on the radiograph.
- There is no artifact, especially on the area of interest.

NOTE: Generally a radiograph need not be repeated if the artifact is located outside the area of interest. Before accepting a film with an artifact, in order to save the patient from a second exposure, you should make certain the artifact does not jeopardize the diagnostic value of the radiograph.

Causes of Poor-Quality Radiographs. When a radiograph fails to meet any of these criteria, identify the probable cause(s) of poor quality and make corrections to improve the next radiograph. Following is a chart indicating signs of poor quality, their probable causes, and recommended corrections:

Signs	**Probable Causes/ Technical Factors**	**Recommended Corrections**
Underexposed[16]	mAs or kVp	Increase mAs or kVp

[16] underexposed: detail lacking because of inadequate density

Overexposed[17]	mAs or kVp	Decrease mAs or kVp **NOTE:** Have exposure timer checked if problems continue.
Scale of contrast too low (fog) or too high	kVp	Increase kVp if too high; reduce kVp o if too low.
Increase or decrease in overall film density	target film distance (TFD)	Correct TFD.
	Film-screen combination	Correct film-screen combination and adjust exposure factors.
	Pathological conditions	Check patient's history and measurement; adjust mAs and kVp.
Loss in detail	Focal-spot size	Use small focal-spot size if number of heat units for x-ray capacity allows; adjust mAs.
	Film-screen combination	Correct film-screen combination.
	Film-screen contact	Replace screen.
Increase or decrease in overall density	target film distance (TFD)	Correct TFD; correct mAs or kVp.
Loss of detail	target film distance (TFD)	Correct TFD; correct mAs or kVp.
	Patient motion	Improve immobilization; adjust mAs to reduce exposure time.
	Object-film alignment	Correct patient-film alignment.

[17] overexposed: detail lacking because of overall grayness and low contrast

Shape distortion	Object-film alignment	Correct patient-film alignment.
	Tube-object alignment	Correct radiographic-tube-to-patient alignment.
Size distortion (magnification)	target film distance (TFD)	Correct target-to-film distance; correct mAs or kVp.
Increase in overall density	Fog	Correct darkroom environment.
Decrease in overall density	Contamination	Correct darkroom environment.
Increase or decrease in overall density	Processing chemicals	Troubleshoot and correct chemical conditions, time, and temperature.
	Artifacts	Improve film handling; repair cassettes; correct film-processing conditions that might have resulted in artifacts.

Evaluating radiographs requires not only knowledge, but experience. You may need help until you gain enough experience and confidence to correctly determine the quality of radiographs.

NOTE: It is a professional challenge to produce a radiograph of optimum quality while keeping the patient's radiation exposure as low as possible. Since the patient's anatomy, physique, and pathological condition present a range of variables to threaten the quality of the radiograph, exposure factors, beam restriction (collimation), and processing need to be standardized. For this reason, many of the accessories are automated.

Quality Control

To ensure the consistent production of high-quality radiographs, you should perform certain quality-control procedures routinely. These procedures include periodic cleaning of the processor, system maintenance, and daily monitoring.

Processor Cleaning. Through continual use of the processor, the transport system can become worn and corroded, the rollers can accumulate deposits of sludge and debris, and the processing tanks can accumulate residual chemicals. All of these can cause artifacts and reduce the quality of radiographs. To keep the processor in good condition, you should clean it at least every three months or after developing 50,000 radiographs. To clean the processor, consult the manufacturer's operation manual. Basically, you remove and clean the transport and crossover racks in the tanks.

System Maintenance. To maintain the processor in good condition, you should generally do the following:

- Observe all moving parts for wear; identify when any of these need replacement.
- Clean the crossovers frequently.
- Leave the cover of the processor ajar at the end of the day to allow the humidity to escape.
- Adjust all belts, pulleys, and gears, as needed.
- Lubricate the moving parts, as needed.
- Replace the filters in the recirculation system on a routine basis.

By performing these maintenance activities, you should be able to replace worn parts before they fail, and thereby reduce unnecessary down time. This is called **preventive maintenance.** When routine maintenance is scheduled on a regular basis, you should be able to minimize **nonscheduled maintenance,** which is emergency repair of the processor.

Daily Processor Monitoring. At least once a day, you should do the following:

- Observe the operation of the processor.
- In a daily maintenance log, record developer- and fixer-replenishment and water-flow rates.
- Record the temperature of developer and fixer solutions.
- Check the levels of replenisher solutions.
- Add fresh replenisher solutions, as necessary.
- Record appropriate measures of density, fog, film speed, and contrast by passing a **sensitometric film strip** through the processor.

NOTE: A sensitometric film strip is used to detect changes in the temperature and concentration of the developer and the fixer and to measure radiographic density and fog, film speed, and contrast. To use it, you should place it in a densitometer, which passes a point-sized light beam of constant hue through the film.

Automatic Processor Problems and Their Probable Causes

By performing these quality-control activities, you should be able to:

- observe any changes in density, contrast, speed, and fluctuation in fog before performing a radiographic xamination
- identify possible causes of malfunctions that affect developer temperature and concentration replenishment, contamination, water-flow rate, etc.

When you note an increase or decrease in film density, you may need to consider possible problems with the processor. These problems and their probable causes are listed in the following chart.

Automatic Processor Problems and Their Probable Causes

Problems	Probable Causes
Underreplenishment	Low replenishing rate; air locks in replenishing lines; clogged filter
Overreplenishment	High replenishing rate
Low or high developer temperature	Faulty thermometer or thermostat; faulty heat exchanger; faulty mixing valve
Decreased developer activity	Contaminated or exhausted developer;improperly mixed developer
Overactive developer	Improper mixing procedures and sequences; high replenishing rate; wrong chemicals
Immersion time prolonged	Faulty transport system; excessive wear of gears and sprockets; incorrect alignment; lack of lubrication

Note: Underreplenishment, low developer temperature, and decreased developer activities result in decreased film density. Overreplenishment, high devloper temperature, overactive developer, and prolonged immersion time result in increased film density.

Summary

Because of their advantages over manual processing, more and more automatic processors are being used. Even with an automatic processor, however, you can produce a poor-quality radiograph. You should be able to identify the signs and probable causes of poor quality and to make corrections for the next radiograph.

In order to ensure that you get high-quality radiographs consistently, you should develop a systematic quality-control program. This together with the correct exposure factors, should help you produce high-quality radiographs.

Positioning Terminology

Standard Terminology

The following terms are commonly used for radiographic procedures and patient positioning:

view: the way the film "sees" the part being x-rayed; applies only to the radiograph.

position: denotes the position of the patient. For example, most routine podiatric radiographs are done with the patient in the erect (upright) position. Other positions are supine, prone, decubitus, and recumbent.

projection: refers to the path of the x-ray beam. The surface of the body that the x-ray beam enters first is named first, and the surfact of the body that the x-ray exits is names last (i.e. dorso-plantar).

<u>The Anatomical Position</u>. To avoid misunderstandings in describing the locations of anatomical structures, use the standard body position as a point of reference. This standard is called the **anatomical position**. If you look at a person whose body is erect and whose arms are hanging at the sides, with the palms of the hands turned forward, you see a person in the anatomical position.

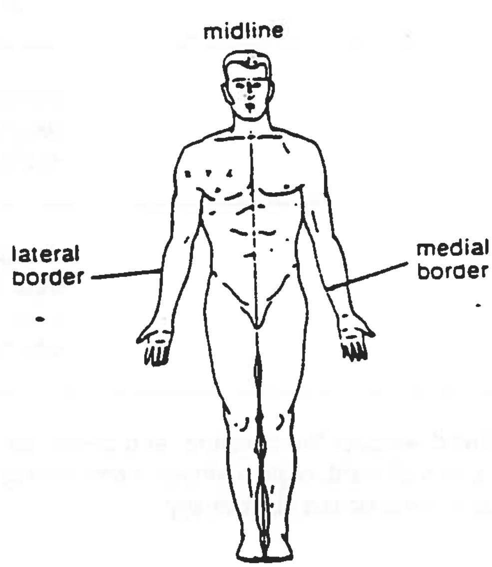


Figure XVIII
Anatomical Position

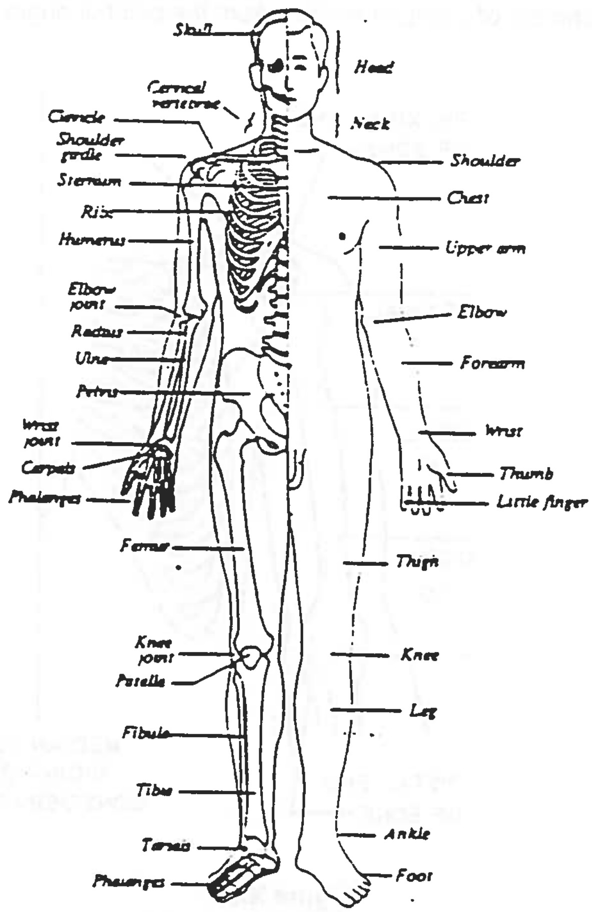


Figure XIX
Anatomical Position Showing the General Structure of the Skeleton

The following terms refer to the body in the anatomical position:

anterior and **ventral**: the front of the body
posterior and **dorsal**: the back of the body
plantar: the sole of the foot
dorsoplantar: a view through the upper surface of the foot to the sole
plantodorsal: a view through the sole of the foot to the upper surface
medial: structures located near the midline of the body
medial border: border of a structure located near the midline of the body
lateral: those structures near the side of the body
lateral border: border of a structure located near the side of the body (the anatomic position of the body farthest from the midline of the body)

For example: The tibia is medial to the fibula, and the fibula is lateral to the tibia.

superior: a position above a particular reference point
inferior: a position below a particular reference point

For example: The knee is superior to the ankle, and the foot is inferior to the knee.

proximal: near the attachment of a limb or nearest the point of origin (see Figure XX)
distal: away from the attachment of a limb or farthest from the point of origin (see Figure XX)

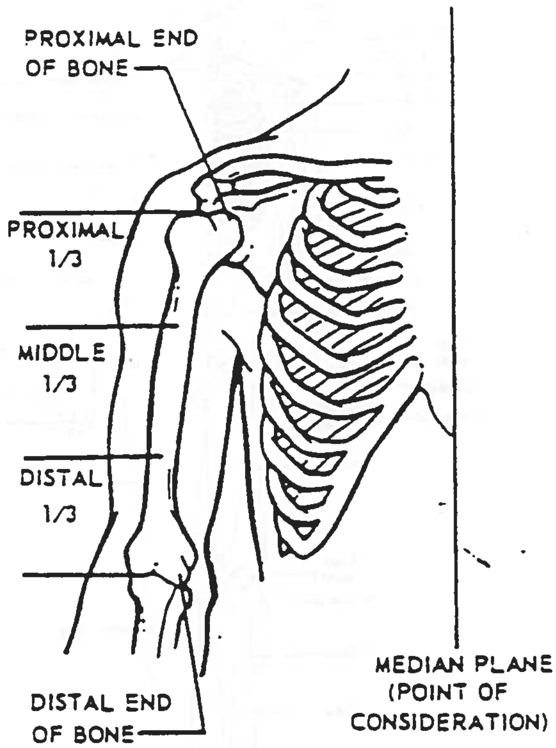


Figure XX
Proximal-Distal Relationships

__Planes of the Body__. The body is divided into imaginary planes, which are used as reference points during positioning. When the body is divided into right and left parts, a **sagittal plane** is established. When it is divided into equal right and left halves, a **median** or **midsagittal plane** is established. When it is divided into front and back parts, a **frontal** or **coronal plane** is established. And when the body is divided into top and bottom parts, a **transverse plane** is established. (See Figure XXI).

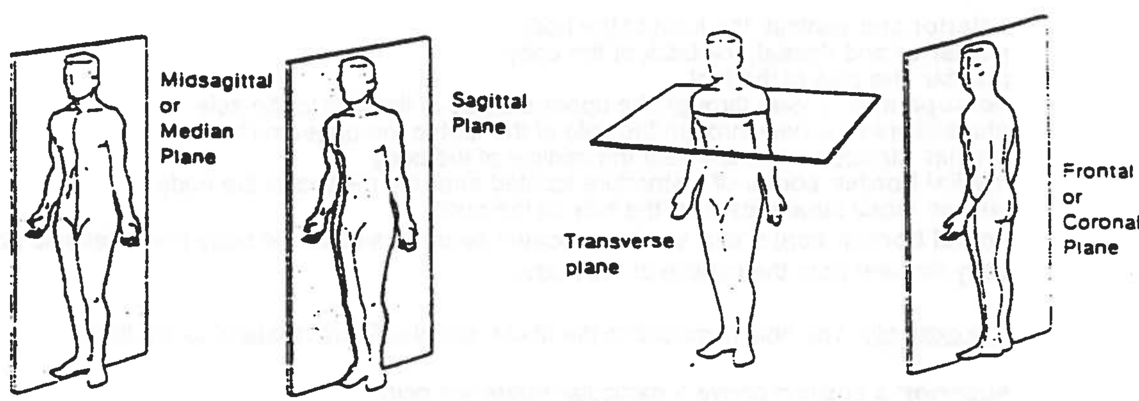


Figure XXI
Planes of the Body

Identification of the Radiograph

As discussed in Unit III, each radiograph must include the patient's identification. In addition, it must include the side of the body examined. Correct identification of the side of the body radiographed is extremely important for accurate diagnosis. If you look at a radiograph of the right foot in a AP position and then you reverse the radiograph, it will look like a radiograph of the left foot. Therefore, **every radiograph must have one marker indicating the side of the body and another marker identifying the patient.**

For the sake of medico-legal precaution and efficiency, all this information should be recorded permanently on all radiographs. For this purpose, you can use a flasher (or ID printer) **before processing the film.** Handwritten identification placed on the radiograph after processing is not admissible in a court of law.

Three-by-five-inch cards and lead markers on an aluminum tab or strip are commonly used for patient-identification information, and lead side markers are used for identifying the side of the body. Other suitable radiopaque materials can also be used if they can be placed on the cassette before the exposure is made.

A film-identification marker set consists of a multiple-compartment storage box, plastic-mounted lead numbers and letters, and a tab or strip on which the data may be assembled.

The following is a **general procedure for placing identification marker set on the radiograph.**

STEP 1: Gather three-by-five-inch cards or a film-identification marker set and lead side markers ("R" for right and "L" for left).

STEP 2: Either write or type the patient-identification information on a three-by-five-inch card. This information should include the patient's name, date of birth, sex, social security number, and file number. Then, on the same or a separate card, write or type the date of the examination and the name of the physician and the medical institution.

Or, using lead numbers and letters, indicate all this information on an aluminum tab or strip. When adopting this method, use the patient's identification number instead of his or her full name.

STEP 3: Place the film-identification marker (either cards or an aluminum tab) along one of the four margins of the cassette, at least three-fourths of an inch in from the outside edge of the cassette.

NOTE: If the marker is to be placed on a cassette in a Bucky tray or on a vertical surface, tape it in place.

STEP 4: Place the lead side marker, either R or L, as follows. Make sure it is out of the way of both the radiographed body part and the extreme corners of the film, since the extreme corners are lead-blocked areas. **For the extremities,** place R for the extremity on the right side of the patient, and L for the extremity on the left side.

STEP 5: Flash the identification information onto an unexposed portion of the film in the darkroom before development. (This step can be done after you make the exposure but before you process the film.)

STEP 6: Position the patient and make the exposure.

CAUTION: All of the information--patient identification, date of examination, and side of the body part--must show on the finished radiograph.

Special Equipment

Weight Bearing Platform. Figure XXIII shows a weight bearing platform used in podiatric radiography.

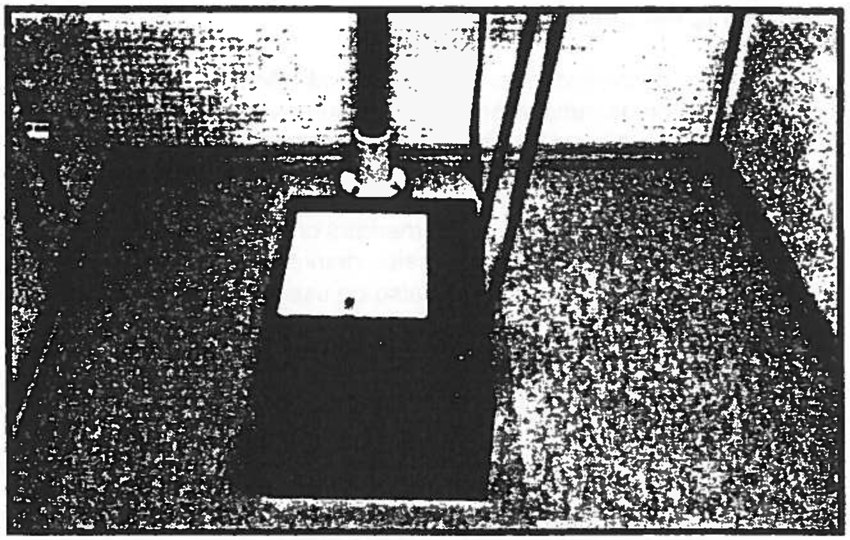


Figure XXIII Weight Bearing Platform

The weight bearing platform is used in most podiatric radiographic positioning. The top of the platform has been cut out to accept a film cassette to be place in a vertical position.

Axial Positioning Device. Figure XXIV shows an axial positioning device.

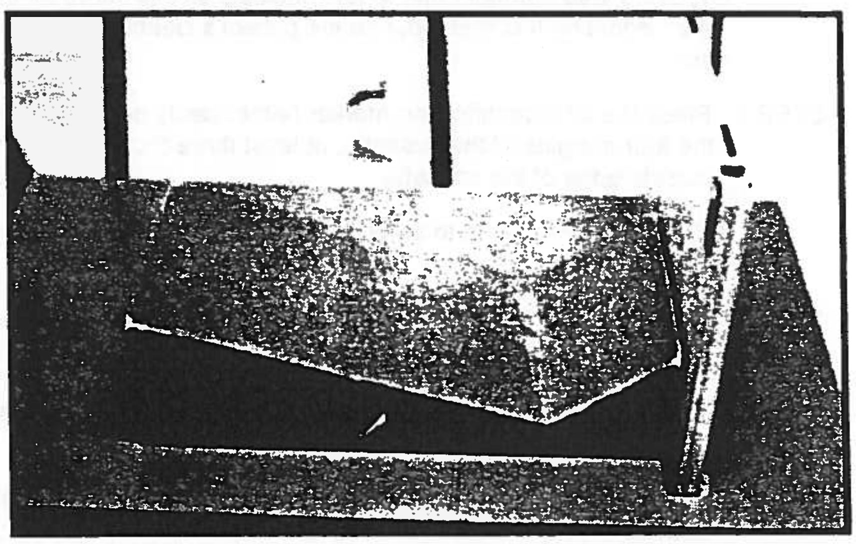


Figure XXIV
Axial Positioning Device

The axial positioning device is used in podiatric radiographic positioning to place the foot in the correct position when radiographing sesamoids.

Special Considerations

This section will show routine positioning that should be used by the basic x-ray machine operator-podiatry. Because of space limitations, weightbearing radiographs taken in angle and base of gait are not shown. The radiographic positioning is the same as that for dorsoplantar and lateral weightbearing radiographs.

The taking of radiographs in angle and base of gait was developed in order to standardize the individual pathomechanical features found in a radiograph so that they can be interpreted and reproduced for each individual. This shows the foot in a functional position rather than a static stance position.

The **angle of gait** is the measurement of the feet in an abductory direction--at a certain distance apart. Formed between feet and line of progression during ambulation.

The **base of gait** is the measurement of the distance between the medial aspects of both heels in progression.

For further information on weightbearing radiographs taken in angle and base of gait please discuss with your podiatrist/employer.

Procedures and Positioning for the Lower Extremity (Below the Knee)

Foot

Anatomy. Figure XXV shows the bones **(phalanges, metatarsals, tarsals)** of the foot.

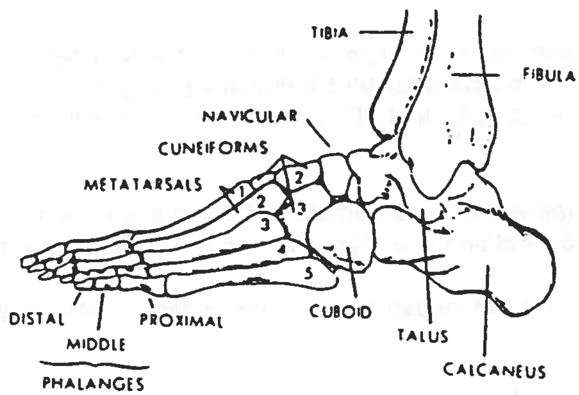


Figure XXV
The Foot

Preparation Procedure. Use this procedure before beginning **any** of the specific projection procedures for the foot.

STEP 1: Have the patient remove any shoes and socks.

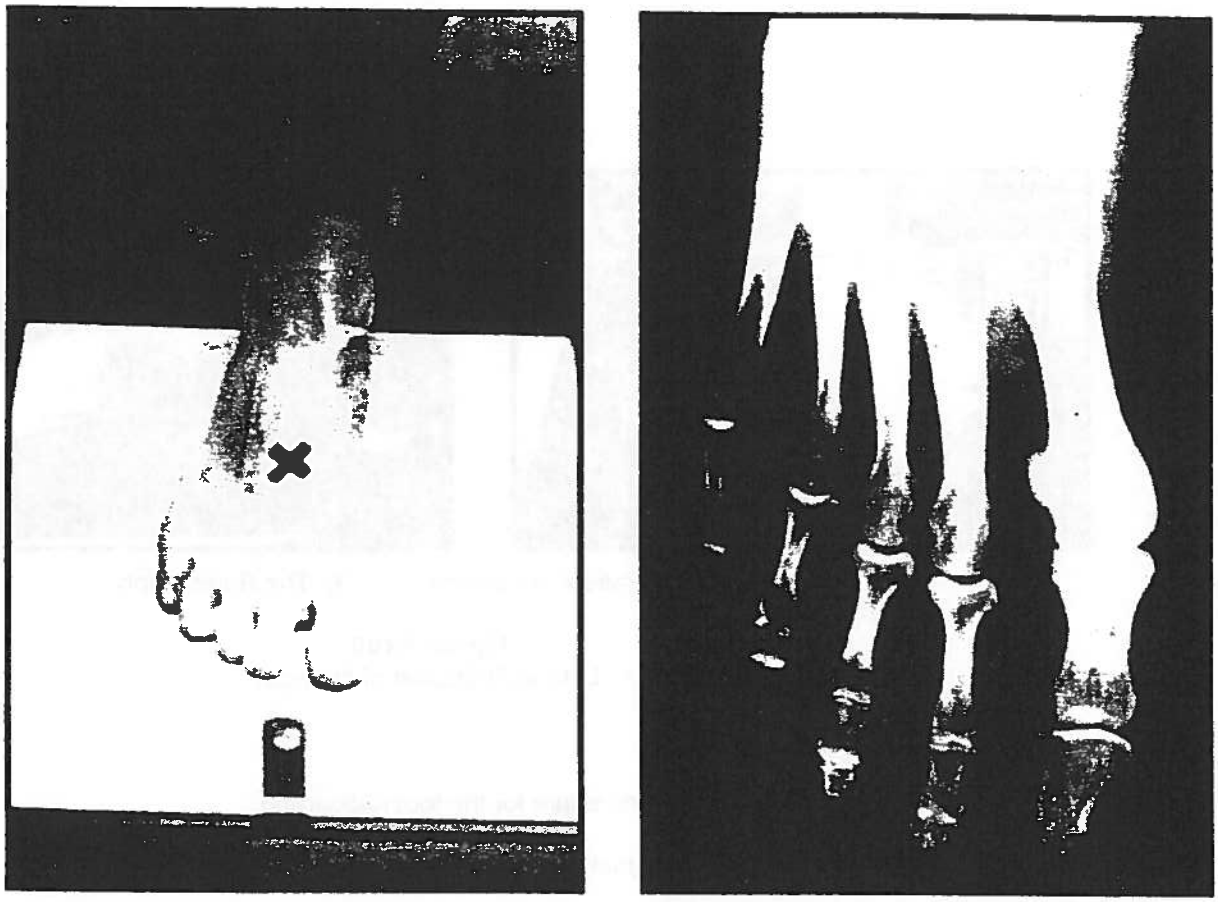
STEP 2: Have the patient stand on the weight bearing platform/film cassette holder.

STEP 3: Place the correct side marker (R or L) on the cassette.

STEP 4: Place the radiographic tube so the CR is directed toward the cassette.

NOTES

Dorsoplantar (DP) or Anteroposterio (AP) Projection: Position Procedure. Figure XXVI shows the patient in position for a dorsoplantar projection of the foot and the resulting radiograph.



A: The Patient in Position B: The Radiograph

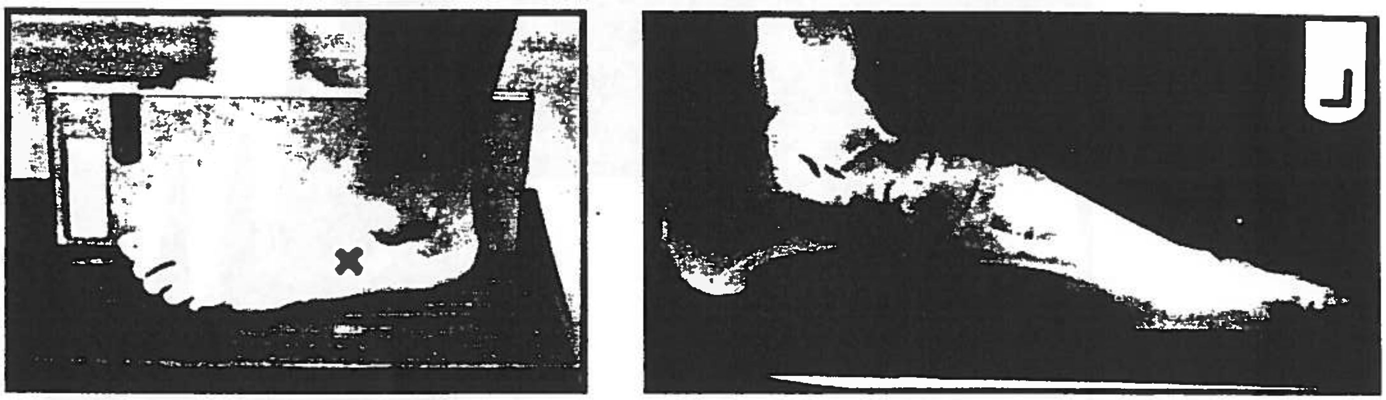
Figure XXVI
A Dorsoplantar Projection of the Foot

STEP 1: Follow the preparation procedure for the radiograph of the toes.

STEP 2: Place the cassette on the weight bearing platform and have the patient stand on the cassette.

STEP 3: Direct the CR at a 15° angle from the vertical through the lateral portion of the navicular if radiographing one foot at a time. If both feet are being radiographed at the same time, then the CR is aimed between the naviculars.

Lateral Projection: Positioning Procedure. Figure XXVII shows the patient in position for a lateral projection of the foot and resulting radiograph.



A: The Patient in Position B: The Radiograph

Figure XXVII
Lateral Projection of the Foot

STEP 1: Follow the preparation procedure for the foot radiograph.

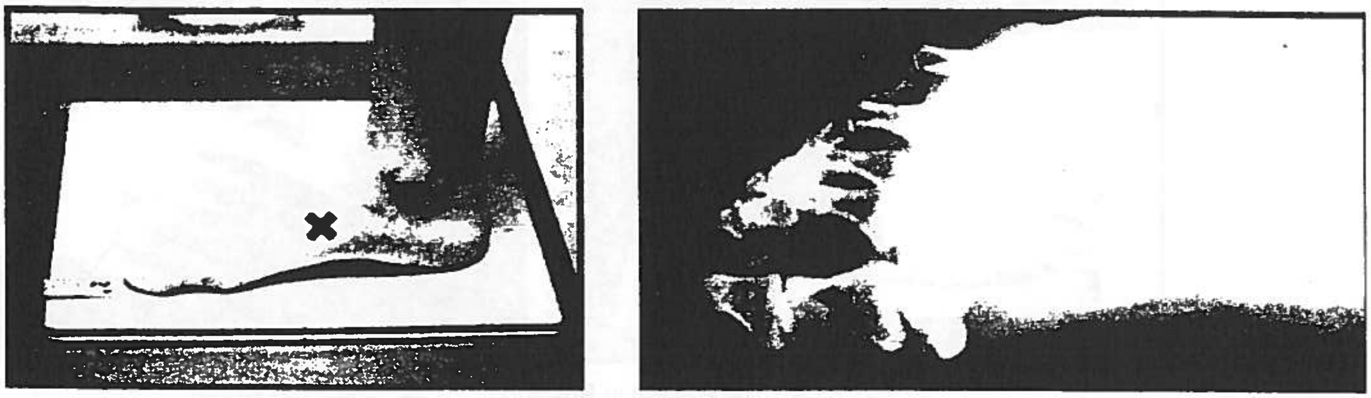
STEP 2: Change the cassette so that the film is unexposed and is vertical in the holder.

STEP 3: Have the patient place the foot being radiographed on the weight bearing platform with the great toe next to the cassette. The foot should form a 90° angle with the cassette.

STEP 4: The CR should be at a 90° angle from vertical and aimed at the cuboid.

NOTES

Medial Oblique Projection: Positioning Procedure. Figure XXVIII shows the patient in position for a medial oblique projection of the foot and the resulting radiograph.



A: The Patient in Position B: The Radiograph

Figure XXVIII
A Medial Oblique of the Foot

STEP 1: Follow the preparation procedure for the foot radiograph.

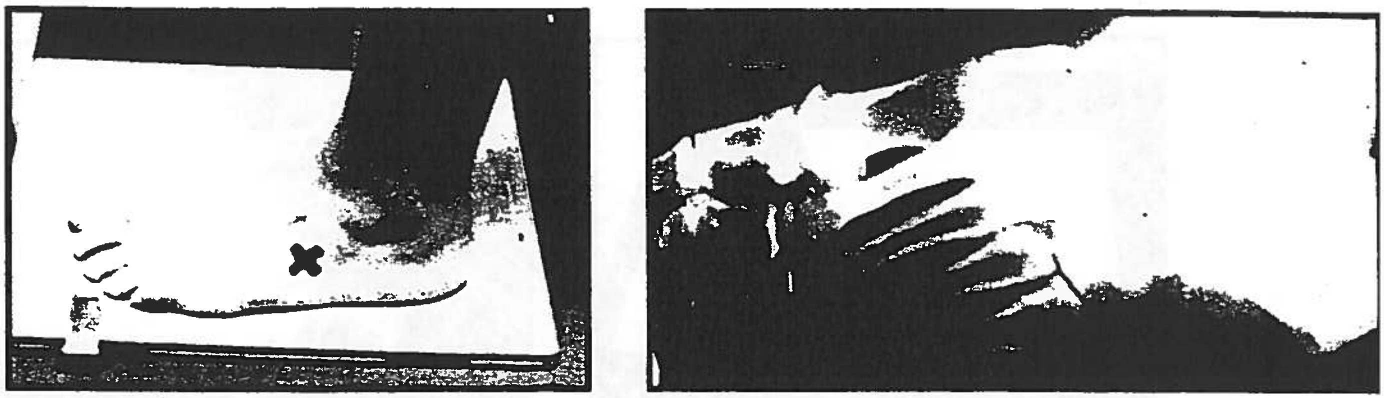
STEP 2: Change the cassette so the film is unexposed.

STEP 3: Have the patient place the foot being radiographed on the weight bearing platform with the foot flat on the film casette.

STEP 4: The CR should be at a 45° angle from vertical and aimed at the navicular.

NOTES

Lateral Oblique Projection: Positioning Procedure. Figure XXIX shows the patient in position for a lateral oblique projection of the foot and the resulting radiograph.



A: The Patient in Position B: The Radiograph

Figure XXIX
A Lateral Oblique Projection of the Foot

STEP 1: Follow the preparation procedure for the foot radiograph.

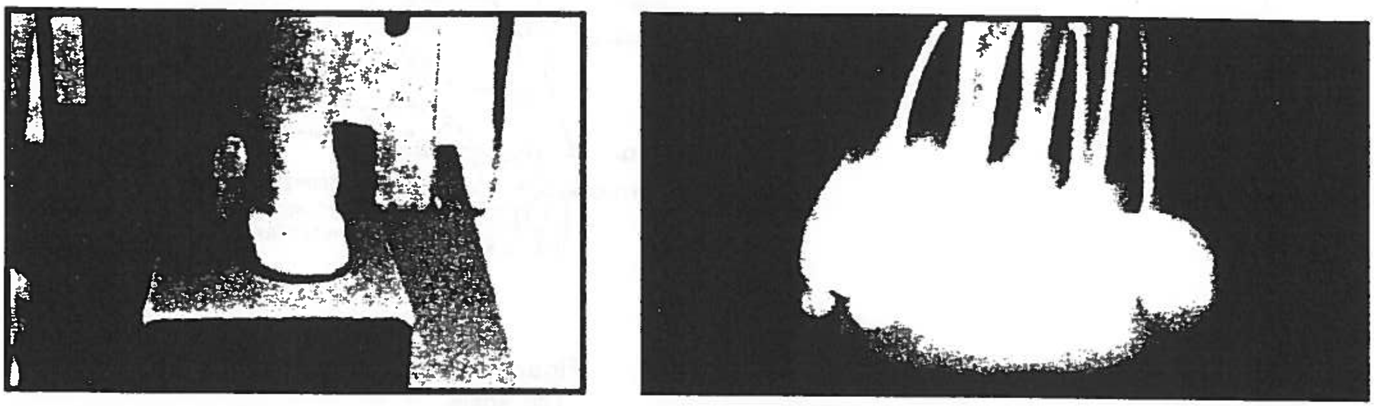
STEP 2: Change the cassette so the film is unexposed.

STEP 3: Have the patient place the foot being radiographed on the weight bearing platform with the foot flat on the film casette.

STEP 4: The CR should be at a 45° angle from vertical and aimed at the cuboid.

NOTES

Axial Sesamoid Projection, Positioning Procedure. Figure XXX shows the patient in position for an axial projection of sesamoids of the foot and the resulting radiograph.



A: The Patient in Position B: The Radiograph

Figure XXX
An Axial Sesamoid Projection

STEP 1: Follow the preparation procedure for the foot radiograph.

STEP 2: Place an axial positioning device on the weight bearing platform in front of an upright unexposed film cassette.

STEP 3: Have the patient place the foot being radiographed on the axial positioning device so that the toes are pointed towards the cassette and are elevated as well as the calcaneus. The foot should form a 90° angle with the cassette.

STEP 4: The CR should be at a 90° angle from vertical and aimed at the plantar aspect of the sesamoids through the axial positioning device.

NOTES

Ankle

Anatomy. Figure XXXI shows the ankle **(talus; distal tibia and fibula; and ankle joint).**

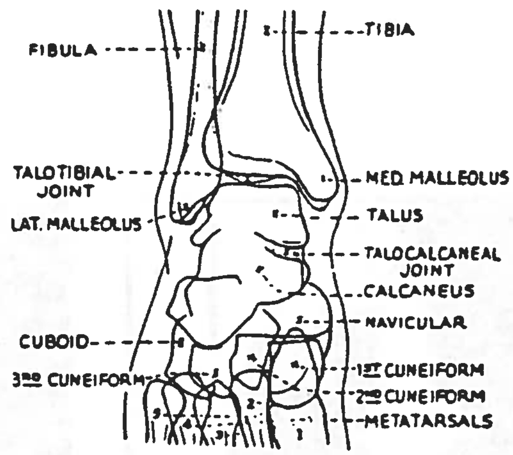


Figure XXXI
The Ankle

Preparation Procedure. Use this procedure before beginning any of the specific projection procedures for the ankle.

STEP 1: Have the patient remove any shoes and socks.

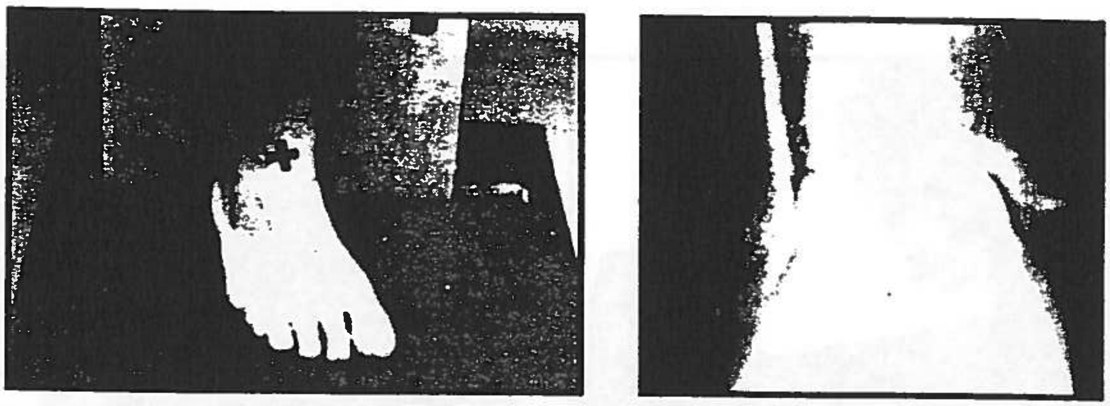
STEP 2: Have the patient stand on the weight bearing platform/film cassette holder.

STEP 3: Place the correct side marker (R or L) on the cassette.

STEP 4: Place the radiographic tube so the CR is directed toward the cassette.

NOTES

Mortise Projection: Positioning Procedure. Figure XXXII shows the patient in position for an Mortise projection of the ankle and the resulting radiograph.



A: The Patient in Position B: The Radiograph

Figure XXXII
A Mortise Projection of the Ankle

STEP 1: Follow the preparation procedure for the ankle radiograph.

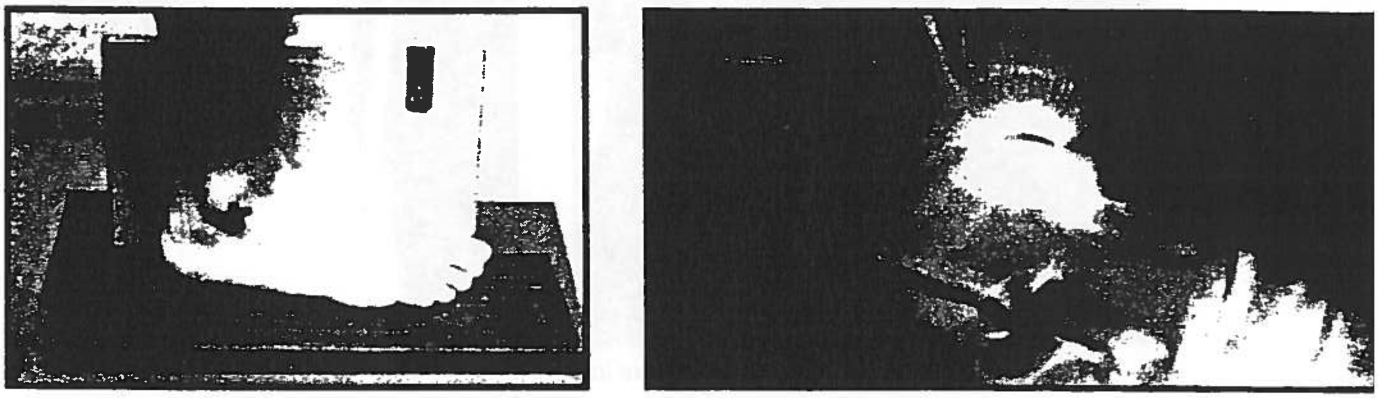
STEP 2: Place a unexposed film cassette in the cassette well.

STEP 3: Have the patient place the foot of the side being radiographed on the weight bearing platform with the heal next to the cassette. The foot should be internally (medially) rotated 15° so that the ankle joint forms a 75° angle with the cassette.

STEP 4: The CR should be at a 90° angle from vertical and aimed through the middle of the ankle joint.

NOTES

<u>Lateral Projection: Positioning Procedure</u>. Figure XXXIII shows the patient in position for a lateral projection of the ankle and resulting radiograph.



A: The Patient in Position B: The Radiograph

Figure XXXIII
A Lateral Projection of the Ankle

STEP 1: Follow the preparation procedure for the ankle radiograph.

STEP 2: Change the cassette so that the film is unexposed.

STEP 3: Have the patient place the foot of the side being radiographed on the weight bearing platform with the medial side of the ankle next to the cassette. The foot should be parallel with the cassette with the malleoli at a 90° angle with the cassette.

STEP 4: The CR should be at a 90° angle from vertical and aimed through the middle of the ankle joint.

NOTES

Calcaneus (os calsis or heel)

__Anatomy__. Figure XXXIV shows the calcaneus (**os calsis**, also called heel).

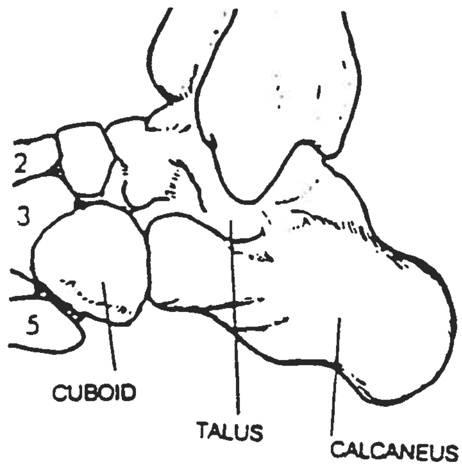


Figure XXXIV
The Calcaneus

__Preparation Procedure__.

STEP 1: Have the patient remove any shoes or socks.

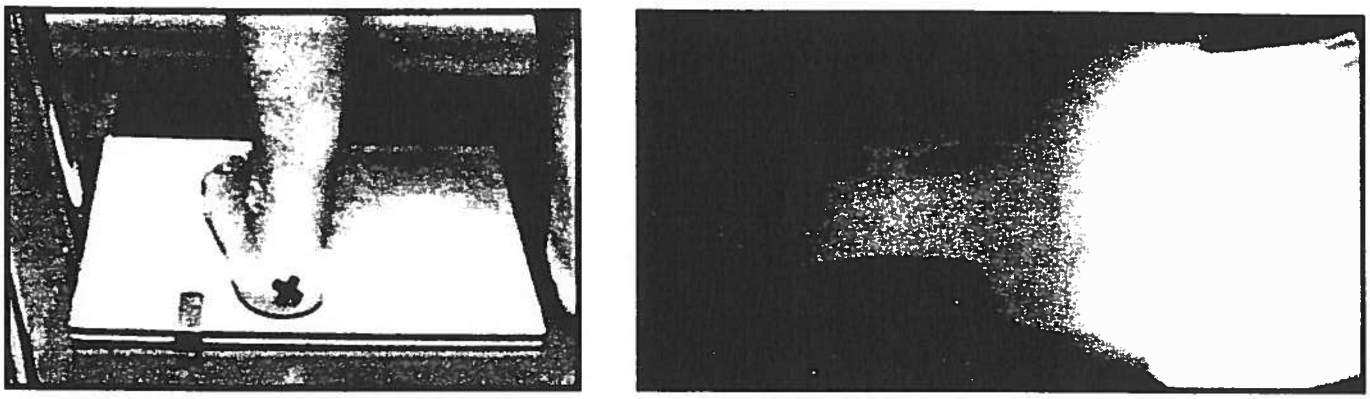
STEP 2: Place an unexposed film cassette on the weight bearing platform.

STEP 3: Have the patient stand on the casette that was placed on the weight bearing platform. (**NOTE:** You may place the cassette on the floor and then have the patient stand on the cassette.)

STEP 4: Place the correct side marker (R or L) on the cassette.

NOTES

<u>Axial Projection: Positioning Procedure</u>. Figure XXXV shows the patient in position for an axial projection of the calcaneus and the resulting radiograph.



A: The Patient in Position B: The Radiograph

Figure XXXV
Axial Projection of the Calcaneus

STEP 1: Follow the preparation procedure for the calcaneus radiograph.

STEP 2: Place the radiographic tube so the CR is angled 45^{o} from the vertical , and is directed through the middle of the posterior surface of the calcaneus.

NOTES

Lateral Projection: Positioning Procedure. Figure XXXVI shows the patient in position for an lateral projection of the calcaneus and the resulting radiograph.

THESE PICTURES WERE NOT AVAILABLE AT PRESS TIME

A: The Patient in Position B: The Radiograph

Figure XXXVI
Lateral Projection of the Calcaneus

STEP 1: Follow the preparation procedure for the calcaneus radiograph.

STEP 2: Have the patient place the foot of the side being radiographed on the weight bearing platform with the medial side of the ankle next to the cassette. The foot should be parallel with the cassette with the malleoli at a 90^{o} angle with the cassette.

STEP 3: The CR should be at a 90^{o} angle from vertical and aimed through the middle of the calcaneus.

NOTES

Stress Views

Because stress views are not always performed in a podiatric office you will not be tested on them. Many patients requiring stress view are referred to other physicians or the procedure is performed in a hospital environment. However, you should become familiar with them since your podiatrist/employer might request them. As with the routine radiographs stress radiographs may be taken weightbearing or non-weightbearing. The following are the most common stress radiographs done in podiatry:

INVERSION STRESS VIEWS-ANKLE—Patient stands with heel in mortise projection, the CR is angled 90° through the center of the ankle, patient is usually anesthetized, the ankle is forcibly inverted to its limit and held in mild plantar-flexion. Opposite views are suggested.

ANTERIOR DRAWER VIEW—Patient is positioned as for a non-weightbearing non-stress dorsoplantar view, with lead gloves and apron the operator supports the leg with one arm and pulls the foot anteriorly with the other. Opposite view is suggested.

STRESS DORSIFLEXION VIEW—Patient is positioned as for a weightbearing lateral foot/ankle, the patient knees are bent forward until a maximum dorsiflexion of foot is obtained.

Special Views

In the field of podiatric radiography as with general radiography special views are sometimes required in order to aid in diagnosis and treatment.

For the purpose of this guide, you will learn about several views that can be done in the podiatric setting and several that some podiatrists are now referring to facilities that have a special radiographic machine that produces tomographic radiographs.

RAISED LATERAL HALLUX—The patient is placed in a weightbearing lateral foot position with the medial side of the foot in question next to the cassette. A piece of radiolucent material is placed under the great toe which raises it above the rest of the toes. The CR is directed horizontally through the great toe.

PA ANKLE (LEWIS)—The patient faces the cassette and stands on the platform with the toes touching the upright cassette. The patient's foot is placed so that it make a 90° angle with the cassette. The CR is directed horizontally through the ankle joint. The resulting radiograph shows an enlarged ankle since the part being radiographed is several inches away from the cassette.

The following two views can take advantage of tomographic radiographs instead of plain film radiography:

HARRIS and BEATH (SKI-JUMP or COALITION PROJECTION)–This is a special view that shows the subtalar joint. The cassette is flat on the weightbearing platform with the patient standing on the cassette. The patient's heel is toward the radiographic tube. Three different radiographs are taken with the CR being placed at 35°, 40°, and 45° respectively.

ISHERWOOD VIEW–This is a serial oblique view to determine a coalition in the subtalar joint.

Transferring the Patient

Checking Equipment for Safety

Check the X-Ray Room. Before you move the patient from a wheelchair or a stretcher to the x-ray table, first check the x-ray room to make sure that

- there is nothing in front of the radiographic table,
- the radiographic tube and tube housing are moved out of the way,
- the equipment involved in the transfer has been placed in the proper location, and
- all electrical equipment is properly grounded.

Examine the Transfer Equipment. Make sure the wheel locks and footrest on the wheelchair or the straps on the cart or stretcher are in good working order. You should also make sure that these items are positioned properly during the moving process. For example, the wheels on a stretcher or wheelchair should be locked during a transfer.

Check Over the Ancillary Equipment. Be sure intravenous (IV) stands and stepstools are sturdy and stable. Make sure monitors and tubes attached to the patient will not get in the way while the transfer is being made. Move the radiographic tube housings above the radiographic table out of the way to protect both patient and workers from bumping into them in the moving process.

Assessing the Patient's Condition

After you have made sure the x-ray room is clear of obstructions and the equipment is safe and before you transfer a patient from one piece of equipment to another, you should assess the patient's condition. Determine whether the patient can play an active role in the transfer and whether you need to take extra precautions. In assessing the patient's condition, you should consider the following questions.

What position is required for the radiographic procedure? A patient is often transferred to the x-ray room on a stretcher or in a wheelchair by an orderly or nurse. However, once the patient is in the x-ray room, you, the x-ray machine operator, determine whether or not the patient needs to be moved. You should not move the patient if the radiograph can be taken with the patient on the stretcher or in the wheelchair. If the patient does need to be moved, you should determine whether the move should be to the radiographic table or to a chair at the end of the table. A patient would need to be transferred from a stretcher or a wheelchair to the radiographic table for a radiographic examination of the chest, shoulder, femur, and upper extremities.

How much motor control does the patient have? To determine whether or not the patient's movements are restricted, you should try to answer the following questions:

1. **Is the patient's mobility limited in any way?** If the patient cannot move from one place to another without any assistance, find out what the limiting factors are and how you can accommodate them.

2. **Does the patient have the strength and endurance to complete the transfer without assistance?** You should not expect a weak patient to be able to hold a strenuous position long enough to complete the transfer.

3. **Can the patient maintain balance in either a sitting or standing position?** A patient who is unable to stand may be able to maintain a sitting position. You may have to give some assistance to ensure that a very young or elderly patient does not fall off the radiographic table.

What is the extent of the patient's injury? Find out what kind of injury the patient has and how the injury may affect the transfer. Determine whether any special care, such as for shock or bleeding, is needed. Check for areas with pain or tenderness. Be sure to guard these body parts against sudden contacts and to provide any necessary support.

What equipment is attached to the patient? If IVs or monitors are attached to the patient, plan your transfer so that it does not interfere with or detach the equipment.

Giving the Patient Good Instructions

Before you begin to move a patient, explain what is about to happen. Carefully given instructions can have a comforting and reassuring effect on the patient. This in turn will make the patient's cooperation and assistance in the transfer easier for you to obtain. The instructions should be simple, concise, and easy to understand. **Keep sentences short and avoid unnecessary technical terminology.** Ask the patient if he or she understands the instructions. Before you begin the transfer, be sure to clear up any questions the patient may have.

Using Good Body Mechanics

To assist the patient in moving from one piece of equipment to another, you must use good body mechanics. Body mechanics refers to the use of your body as a machine. When using good body mechanics, all parts of your body are in proper alignment and balance, which will help you perform the patient transfer efficiently, safely, and without strain.

The rules of good body mechanics are based on the laws of gravity. Gravity is the force that pulls objects toward the center of the earth. Any movement requires an expenditure of energy to overcome the force of gravity. When an object is balanced, it is firm and stable. If it is off-balance, it will fall because of the downward pull of gravity.

Three terms are useful to know in any discussion of balance (see Figure XXXVII):

1. <u>center of gravity</u>: the point at which the mass of any body is centered. When a person is standing, the center of gravity is the center of the pelvis.

2. <u>base of support</u>: the portion of the body that is in contact with the floor. The base of support provides the stability needed to keep the body from toppling over.

3. <u>line of gravity</u>: an imaginary line that passes through the center of gravity.

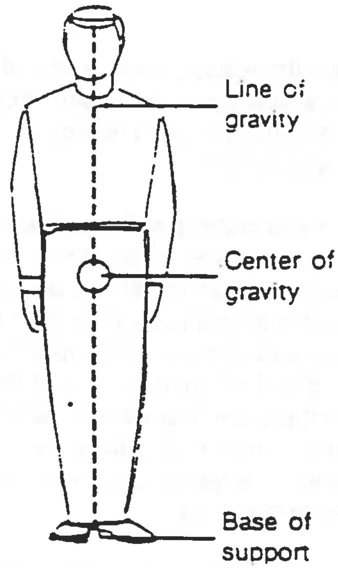


Figure XXXVII
Balance and Gravity

Following are four general rules for **correct upright posture,** which is required for good body mechanics:

- Stand with your feet parallel and perpendicular to the lower legs. Keep your feet parted about four to eight inches. Keep your body weight distributed equally on both feet.
- Don't lock your knees. Slightly bent knees will serve as shock absorbers for your body.
- Keep your buttocks in and your abdomen up and in. This posture prevents strain on your back and abdominal muscles. Hold your chest up and slightly forward, so that your lungs can expand and fill with air.
- Hold your head erect. This puts your spine in proper alignment.

When moving patients, follow these general rules for **good body mechanics**:

- Provide a stable base of support, with the feet separated and one foot slightly ahead of the other. Keep the trunk fairly straight.
- Distribute weight evenly on both feet, with knees slightly bent.
- Keep the object to be lifted close to the body.
- Work at a comfortable height to minimize muscle strain. Bend the knees when reaching near the floor.
- When possible, drag, roll, or push the patient rather than lift.

- Keep the back straight and do not twist the trunk of your body when lifting or carrying.
- Use your hips and legs when lifting.

__Methods of Patient Transfer__. There are three basic ways to transfer patients. The first two, which are **between stretcher (cart, gurney)** and **radiographic table and between wheelchair and radiographic table,** require little or no assistance from the patient. The third--**ambulation**[19]--is used with a patient who can walk with some assistance.

Moving the patient between stretcher and radiographic table. If the patient is unconscious or unable to cooperate in the move, the patient's spine, head, and extremities must be well supported. One convenient way to do this is **to place a sheet under the patient** and use it to slide the patient from one surface to another. If the patient is an adult, three or four attendants should assist in the move. One should stand at the patient's head to guide and support it during the move; another should be at the side of the table to which the patient will be moved; and the third should be at the side of the stretcher on which the patient is lying. If there are four people, two may stand at each side. The sheet should be rolled by the side of the patient so that it can easily be grasped by the attendants closest to the patient's body. The team should agree on when to begin the move (for example, 1, 2, 3, lift). Together they gently transfer the patient to the table.

NOTE: Patients on stretchers should be strapped; since stretchers are narrow, straps are needed as restraints to prevent falls.

Moving the patient between wheelchair and radiographic table. The patient who must be moved from wheelchair to radiographic table or the reverse requires assistance.

To move a patient from **wheelchair to radiographic table,** follow these steps.

STEP 1: Make sure the wheelchair footrest is out of the way.

STEP 2: Check to see whether the wheelchair wheels can be locked. If so, go to STEP 3; if not, go to STEP 4.

STEP 3: If the wheels can be locked, do the following:

- Lock the wheels.
- Face the patient.
- Place the patient's hands on your shoulders.
- Place your hands on the patient's waist or upper back.
- Help the patient to stand.

STEP 4: If the wheels do not lock, do the following:

- Stand on the right side of the patient.

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[19] __ambulation__: walking

- Put your left foot behind one wheel.
- Put your left arm around the patient's back and your right hand under the patient's elbow.
- Help the patient to stand.

STEP 5: Help the patient walk up to the stepstool (or footstool) and the radiographic table.

NOTE: You should also provide a footstool for the patient when assisting a patient out of a bed that cannot be lowered.

STEP 6: Help the patient turn around so that his or her back is toward the table.

STEP 7: Help the patient step on the stepstool and sit on the radiographic table.

STEP 8: Lay the patient on the table, as follows.

- Put one of your arms around the patient's back and your other arm under his or her knees.
- Swing the patient into a lying-down position.

Use the following steps as a general guideline for moving the patient **from the radiographic table to the wheelchair:**

STEP 1: Give the patient a moment to sit and regain his or her sense of balance.

STEP 2: Assist the patient to stand, as follows.

- Stand in front of the patient.
- Bend your knees, flexing one knee against the table.
- Place your arms at the patient's sides.

NOTE: If the patient needs only minimal assistance, you may stand at the patient's side, taking the patient's arm to assist him or her off the table.

CAUTION: *NEVER* allow the patient to step down from a radiographic table without providing a secure stepstool for him or her to step onto before stepping onto the floor.

STEP 3: Position the wheelchair to face the patient, close enough so that he or she can be seated in the wheelchair with one pivot.

STEP 4: Sit the patient in the wheelchair, as follows.

- Stand in front of the patient. Spread your feet for a broad base of support and do not lock your knees.
- Support the patient at both sides. Pivot with the patient and sit the patient in the chair.

Moving the patient by assisting with ambulation. When a patient is ambulatory, you should transfer the patient by helping him or her to walk. You should walk at the patient's side and do one of the following.

- Give minimal support: let the patient hold your hand or elbow.
- Give moderate support: hold the patient's hand with one hand and place your other hand around the patient's waist.
- Give more-than-moderate support: support both sides of the patient.

Summary

Moving a patient should be done rapidly and safely. You should always strive to **prevent pain or injury, assure the patient's safety,** and **use good body mechanics.**

Successful patient transfer requires that you do the following:

1. Perform safety checks on hospital equipment.
2. Assess the patient's condition.
3. Give the patient easy-to-understand instructions.
4. Use good body mechanics.

When transferring a patient from one piece of equipment to another, follow the rules of good body mechanics:

- Provide for a stable base of support, with the feet separated.
- Keep weight evenly distributed, with the knees slightly bent.
- Keep the back straight and do not twist the trunk.
- Keep the object to be lifted close to the body.
- Work at a comfortable height.

The three basic ways of transferring patients are (1) between stretcher and radiographic table, (2) between wheelchair and radiographic table, and (3) by ambulation. Whatever transfers you assist in, it is important that you provide adequate support.

Using Aseptic and Sterile Techniques

One of your responsibilities as an x-ray machine operator is to prevent the spread of microorganisms that carry disease and infection. To achieve this goal, you must practice good medical asepsis. By observing medical aseptic practices, you will not destroy all organisms, but you will be able to reduce the spread of disease.

- Wash your hands before and after you give any care to a patient or handle supplies or equipment used for care.
- Always handle bodily discharges as if they contained pathogenic microorganisms.
- Discard all disposable supplies according to your agency's policies.
- Use supplies and equipment for one patient only. If they are reusable, they should be cleaned thoroughly and disinfected or sterilized.
- Cover all breaks on the skin with sterile dressings.
- Keep soiled supplies and equipment away from your clothes.
- Because the floor is heavily contaminated, discard or resterilize any items that fall onto it.
- Keep rooms as clean, bright, dry, and airy as possible to lessen the microorganisms' chance of survival.
- Rinse urinals and bedpans and send them out to be sterilized.
- Avoid raising dust because it carries microorganisms.
- When cleaning a large item or surface, begin with the least-soiled area and progress to the most-soiled area.
- Do not reuse rags or mops for cleaning until they have been properly disinfected and dried.
- Place wet or damp items, such as dressings, in tightly scaled waterproof bags before discarding.
- Clean the radiographic table with disinfectant after each use.
- If you are in doubt about the sterility or cleanliness of any item, **do not use it.**

In addition to these practices related to patient care, you should also observe the following personal grooming practices to help prevent the spread of microorganisms.

- Keep your hair short or secured, if long.
- Wear only plain band rings when on duty.
- Wear your wristwatch high enough so that it does not become contaminated.
- Avoid loose or dangling jewelry.
- Keep your fingernails short and well groomed.
- Wear clean clothes and shoes.
- Bathe daily.

Supplies Used to Prevent Disease Transmission

As an x-ray machine operator you will be responsible for keeping the work area as germ-free as possible. You will use a number of supplies, including disinfectants and antiseptics, such as soap. Disposable supplies, used only once or for only one patient and then discarded, help cut down on the spread of microorganisms and save work time. Disposable and nondisposable sterile supplies include gloves, gowns, masks, and caps. Nondisposable supplies must be disinfected or sterilized by boiling water, free-flowing steam, steam under pressure, or dry heat.

Mechanisms of Transmission

Almost any microorganism present in any area other than its natural environment may cause disease or infection. To survive, microorganisms need food. warmth, water or moisture, and sometimes oxygen. They thrive in dark, damp areas with little or no air circulation. If not kept clean, any area or piece of equipment can be considered contaminated. Any person can become infected unless asepsis is practiced.

Some microorganisms produce reproductive spores, which are similar to eggs. Like eggs, these spores have "shells" or coatings that protect them from dryness, cold, and heat, and compensate for the lack of nourishment. With such protection, spores are difficult to destroy.

Microorganisms can transmit disease by both direct and indirect contact. Direct contact means that you actually touch an infected area or get very close to a person who has a communicable disease. Indirect contact occurs when you touch objects or surfaces such as dressings or equipment that have been contaminated.

In order to control disease transmission and to reduce the spread of microorganisms in your work environment, you will need to practice good medical aseptic technique. (Aseptic practices arc discussed later in this section.)

Disposal Methods For Contaminated Items

Disease transmission can be prevented through proper disposal of contaminated waste. When disposing of wastes in the radiology room, you should follow these rules.

- Unless they are being saved for analysis, flush away the contents of urinals or bedpans immediately after use.
- Pour liquids to be discarded directly down a toilet or drain. Avoid spilling or splashing them.
- Place other wastes in identified boxes, plastic bags or other containers; these containers are marked "contaminated materials" and usually are colored red. These materials generally are incinerated.

Sterile Technique

At times you will have to work in a sterile environment in which all items must be free of **all** microorganisms, including their spores. This is the case when you are introducing a catheter or needle into the patient's body. You can prevent the introduction of organisms by using sterile technique, which is based on two principles: (a) a sterile area or object will become contaminated when touched by an unsterile object, and (b) a sterile area or object will become contaminated by microorganisms that are carried in dust, lint, respiratory droplets, and air currents.

The following practices of sterile technique are based on the above principles:

- Do not turn away or walk away from a **sterile field.**[20]

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[20] sterile field: an area protected from microorganisms usually by a sterile sheet or covering onto which sterile objects may be placed

- Avoid talking, sneezing, or coughing over a sterile field. This precaution will help prevent contamination by droplets from the mouth and nose.
- Hold all sterile objects above waist level. This practice will help you keep the object in sight and avoid accidental contamination.
- Open sterile packages so that the edges of the wrapper are facing away from you. This measure will help you avoid the possibility of your clothing touching a sterile surface or of your having to reach over a sterile field.
- Avoid spilling solutions on a sterile setup. The moisture will penetrate the sterile field and contaminate it.
- Never reach over a sterile field. Your clothes, which are not sterile, might contaminate the field by touching it or by dropping particles of dust or lint on it.
- Since your hands cannot be sterilized, wear sterile gloves or use sterile forceps to handle sterile supplies and equipment.
- Avoid drafts from fans, windows, and so on near the sterile field, as air currents carry microorganisms.
- Use sterile masks, gowns, gloves, and other coverings as appropriate to the situation. This measure will lessen the likelihood of your spreading microorganisms in the sterile field.

If you have any doubt as to whether or not supplies or equipment are sterile, do not use them.

Appropriate Uses of Aseptic and Sterile Techniques

There is a difference between aseptic technique and sterile technique. When you use aseptic technique you are, insofar as possible, eliminating microorganisms through the use of water, soap, friction, and other agents. When you use sterile technique you are totally destroying microorganisms and their spores by means of a heat or chemical process.

In your daily routine as an x-ray machine operator, it **will not** be practical or necessary to practice sterile technique at all times, but you must **always use aseptic technique.** You will be required to use sterile technique whenever you have to introduce something into the patient's body by catheter or needle. For most other situations, aseptic technique is sufficient. Guidelines are provided at each institution.

Summary

One of your responsibilities as an x-ray machine operator is to prevent the spread of infection and disease to your patients and yourself.

Supplies commonly used in the prevention of disease transmission include disinfectants, antiseptics, gloves, gowns, masks, and caps. Most of these supplies are disposable; those which are not disposable must be disinfected or sterilized.

Infection and disease are caused by microorganisms that thrive when they have food, warmth, moisture, and/or oxygen. These microorganisms can be transmitted by direct and indirect contact. In order to stop their transmission, you need to use aseptic and sterile techniques. Aseptic technique, which is practiced all the time, lessens the number and spread of microorganisms, but does not kill their spores, whereas sterile technique is used only when it is necessary for items to be free of all microorganisms, including their spores.

Handling Emergency Situations

Fainting

Fainting, caused by an inadequate flow of blood to the brain, may result from strong emotions, exhaustion, heat, bleeding, overcrowded rooms, or other factors. Patients who are most likely to faint are those who have just left a laboratory where blood samples were drawn, who are weak and exhausted after preparing for a special examination, who are suffering from severe emotional shock, who have not eaten for several hours, or who are in the early months of pregnancy.

Signs and Symptoms. Some patients complain of being sick and dizzy. Others lose consciousness without warning. The symptoms in each case are a pale face, moist skin, weak pulse, shallow breathing, and dilated (large) pupils.

After regaining consciousness, some patients describe the experience by saying that a black cloud seemed to pass before their eyes as they were losing consciousness.

X-Ray Machine Operator's Responsibilities. The method of handling or treating a fainting patient depends on whether or not there is some warning that the patient is about to faint. Following are three procedures you can use, depending on whether the patient is able to lie down or sit up, or whether the patient has fainted or fallen without warning. You should know what to do and what treatment to administer in each instance.

When the patient who feels faint is able to lie down, follow this basic procedure.

STEP 1: When the patient complains of feeling sick and dizzy, lay the patient down.

STEP 2: Send for a licensed physician immediately.

STEP 3: Elevate the patient's legs by placing a pillow, sandbag, or other object under them.

STEP 4: Loosen any tight clothing.

NOTE: Bathing the patient's face with a cloth or towel soaked in cold water is also helpful.

STEP 5: You may administer an ammonia inhalant under the patient's nose.

STEP 6: Give the licensed physician a complete report of your observations.

STEP 7: Follow any instructions that the licensed physician may give you to help the patient.

When the patient who feels faint cannot lie down, do the following.

STEP 1: Sit the patient in a chair or on a stool with his or her head bent forward between the knees.

STEP 2: Send for a licensed physician immediately.

STEP 3: Steady the patient so that he or she cannot fall forward to the floor if he or she should suddenly lose consciousness.

STEP 4: Administer an ammonia inhalant under the patient's nose, if necessary.

STEP 5: Follow any instructions that the licensed physician may give you to help the patient.

When the patient has fallen without any warning, help the patient as follows.

STEP 1: Place the patient in a supine position.

STEP 2: Send for a licensed physician immediately.

STEP 3: Elevate the patient's legs with a pillow, sandbag, or other object.

STEP 4: Loosen any tight clothing.

STEP 5: Follow any instructions that the licensed physician may give you to help the patient.

Respiratory and Circulatory Emergencies

A person who has stopped breathing or whose heart has stopped beating is not necessarily dead, but is in immediate danger of dying. Life is dependent upon oxygen. The body cannot store oxygen, and the blood can hold only a limited amount of this element for a short time. It is imperative that when the heart stops beating (cardiac arrest) you not only perform external cardiac compression but also oxygenate the blood by means of artificial respiration.

It is recommended that all basic x-ray machine operators attend a basic life-support course to learn how to administer CPR. Such courses are offered by the American Red Cross and the American Heart Association. CPR courses cover mouth-to-mouth breathing; one- and two-rescuer CPR; care for choking victims, both conscious and unconscious; and respiratory emergencies and CPR for babies and children.

Before performing CPR, check the patient's airway, pulse, and respiration and send for a licensed physician.

Bleeding

Bleeding (hemorrhage) is the loss of blood externally or internally. Since you, as a basic x-ray machine operator, will be able to identify only external bleeding, internal bleeding is not covered in this study guide.

There are three types of external bleeding:

- arterial--loss of blood from an artery
- venous--loss of blood from a vein
- capillary--loss of blood from capillaries

Signs and Symptoms. A bleeding patient will exhibit these symptoms: pool of blood close by; rapid pulse; low blood pressure; and pale, clammy, cool skin.

X-Ray Machine Operator's Responsibilities. Follow this general procedure for handling a bleeding patient.

STEP 1: Apply pressure directly to the wound, using a sterile dressing.

STEP 2: Send for a licensed physician.

STEP 3: Report to the licensed physician what you have observed and done for the patient.

STEP 4: Follow the licensed physician's instructions in order to help the patient reach **hemostasis**[24].

Summary

In order to handle the emergency situations while the patient is in the radiographic room, you should be able to identify the major signs and symptoms of emergencies and to treat them. For any medical emergency situation, you must send for a licensed physician. In a respiratory and circulatory emergency, you must also start CPR without delay.

[24] hemostasis: arrest of bleeding