LESSON ASSIGNMENT

LESSON 4
Special Radiographic Procedures

TEXT ASSIGNMENT
Paragraph 4-1 through 4-48.

LESSON OBJECTIVES
After completing this lesson, you should be able to choose correct answers to questions about:

- Mammography.
- Obstetrical radiography.
- Radiographic demonstration of fluid levels.
- Pediatric radiography.
- Tomography.
- Orthoradiology.

SUGGESTION
After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.
LESSON 4

SPECIAL RADIOGRAPHIC PROCEDURES

Section I. MAMMOGRAPHY

4-1. INTRODUCTION

Radiographic examination of the female and male breast is known as mammography. This examination is used for the investigation of pathological symptoms to detect the nature and causes for those symptoms, to differentiate between benign and malignant tumors, and to determine a course of treatment.

4-2. ANATOMY AND PHYSIOLOGY OF THE BREAST

Functionally, the female breasts are accessory glands of the reproductive system. Several types of tissue occur in varying amounts, depending upon the age and physical condition of the patient.

a. The External Structure. The surface components of the breast include the skin, the areola, and the nipple. Usually, the breasts extend from about the second rib to the sixth or even seventh rib and from the lateral margins of the sternum to the axilla. Although breasts differ in size, the average craniocaudad (vertical) diameter is between 12 to 14 cm while the transverse (horizontal) diameter is slightly larger. In figure 4-1, note the structures of the breast, specifically the areola and the nipple. The nipple is a projection of areolar tissue on the apex of the breast. Its tip is perforated by 15 to 20 tiny orifices to the lactiferous tubules.

Figure 4-1. Breast diagram showing the breast structures.
b. **The Internal Structure.** The inner components of the breast are comprised of fibrous, glandular, and fatty tissue. They are augmented by a segment of the vascular system that includes a rather extensive lymphatic network. The intercostal and pectoral muscles form the breast wall.

(1) The fibrous tissue consists of two layers of fascia suspensory ligaments and an irregularly-pitted framework for the glandular tissue. The fascia layers, superficial and deep, are joined and completely house the mammary gland. The suspensory ligaments are vertical hands of elastic fibrous tissue that pass through the glandular tissue and connect the deep layer of fascia with the skin. The remainder of the fibrous tissue comprises the honeycombed framework for the mammary gland.

(2) The mammary gland consists of 15 to 20 lobes, each of which is composed of numerous lobules. All are interconnected by the lactiferous ducts, which form a distinct network. The tiny ducts from the lobules, called terminal ducts or acini, empty into the larger main ducts. These, in turn, empty into the lactiferous tubules that extend from each lobe into the nipple.

(3) Fatty tissue completely surrounds and is distributed in the glandular tissue in varying amounts, depending upon the patient's age and obstetrical condition. Figure 4-2 shows the internal structure of the breast.

![Figure 4-2. Internal structure of the breast.](image-url)
c. **Structural Variations.** Structural variations result in the breasts being classified as virginal, adult (mature), lactating, menopausal, or atrophic.

(1) **The virginal breast.** The virginal breast appears relatively dense on a mammogram because it consists mainly of fibrous and glandular (fibroglandular) tissue. Minimal subcutaneous fatty tissue is present which accounts for the radiolucent margin.

(2) **The mature breast.** The mature breast usually has the widest variation in appearance on a mammogram. The reason is that there is a somewhat equal balance between fibroglandular and fatty tissue. The mature breast can be considered average in terms of density.

(3) **The lactating breast.** The glandular tissue proliferates and becomes engorged with milk secretion during and after pregnancy. During the period, the glandular tissue compresses the fibrous tissue and causes an increase in both size and density of the breast. The breast is denser during the lactation period than it is at any other stage. Following the lactation period, however, density decreases when the need for fluid is gone and both the lobes and ducts decrease in size. At the time, fatty tissue begins to develop and fills the space formed by expansion.

(4) **The menopausal breast.** As a woman approaches and passes through the age of menopause, commonly called "change of life," the structure of the breast is again modified. Hormonal stimulation of the glandular tissue progressively decreases, which results in a gradual loss of both glandular and fibrous tissue. These tissues are replaced, in part, by fatty tissue, the breast becomes softer, and there is less fibroglandular tissue.

(5) **The atrophic breast.** As the menopausal stage progresses, fatty tissue continues to replace fibroglandular tissue until the breast is comprised solely of fatty tissue. When this transition is complete, the breast is referred to as being atrophic.

**4-3. FOCAL-SPOT SIZE**

There are two important factors to consider when selecting the focal spot to be used in mammography. The first, and perhaps most important, consideration is the capacity of the tube to withstand the heat generated in a single exposure. Naturally, a large focal spot can tolerate higher exposures than a small one. Consequently, when high exposure factors are used, it may be necessary to use a large focal spot. However, if the exposure factors are low enough to permit the use of a small focal spot, then it should be used. Remember, a smaller focal spot gives better detail, and detail on a mammogram is extremely important.
4-4. ANODE STORAGE CAPACITY

To produce the desired contrast on a mammogram, it is necessary to use low kVp. Low kVp in conjunction with high mAs (which is generally used in mammography) produces a tremendous amount of heat in the tube. For example, suppose the technique for a single projection is 26 kVp and 1,800 mAs. This would produce 46,800 heat units (HU) (26 X 1,800 = 46,800). Since three views of each breast are normally included in a mammography study, the total would be 280,800 HU (6 X 46,800 = 280,800). The anode storage capacity of most x-ray tubes is considerably less than the 280,800 HU in the hypothetical case described above. Therefore, to prevent damage to the anode, it would be necessary to allow the appropriate cooling time between exposures. Cooling times is based on the anode-cooling curve found on the tube-rating chart.

4-5. FILTRATION

Radiographic demonstration of the differences in breast-tissue density requires a soft, heterogeneous x-ray beam. Ideally, then, mammography should be accomplished with absolutely no filtration. However, in the interest of keeping patient dosage to a minimum, NCRP (National Council on Radiation Protection and Measurements) Reports No. 33 requires certain amounts of filtration for all radiographic examinations. For operating voltages up to and including 50 kVp, the report requires at least 0.5 mm aluminum equivalent. Standard x-ray tubes may or may not have the required 0.5 mm aluminum equivalent in the form of inherent filtration. If not, additional filtration to achieve this standard must be added. Some special-purpose tubes usually have less than 0.5 mm inherent filtration. For example, a beryllium-window tube only has from 0.1 to 0.3 mm. When filtration must be added, use clear plastic to avoid blocking the filament flow since "light" from the filament helps in positioning the cone.

4-6. BEAM-RESTRICTING DEVICES

SR (scatter radiation and secondary radiation) must be kept at a minimum because it can cause film fogging that is degrading to radiographic detail. To reduce SR and to keep the skin dose to the patient at a minimum, the primary beam should be restricted so that it covers the breast. Extension cylinders, modified collimators, and specially constructed cones are used to restrict the x-ray beam.

4-7. FILMS

Standard, coarse-grained radiographic films are inadequate for the fine detail required in mammography; thus, fine-grained or special mammography films are used. Some radiologists prefer to use a "package" of two or more films. By using films of various speeds, visualization of the deep fibroglandular structures as well as of the peripheral anatomy is provided. Some mammography films can be processed automatically while other films must be processed.
4-8. TECHNICAL FACTORS

a. The technical factors used in mammography depend upon several variables. Such things as film speed, output characteristics of the x-ray tube, tube capacity, and filtration must be considered. The kVp should be 20 to 35 (except for the axillary projection) because, in this range, the small differences in photon absorption are enough to provide adequate contrast. SID can be from 18 to 40 inches. As a general rule, the mAs can be as much as 1800, depending upon the kVp, SID, and the speed of the film. For example, using type M film with 26 kVp and 36-inch SID, the mAs would be about 1800. On the other hand, if the same kVp and SID were used with type AA film, less mAs would be required because type AA is faster than type M.

NOTE: Check with the manufacturer for specific technique ranges.

b. Normally, when establishing a technique, it is only necessary to determine the factors for the craniocaudal projection of a medium-sized mature breast. Variations in technique because of breast size, breast density, and projection can be determined from the initial factors.

c. One method for establishing a technique is to make trial exposures of an aluminum step wedge with the central ray directed to the 15 mm step. Using predetermined mAs and SID, depending upon the film speed; the kVp is varied until the 15 mm step is faintly penetrated. This setting is used for the craniocaudal projection.

d. For the mediolateral projection, 2 kVp are added to the craniocaudal kVp, with the remaining factors unchanged. The axillary projection requires about 50 kVp.

NOTE: The kVp cannot exceed 50 if only 0.5 mm aluminum-equivalent filtration is used.

e. The density of the breast also requires variation in technique. Usually, a change of about 2 kVp is enough to compensate from one density category to the next. For example, if 28 kVp is used for a mature breast, 26 kVp would suffice for a menopausal breast.

f. As a general rule, the requirement for altering the technique to compensate for the different breast sizes is just the opposite from most other examinations. For example, a larger breast usually contains a greater proportion of fatty tissue and lies flatter on the film holder. Consequently, less technique is required. Smaller breasts usually contain a greater proportion of fibroglandular tissue and require more technique. One good way to compensate for these differences is to take advantage of the inverse square law by altering the SID. This method also allows precise restriction of the primary beam, which (as previously mentioned) is important. To put this in perspective, consider the following comparison between a medium-sized breast and a large breast.
(1) The large breast usually requires both a larger cone field and a decrease in technique. By increasing the SID over that used for the medium breast, both of the requirements are met.

(2) Two exceptions to this method are the small breast containing mostly fatty tissue and the large breast containing mostly a fibroglandular tissue. These are usually identified by the x-ray specialist before the examination and appropriate compensations are made.

4-9. PATIENT POSITIONING

The projections most commonly used for mammography studies are: craniocaudad, mediolateral, and axillary.

a. Craniocaudad. In figure 4-3, the major considerations associated with the craniocaudad projection are illustrated. When positioning a patient for this projection, use the following as a guide.

![Figure 4-3. The craniocaudad projection, position and mammogram.](image)

1. The patient must put on a gown with the opening in front. (Use surgical gowns or isolation gowns if the x-ray gowns do not open.)

2. Have the patient sit on an adjustable (rotating type) stool.

3. If available, use a room containing a table with horizontally sliding top. This allows the patient to sit under the tabletop, making it possible to get very close to her chest.

4. Place the film holder very close to the patient's chest. It must be touching. If it is flexible, you may bend it slightly under.

5. Have the patient place her hand behind her back.
(6) Bend her slightly backward and place the complete breast on the cassette.

(7) Position the tube so that the CR is directed to the midpoint of the base of the breast.

b. Mediolateral. Figure 4-4 illustrates the mediolateral projection. The procedures are as follow.

Figure 4-4. The mediolateral projection, position and mammogram.

(1) Unless there is a special apparatus for mammography procedures, the mediolateral is best taken with the patient on the radiographic table top, lying on the side (laterally recumbent).

(2) Place a pillow or cushion beneath her head and shoulders. A positioning block (square or triangular, whichever is better) is placed beneath the cassette. This puts the breast in a true lateral position.

(3) Have the patient hold the opposite breast close to her chest so that it will not be superimposed over the breast being x-rayed. The hand on the projection side should be placed beneath her head.

(4) The film is placed in a position to completely cover the breast. Two projections may be taken on one film if the breast size will permit.

(5) The CR is directed to the midpoint of the base of the breast.
c. **Axillary.**

(1) Figure 4-5 demonstrates the axillary position. With the patient supine on the table, the film is positioned so that the axillary area, the tail of the breast, and the upper quadrant of the breast are included on the film.

![Figure 4-5. The axillary projection, position and mammogram.](image)

(2) The patient is rotated toward the side being examined until the tail of the breast is projected beyond superimposition of the chest wall (body rotation is usually between 15 and 30 degrees).

(3) The CR is directed perpendicularly to the film.

**4-10. GENERAL CONDITIONS**

a. **All Projections.**

(1) Always place the identification markers along the axillary margins of the film. This will help the radiologist maintain orientation as he interprets the film.

(2) Ensure that coning is such that the breast is demonstrated in a constricted cone field. The light from the filament will indicate the cone field.

(3) Ensure that the patient's position is as comfortable as possible so she can more readily maintain the position throughout the exposure.

(4) Wait until you are ready to make the exposure before giving the patient breath control instructions. The longer she must hold her breath, the greater the chance for involuntary motion.
(5) Make both projections of each position on the same film when possible (that is, both craniocaudad, both mediolateral, et cetera).

b. **Craniocaudad.**

(1) Ensure that the film holder is in close contact with the chest wall. Such placement will result in demonstrating the maximum amount of breast tissue.

(2) Have the patient sit up straight and even lean backwards a bit to preclude superimposition of the clavicle over the breast.

c. **Mediolateral.** Make sure that the opposite breast does not overlie the one being examined. At times, it may be necessary to have the patient hold the opposite breast to preclude such superimposition.

**Section II. PEDIATRIC RADIOGRAPHY**

**4-11. INTRODUCTION**

Pediatric radiography deals with infants and children up to 12 years of age. With certain exceptions, the basic fundamentals of the technique are substantially the same as for any other age group.

**4-12. HANDLING OF INFANTS AND SMALL CHILDREN**

The handling of infants and small children requires special care and patience on the part of everyone concerned in the examination. When it is apparent that an infant or a small child is going to be difficult to manage, it may be helpful to have one of the parents or a family friend remain in the room during the examination. However, in some cases, it may be best to have a nurse or other attendant help to manage the intractable child while the relatives remain elsewhere.

**4-13. PHYSICAL FACTORS**

a. **Size.** The factor of size is a definite problem in estimating exposure techniques, but it affords certain advantages in the shorter SID can be used without incurring excessive image distortion. When the x-ray tube has a relatively low mA capacity, the shorter SID permits the use of a shorter exposure time. Also, the size of the patient will determine the size of the film to be used. The factor should always be considered before going to the ward for bedside radiography.
b. **Tissue Density and Tissue Contrast.** Radiography of an infant's chest normally requires a higher range of x-ray intensity in relation to a given part-size than in the case of an adult. This is mainly due to the difference in the ratio of aerated to non-aerated tissue in the thoraces of infants and adults. The opposite is the case for the other parts of the body; that is, for a given part-size, less exposure energy normally is required for a very young patient. The foregoing facts should be carefully evaluated when it is necessary to modify tabular exposure techniques that are based on factors scaled for routine radiography of adults.

c. **Motion.** The greatest obstacle to overcome in the normal course of pediatric radiography is the adverse effect of motion—whether voluntary or involuntary. In a young child (and especially in an infant), respiratory and cardiovascular motions are much more rapid than in the average adult patient. The most effective method for overcoming this limiting factor is by reduction of the exposure time.

d. **Susceptibility to Infection.** The x-ray specialist should always wash his hands thoroughly before handling any pediatric patient. If suffering from a minor respiratory complaint, he should wear a mask.

4-14. **RADIOGRAPHIC PROCEDURE**

a. **Preliminary Procedure.** The selection of technique factors, films, work-up of identification material, and other necessary preparations should be completed before the patient is brought into the exposure room. This will enable the x-ray specialist to give his full attention to the handling of the patient. Calling the ward for pediatric patients should be deferred until it is certain they can be given immediate attention.

b. **Positioning.**

   (1) For the most part, the positioning procedure for pediatric patients should conform to the essential technical considerations prescribed for the standard positions with respect to a given examination.

   (2) Awkward positions should be avoided. Whenever possible, advantage should be taken of unorthodox angulations or positions of the x-ray tube.

   (3) Unless otherwise indicated, examination of the extremities for a given view should be done bilaterally, preferably by simultaneous exposure on the same film.

   (4) In chest examinations, it is advisable to make two films, one at inspiration and one at expiration.
c. **Immobilization.**

   (1) The assistance of one or more persons other than radiological personnel may be enlisted to aid in immobilizing the patient according to the demands of the particular situation.

   (2) A strap made of clean cotton webbing, 2 inches wide and about 2 1/2 to 3 feet in length, should be provided for immobilization of the skull in the lateral position. When this is needed, an assistant holds the strap tautly across the frontal and parietal areas with the head turned to be lateral position. If such a strap is not available, a suitably folded hand towel can be used.

   (3) A pair of large-sized synthetic rubber sponges held firmly against the sides of the patient's head may be of considerable help in obtaining AP or PA projections of the skull with the least likelihood of the assistant's hands being superimposed on the image.

   (4) A suitable modification of the Sayre apparatus ("head sling") may be used to considerable advantage for radiography of the head or neck with the patient in the upright position.

   (5) In certain cases, it may be helpful to snugly wrap the patient's body (from the shoulders down with the arms alongside the body) in a suitable sheet. This procedure is often referred to as "mummification."

d. **Precautions.**

   (1) Lead-impregnated aprons, gloves, and protective shielding must be provided for protection against irradiation for persons assisting in the immobilization of the patient during exposure. The area of irradiation should be confined to the most practicable limits by the proper use of cones, cylinders, diaphragms, or collimators. Under no circumstances should an x-ray specialist hold a patient during exposure. Gonads should be protected with lead shields when practicable.

   (2) Under no circumstances should the patient be left unattended for any length of time while on the x-ray table or in a crib with the guard railing down. The danger of the child falling off the table or out of the crib is very great.

   (3) Loose articles that can be swallowed, such as diaper pins or identification materials, should be kept out of reach of the child at all times.

   (4) If the patient is being held in an immobile position by an assistant, the x-ray specialist should not make the exposure until he has made sure that the assistant's hands are not interposed over any area of the patient in line with the path of the exposing x-ray beam.
(5) When verbal communication is possible, the instructions as to breathing control should be as simple and short as possible. Remember that children have a very short span of attention. When necessary, crying may be induced in infants and the exposure made at the beginning of the cry.

e. **Use of Contrast Media.**

(1) For gastrointestinal examination of infants, approximately 4 ounces of barium sulfate and 5 percent sterile glucose water should be prepared in sterile nursing bottle. Several sterile nipples with openings of different sizes should be provided to meet the demands of particular situations. The preparatory phase of the examination is carried out according to clinical dictates. Usually, food and fluids are withheld approximately 4 hours prior to examination. Incidental fluoroscopy and radiography will be done according to the directions of the radiologist. In children over 2 years of age, the examination is normally carried out in a manner similar to that for an adult.

(2) The contrast medium used for esophageal studies may be the same as that used for gastrointestinal examinations. The contrast substance may be introduced by ingestion from a nursing bottle or by way of a suitable catheter attached to a syringe and transnasally inserted into the esophagus. Radiography is frequently limited to spot-filming.

(3) For barium enema examinations, a suspension consisting of barium sulfate and water is introduced under fluoroscopic control throughout the anus via a suitable catheter. Retention of the contrast substance in the bowel may be facilitated by holding the buttocks together with adhesive tape. Incidental radiography or spot-filming is carried out according to the directions of the radiologist.

(4) The techniques for other contrast studies (such as intravenous and retrograde pyelography, cystography, and urethrography) are essentially the same as for adult patients. The chief difference is that the amount of contrast media used in pediatric radiography is scaled to the size and age of the individual patient. In certain examinations, infants and children under 5 years of age are examined on the horizontal fluoroscopic or radiographic table.

f. **Radiographic Measurements.** Radiographic measurements for determining the exact length of certain body structures, such as the long bones, may be done by means of one of the orthoradiographic techniques.

g. **Bone Age.** At times, it is necessary to x-ray children to determine the bone age. The x-rays are compared with growth charts found in many publications to find out if the growth process varies from normal. The radiographs taken depend entirely upon the radiologist. PA hands and wrists and dorsoplantar feet are commonly employed. Others include AP projections of joints such as elbows, shoulders, hips, knees, and ankles.
h. **Technique factors.** The technique adjustments in Table 4-1 are intended as a starting guide only. Specific technique factors are listed for certain age groups and fractional designations are given for other age groups. The fractional designations refer to corresponding technique factors scaled for average adult patients. For example, "1/3 basic mAs" means that the technique factors customarily used for comparable examinations of adult subjects remain constant, except that the mAs value is reduced to one-third. This is not to imply that changing the mAs is the only way to adjust the technique. The kVp, or both mAs and kVp, can be adjusted to provide satisfactory results.

<table>
<thead>
<tr>
<th>Pediatric Adjustments To Technique</th>
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<tbody>
<tr>
<td>0-1 year</td>
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<tr>
<td>2-4 years</td>
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<tr>
<td>5-11 years</td>
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<td>12+ years</td>
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Table 4-1. Pediatric radiography: Suggested starting technique factors for ages 0 to 12 years.

**Section III. TOMOGRAPHY**

**4-15. INTRODUCTION**

a. Since the introduction of computed tomography (CT) and magnetic resonance imaging (MRI) with their excellent contrast resolution, tomography is less frequently used. Conventional methods of radiography often resulted in the superimposition of images on a two-dimensional film. To demonstrate a particular layer of the body unobscured by images of overlying and underlying structures, a special technique known as tomography can be employed. Tomography is now applied principally to high-contrast procedures such as imaging the calcified stones in the soft tissues of the kidney.

b. Tomography (body-section radiography) encompasses several methods by which a specific layer of the body can be demonstrated to the exclusion of overlying and underlying structures. Images of objects lying in other planes are eliminated, or at least minimized, by blurring. For example, a lesion in the chest may be radiographed free of overlying rib shadows. Figure 4-6 is an example of a tomogram of the temporomandibular joint.

c. Tomography is a useful technique in all phases of radiography and can reveal the correct diagnosis in many instances when it would otherwise be missed. It can be used successfully with and without contrast media and plaster casts.
Figure 4-6. A series of radiographs of the temporomandibular joint produced by tomography. The mouth is closed in the first three images and open

4-16. TOMOGRAPHIC SYSTEMS

Radiography of a layer or section of the body is known by many names such as tomography, stratigraphy, laminography, and planigraphy. As a general rule, the names were applied to the patented apparatus. However, the basic principles of operation are the same. To standardize the nomenclature, the International Commission on Radiological Units and Measurements (ICRU), in Handbook 89, recommends that tomography be used to describe all body-section techniques. Handbook 89 further classifies the systems according to the methods involved. This study guide describes two moving tube systems, called rectilinear and pluridirectional.

a. **Linear.** The tube and film move in a straight line. This movement can be described as plane-parallel. Some tomographic apparatus will only perform a linear movement longitudinally to the long axis of the table. Others will perform crosswise and diagonal movements with respects to the long axis of the table. See figures 4-7 and 4-8. Linear movements are often adequate for tomograms of the lungs, kidneys, and simple bony structures.

b. **Pluridirectional.** Pluridirectional (multidirectional) systems, as a general rule, produce better tomograms of areas that require maximum blurring, such as the optic canal, inner ear, and complicated bone structures. In polytomography, the term is usually used for pluridirectional system in which there is a wide variety of movements. They include circular, elliptical, hypocycloidal, spiral, sinusoidal, and random movements. The first three of these are discussed below.

(1) **Circular.** Although the circular movement is the simplest of the polytomographic movements, it offers complete blurring. Circular movement is accomplished with the tube tilted 20° to 40°. The pattern is beneficial for views of the lumbar spine.
Figure 4-7. Tomography.

Figure 4-8. An apparatus designed for tomography.
(2) **Elliptical.** The elliptical movement appears as an oblong circle. Most polytomographic units will produce an elliptical movement longitudinally, crosswise, or diagonally to the long axis of the table. It is usually used for lateral projections of the lungs. It is also excellent for studies of the cervical and dorsal spines.

(3) **Hypocycloidal.** Hypocycloidal is the most complex of the polytomographic movements. It makes a pretzel-like cut that produces the most complete blurring. Virtually all overlying and underlying structures, bony or otherwise, can be totally obscured by this movement. It can be used for skull detail and is excellent for joint spaces.

### 4-17. PRINCIPLES OF TOMOGRAPHY

a. **Apparatus.** Basically, a rectilinear tomographic apparatus consists of a standard radiographic table, a movable cassette tray, and a movable tube head. (Polytomographic apparatus is designed specifically for polytomography and is much more complex than rectilinear apparatus.) The tube head and the cassette tray are attached to opposite ends of a vertical bar which is provided at a selected point between the tube and the cassette tray.

b. **Fulcrum Point.** The point or level at which the vertical bar is pivoted is known as the fulcrum point. At this point, there is controlled minimum motion. This is the operating principle of tomography; above and below this point, there is motion when the tube is moved. The fulcrum point also determines the focal plane.

c. **Focal Plane.** The level or plane of the body section to be examined is known as the focal plane or datum plane. The level corresponds to the fulcrum point.

d. **Operation.** As the tube travels in one direction, the cassette tray travels in the opposite direction. The exposure is made during this movement. Shadows of the image at the focal plane will appear on the same area of the film throughout the movement and exposure. This is true because at the fulcrum point or focal plane, there is minimal movement. On the other hand, the shadows of all other planes below and above the focal plane will be projected on different portions of the film during the movement. The result will be a sharp and discernible image at the focal plane. All other images will be blurred out and therefore, indistinct.

### 4-18. FACTORS OF SECTION THICKNESS

The thickness of the layer, commonly referred to as the cut, is measured in millimeters (mm) and is controlled by two factors: the amplitude of tube travel and the SID.
a. **Amplitude.** Amplitude is the distance, in inches, that the tube travels during the exposure. A short amplitude will project a thick section; a long amplitude will project a thin section. Amplitude is usually automatically set when a particular movement is selected on polytomographic units. On rectilinear units, the amplitude must be set manually.

b. **Focus-film Distance.** When the amplitude remains constant, the shorter the SID, the thinner the section. This is true because more tube movement (and consequently more blurring) occurs in the planes above and below the focal plane. On the other hand, the greater the SID, the thicker the section.

**4-19. MILLIAMPERE SECONDS**

Because of the increase in part thickness due to tube movement, the mAs (milliampere seconds) must be increased from 50 percent to 100 percent over the mAs normally used in radiography for the same body part.

**4-20. EXPOSURE TIME, AMPLITUDE, AND RATE OF TUBE TRAVEL**

In polytomography, amplitude and rate of tube travel are automatically set when a particular tube movement is selected. Exposure time for each movement is found in the manufacturer's operating manual. In rectilinear systems, the three factors can usually be adjusted to fit the situation.

a. **Exposure Time.** To find the exposure time when the amplitude and the rate tube travel (in inches per second) are known, divide the amplitude by the rate. The formula is expressed as follows:

\[
\text{Exposure} = \frac{\text{Amplitude (distance of tube travel)}}{\text{Rate of tube travel}}
\]

**EXAMPLE:** If the amplitude is 15 inches and the tube is to travel 10 inches per second, then the exposure time would be 1.5 sec.

b. **Amplitude.** When the exposure time and the rate of tube travel are known, multiply them to find the amplitude as follows:

\[
\text{Amplitude} = \text{Rate of the travel} \times \text{exposure time}
\]

**EXAMPLE:** If the rate is 10 inches per second and the exposure time is 1.5 sec, the amplitude would be 15 inches.
c. **Rate of Tube Travel.** When the amplitude and the exposure time are known, divide the amplitude by the exposure time to find the rate of tube travel, as follows:

\[
\text{Rate of tube travel} = \frac{\text{Amplitude}}{\text{Exposure time}}
\]

**EXAMPLE:** If the amplitude is 15 inches and the exposure time is 1.5 sec, then the rate would be 10 inches per second.

**NOTE:** There are still equipment sets in hospitals around the world where these calculations are needed. Most tomographic equipment today is computerized and performs the calculations for the technologist.

### 4-21. GENERAL PRINCIPLES

a. **Introduction.** For a tomographic examination, the patient is positioned on the table as for ordinary radiography. The part is measured and the basic exposure technique selected. Then a fulcrum point is selected on the basis of a lateral exposure to correspond to the level of the focal plane in centimeters. Usually, several exposures correspond to the level of the focal plane in centimeters. Usually, several exposures or cuts are made at different planes until the desired plane is demonstrated. In sections where tomographic units are available, precise operating instructions depend upon local policy. However, certain general instructions apply in most cases.

b. **Control of Image Detail.** Because of the blurring effect, the image is likely to have reduced sharpness unless you:

1. Use the minimum source to image distance (SID).
2. Select an SID of at least 30 inches.
3. Use a small focal spot.
4. Select an exposure technique that will provide adequate penetration.
5. Ensure that the section is not more than 2 to 3 mm thick.
6. Give the patient breathing instructions just before the exposure. Do not forget that tomographic exposures are longer than normal radiographic exposures. This gives the patient more time in which to breathe, thereby, increasing the possibility of motion.
c. **Positioning Instructions.** In polytomography, the tube movement is usually selected on the basis of how well it will demonstrate a particular body part. Many tomographic units, however, only have a rectilinear movement in one direction, longitudinally to the long axis of the table. With a rectilinear movement, it is necessary at times to alter the patient's position to achieve the best results. For maximum blurring, the superimposed structures should be at a 90º angle to the tube movement.

(1) If, for example, the ribs are under study, the patient should be positioned across the table. This will place the spine (the major superimposing structure) at a 90º angle to the tube movement; consequently, it will be blurred. But the ribs, positioned so that they are parallel to the tube movement, will be clearly demonstrated. When there are two major superimposing structures at right angles to each other, the patient may be positioned at an angle of 25º to 30º to the direction of tube travel. An example of this is the sternum. If the patient is aligned parallel to the tube travel, the spine will be parallel with the tube movement and will not be effectively blurred.

(2) If the patient is positioned across the table, the ribs will not be effectively blurred because the ribs will be parallel to the tube movement. The solution, then, is to position the patient so that both the ribs and spine, each about 25º to 30º to the direction of the table movement, will be blurred. This will provide a good demonstration of the sternum.

d. **Patient Preparation.** During an average tomographic examination, the patient will receive about the same amount of radiation that he would receive in a fluoroscopic and radiographic examination of the spinal canal (myelography). This is true because the mAs is increased and because several "cuts" are usually required in one examination. To minimize the amount of radiation the patient receives, you should see that a minimum of 4 mm of total filtration is provided.

**Section IV. ORTHORADIOGRAPHY FOR SKELETAL SURVEYS**

**4-22. INTRODUCTION**

a. Orthoradiography is a radiographic procedure whereby the factor geometrical distortion is eliminated or is minimized to such an extent that it is possible to record the exact form and size of structures inside the body. It is of particular value in obtaining accurate measurements of the long bones of the skeletal system. It may be used, for example, to determine the length of the femur prior to insertion of an intermedullary nail or to maintain an accurate record of progress or regress in certain pediatric cases.

b. In orthoradiography, a particular portion of the x-ray beam is used in such a way as to protect a specific dimension of an object in true size. The image produced, when measured, corresponds in size to the actual dimension of the object under consideration.
c. The major factors in the application of this principle are:

1. Position of the source-point of radiation and focal-spot size.
2. Alignment of the CR.
3. Point on object under consideration.
4. Film-object plane.
5. Alignment of divergent rays in relation to CR.

d. Neither SID nor the OFD exert any significant influence on the outcome of the end result insofar as a specific dimension is concerned. Divergent rays falling in a plane in line with the CR and at right angles to the long axis of the object have the same dimensional validity as the CR. However, it is a good rule to keep the OFD (object film distance) to a practical minimum and the SID to a feasible maximum in order to obviate the penumbra effects due to focal-spot size and magnified distortion inherent in short SID.

4-23. METHODS

a. General. The principles of orthoradiography may be incorporated in numerous methods, depending upon the nature of the problem and the facilities available. The method most generally used is spot-scanography. The following methods are rarely used today, having been replaced by other modalities. They can still be encountered in some facilities.

b. Spot-Scanography. In spot-scanography, two "spot" exposures are made at specific points on the object. The film-object plan is parallel and the CR is perpendicular to the film plane. Film identification is "burned-in" after completion of the spot exposures. If the object under consideration is of such length that it overrides the film, the film may be placed diagonally with the long axis of the object. Measurements are made after the film is processed.

c. Spot-Scanography in Combination with Calibrated Rule. The method is identical to that described above, with the exception that a radiopaque calibrated rule is placed on the film alongside the object. This rule may consist of a strip of lead 3/4 inch wide and of sufficient length. One edge of the strip should be notched at 1-cm intervals. The lead strip should be mounted on a flat piece of wood or aluminum, to provide rigidity and ensure the maintenance of accurate length. Commercially produced rulers are available for this purpose. These measure 100 cm long and are calibrated in 1-cm increments. Calibration markings and numbers are painted with lead-impregnated paint to provide visibility on the radiography. By using two separate films, this method.
permits scanography of objects any length. When the rule is placed on the films, it should be aligned so that it is parallel with the long axis of the object under consideration. Cone coverage must be sufficient to demonstrate both the point on the object and the corresponding portion of the calibrated rule. Measurement is accomplished by aligning the point on the object with the known markings on the calibrated rule. Either non-Bucky or Bucky technique may be used. The calibrated rule should be placed on the tabletop. In this way, both exposures can be accomplished on a single film.

d. **Slit-Scanography.** This method is useful in that it produces an image that shows the object in its entire length. Any part or portion of the object may be measured. In slit-scanography, a narrow slit is used beneath the x-ray tube or the lip surface of a cone in such a way that a line or sheet of x-rays is used. As the x-ray tube moves over the object from one end to the other, the rays of the central beam pass through the part at the same angle. A sheet of lead, about 3/16 inch in thickness and a proper size to fit into the slot under the tube where filters are generally inserted, may be used. The width of the slit should be about 1/4 mm. The length of the cut in this piece will depend on the extent of lateral coverage desired or necessary in relation to the long axis of the object. For detail information on this method and other methods of orthoradiography, the x-ray specialist should consult standard texts.

Section V. THE SKELETAL SYSTEM

4-24. GENERAL

One of the most important, yet frequently overlooked, aspects of radiography is the dealing with the skeleton as a system rather than as a unit made up of individual components. For example, bone radiography of the upper extremity is usually thought of in terms of a hand, a wrist, a forearm, a humerus, etc., rather than the entire extremity combined. Radiographs of these individual bone elements are usually made for the purpose of diagnosis as a direct result of trauma. Do not forget that the skeleton is often x-rayed as an indirect result of trauma or as the result of some impairment of the normal function of the skeletal system in the process of one growth. It is with broader viewpoint that radiography of the skeletal system is primarily concerned.

4-25. DEFINITION

Radiography of the skeletal system may be defined as the interpretation of the condition and relationship of the bony structures by means of radiographic visualization.
4-26. PURPOSE

The purpose of radiography is to demonstrate the general condition of the bony structures with regard to existing disease or with regard to the functional status. It can be used to:


b. Diagnose the various bone deformities caused by diseases such as scurvy, rickets, or other vitamin deficiencies and the various arthritic conditions.

c. Visualize any existing pathology including which may have metastasized from another area.

d. Determine the bone age of an individual in comparison to his chronological age.

4-27. CLINICAL PROCEDURE

Radiography of the skeletal system includes a number of examinations. The anatomical areas concerned govern the x-ray procedures used. Some of the more common examinations are described in paragraphs 1-7 through 1-11.

4-28. ARTHRITIC SURVEY

This survey will primarily be used to diagnose bone deformities in all areas of articulation caused by arthritis. The number of radiographs taken will be governed by the routine established in the specific clinic; however, the radiographs will always be taken of the primary joint spaces of the body. When a severe arthritic condition is found within one joint space of the body, it is very possible that other joint areas are also involved. It is for this reason that this survey has been established. In order to complete this survey clinically, it is customary to perform right angle viewing of the specific areas in question. Added suggested routines are as follows:

a. AP and lateral elbows, knees, and ankles.

b. Laterals only—cervical, dorsal, and lumbar spines.

c. AP pelvis.

d. Bilateral-PA hands and wrists, DP feet, and AP shoulders.
4-29. METASTATIC SURVEY

a. The usual sequence of a highly virulent disease, such as tuberculosis or cancer, is to involve not only the immediately affected area but also other areas of the body. This transfer of a disease from one organ or area to another is referred to as metastasis. When disease metastasizes to bone, usually the shafts or bodies of bony structures are the areas primarily involved. Accordingly, the x-ray procedure will be compensated to stress the primary areas of involvement. Here, too, because metastasis to any area is possible, a clinical routine must be established as to what specific views are to be taken and how many specific bones are to be included. Suggested routine: lateral skull, PA chest, AP and lateral dorsal and lumbar spines, and AP pelvis.

b. In addition, radiographs of organs or soft tissue surrounding the diseased areas must be made in order to establish whether or not the pathology has spread to adjacent tissues. The lungs constitute one of the most common areas of involvement. These organs are very receptive to metastatic action. Long bone survey may be done in conjunction with metastatic survey.

4-30. LONG BONE SERIES

This examination is usually done for the purpose of diagnosing malformations of long bones caused by disease, a retardation of bone growth, or a stoppage of the normal bone growth process. The patient will usually exhibit various symptoms such as curvature of the extremities (bowlegs, knock-knee, etc.) or a shortening of one of the extremities. When shortening does occur, differentiation can be established as to whether the shortening is functional or anatomical. This is accomplished by measurements of both related extremities to determine actual figures. An anatomically short extremity will show a shorter measurement of the bones than the other. Conversely, a functionally short extremity, usually due to occupation or bad posture, will have the same bone measurement as the other comparative extremity. The shortening in the latter case is due to the carrying angle of the body. A long bone series, then, is a comparative study in which both related extremities are examined. Suggested routine: AP only, bilateral, full-length humerus, distal femurs, legs, and AP pelvis.

4-31. BONE AGE

Normally, the body follows an average bone pattern with regard to ossification of certain areas at specific time intervals. Any gross deviation from this average is considered abnormal and may be the means by which certain pathologies are diagnosed. Ideally, radiographic of the entire skeleton would be studied before the skeletal age is estimated. In daily clinical practice, however, the time-consuming, expensive radiographic examination of all of the bones cannot be carried out except in special cases. For this reason, a small and convenient portion of the skeleton, commonly the wrist and hand, is considered representative of the entire skeleton in the
assessment of bone age; however, during the first months of life, the feet are more satisfactory for appraisal of bone age because more ossification centers appear at an earlier age than in the hand. Associated radiographic views will be governed by the established routine of various clinics. The procedure is always such that comparative views of two similar areas are taken, that is, both hands, both feet, both forearms, etc.

4-32. SCANOGRAPHY

a. Scanography is a radiographic procedure that provides an accurate measurement of long bones. It consists of taking radiographs of the joints of long bones using a special metal ruler taped to the table. This examination is done quite frequently on children if the physical findings suggest a difference in the length of their extremities. It may also be used to determine the length of the femur before the insertion of an intermedullary pin in surgery. The method generally used is spot scanography.

b. In addition to the standard x-ray unit, a special radiopaque rule is needed to accomplish the examination. The positions in this examination are standard AP positions of the lower extremities. We will discuss both the use of the ruler and the importance of the proper position.

4-33. SPOT SCANOGRAPHY

In spot scanography, two “spot” exposures are made at specific points on the part. The film-object plane is parallel and CR is perpendicular to the film plane. The part and film remain in the same position during both exposures. The film identification is “burned-in” after completion of spot exposures. If the part under consideration is of such length that it overrides the film, the film may be placed diagonally with the long axis of the part. Measurements are made after the film is processed.

4-34. PRINCIPLES OF SCANOGRAPHY

The radiopaque ruler is a specially constructed ruler. It is evenly graduated, usually at 1-cm intervals, up to 100 cm. This is a sufficient length to include the long bones of the lower extremities. Its purpose is to show the magnification of the part in relation to the ruler. A perpendicular central ray is used to reduce the magnification caused by divergence of the beam. This provides for an accurate measurement. The central ray must be restricted to the area of interest; this requires proper collimation.
4-35. PROCEDURES

Place the ruler on the midline of the table and tape it there so that it cannot move. Position the patient over the ruler and in the supine position with the medial plane centered to the table and the ruler. You will concern yourself with three joints of the lower extremities and make three exposures on one masked film. With this in mind, position the level of the hip to the uppermost part of the ruler. True positions of the lower extremities are essential. Therefore, if there is any rotation of a part, true measurement will not be possible. Both extremities are x-rayed for comparison. The first exposure is made of both hips and is properly collimated to a 14 by 5-inch field. This will include both hips on the upper part of the film. After the first exposure, without moving patient or ruler, center the central ray to a point midway to the apex of the patella. Center the middle portion of the film to that point and make the second exposure. Center the third exposure to a point midway between the malleoli of the ankles with the bottom portion of the cassette centered to that point. This will give you a radiograph of hips, knees, and ankles, along with the ruler, on the same film. The exact length of the bone can then be determined by measuring from joint to joint.

4-36. SCOLIOSIS

If the spine is viewed from the posterior or anterior perspective, the vertebral column is usually nearly straight with little lateral curvature. Occasionally, a slight lateral curvature occurs in the upper thoracic region of a healthy adult. This curvature is usually associated with the dominant extremity; this curvature may be convex to the right in a right-handed person and convex to the left in a left-handed person. An abnormal or exaggerated lateral curvature is called scoliosis (sko"le-o ‘sis). This is a more serious type of problem that occurs when a pronounced S-shaped lateral curvature exists. This may cause severe deformity of the entire thorax. The effect of scoliosis is more obvious if it occurs in the lower vertebral column where it may create a tilting of the pelvis with a resulting effect on the lower limbs, thus creating a limp or uneven walk. Although many individuals normally have some slight lateral curvature of the thoracic spine, an abnormal or exaggerated lateral curvature of the spine is scoliosis. Scoliosis is most common in children 10 to 14; it is more common in girls. It may require wearing a back brace for a period of time until the condition of vertebral stability improves.

a. Radiographic Examination.

(1) Radiographs are made as requested by the patient’s physician. The routine radiographs are PA or AP (posterior-anterior or anterior-posterior) projections and the lateral position. The patient may be positioned either erect or recumbent. The weight must be evenly distributed on both feet if the patient is erect.

(a) Structures shown: The lumbar and thoracic vertebrae, as well as the approximately 2 inches (5cm) of the iliac crests.
(b) Position: Thoracic and lumbar vertebrae are demonstrated in as true AP and lateral projections as possible. Some rotation of pelvis and/or thorax may be apparent because scoliosis generally is accompanied by a twisting or rotation of involved vertebrae.

(c) Collimation and CR: Vertebral column should be in center of collimation field/IR (image receptor).

(d) Shielding: Shield gonadal region without obscuring area of interest. Use breast shields for young females. Shadow shields placed on collimator may be used. See figure 4-9.

Figure 4-9. AP projection.
(2) The Clear Lead Compensating Filter System protects the patient and reduces exposure to breasts and gonadal areas. It is used at 40 inches or 70 inches. It is magnetic and is quick and easy to use. Clear Lead avoids graininess of aluminum filters and eliminates burn areas. See figure 4-10.

![Compensating filters](image)

Figure 4-10. Compensating filters.

(3) Alternate series: Include different methods of demonstrating the effects of the curvature. In addition to the AP and PA views, left and right lateral-bending and hyperextension-hyperflexion series are sometimes done to demonstrate the actual range of motion to compare to degree of curvature.

(4) Measurement of scoliosis: There are two accepted methods of measurement--the Cobb and Ferguson methods of scoliosis measurement.

   (a) Cobb’s method is the standard method of measurement. It is primarily used for curvatures over 50 degrees.

   (b) Ferguson method involves obtaining two images, one standard erect AP and PA and one with the foot or hip on the convex side of the curve elevated. It is primarily used for curvatures under 50 degrees.

b. Treatment. Treatment of scoliosis varies with the severity and involves the use of braces and, in the severest cases, surgical insertion of spinal fixation devices. The prototypical spinal fixation device is the venerable Harrington rod (figure 4-11). They come in two types: distraction and compression. The hooks, by design, are placed under the lamina or transverse processes and the device is either extended or compressed to the desired position. Sometimes both types of rods will be used in the same spine.
Section VI. RADIOGRAPHIC DEMONSTRATION OF FLUID LEVELS

4-37. INTRODUCTION

The collection, dispersion, shifting, or superimposition of free fluid with contiguous or ambient structures within the body cavities often requires a special technique for adequate diagnostic demonstration, such as differentiation between free fluid and thickened membranes or determination of the amount and behavior of free fluid within a body cavity. The procedure by which this is accomplished is known as fluid-level radiograph. The regions most commonly examined are the paranasal sinuses, the interpleural spaces, and the abdominal cavity.

4-38. PRINCIPLES

a. There is one prime requisite that must remain constant at all times when performing fluid-level radiography—the CR (or projection) must always be horizontal. Also, as nearly as circumstances permit, the horizontal CR should be parallel with, and at the same elevation as, the plane of the fluid level.

(1) Figure 4-12, part A, shows the horizontal CR at the same elevation as the plane of the fluid level. This demonstrates the plane of the fluid level with clear demarcation.

(2) Figure 4-12, part B, shows the effect of aligning the horizontal CR at a lower elevation in relation to the fluid level, the actual projection being accomplished by vertical divergent rays origination from the same source-point as the horizontal CR. The resultant image demonstrates a distorted and diffused outline of the fluid level which, in some cases, may be of doubtful diagnostic value.
(3) Figure 4-12, part C, shows the same object projected by a vertical CR. This illustrates a violation of the basic rule with respect to the constant horizontal CR. In a strict sense, no fluid level as such is demonstrated by the use of a vertical CR. Projections of this nature are sometimes used; however, to supplement regular fluid-level projections for purposes of comparison with previous or subsequent radiographs or to demonstrate certain aspects pertaining to the collection, dispersion, or characteristic behavior of free fluid.

Figure 4-12. Schematic representation of fluid-level radiography with a drinking glass partially filled with barium sulfate suspension demonstrated in steps A, B and C.
b. When it is necessary or desirable to demonstrate multiple fluid levels (situated at different elevations in relation to the horizontal CR) on a single radiograph (for example, the abdominal region), increasing the SID will tend to obviate some of the adverse effects of "off-center" projection.

c. In general, the behavior of free fluid is demonstrated radiographically in figures 4-13 (exposed with CR in vertical position) and 4-14 (exposed with CR in horizontal position). Notice in figure 4-13, there is no evidence of the disposition of fluid, while in figure 4-14; the fluid is in well-defined levels.

Figure 4-13. Projection of abdomen made with the central ray in the vertical relationship and the patient in the supine position. This view shows no definite evidence of the disposition of fluid.

Figure 4-14. Projection of abdomen made with the central ray in the horizontal relationship and the patient in the erect position. Note disposition of fluid into well-defined levels.

4-39 CLINICAL PROCEDURE

a. After the patient has been placed in the position in which the radiograph is to be made, it is generally advisable to allow an elapse of 2 to 4 minutes before making the exposure. This interval permits gravitation or "settling" of the free fluid.

b. Fluid-level radiography can be performed with the patient in the erect, supine, prone, or lateral decubitus position or with the patient placed in various inclined-plane positions, depending upon clinical desires or dictates (figures 4-15 and 4-16).
Figure 4-15. Demonstration of fluid level in the chest cavity with the patient in the erect position and the central ray projected in the horizontal direction.

Figure 4-16. Demonstration of fluid level accomplished with the patient in the lateral decubitus position and the central ray projected in the horizontal direction.

c. Oftentimes, in order to accomplish fluid-level studies of a special kind, it is necessary to introduce a contrast medium (for example, Lipiodol or a similar substance) into the body cavities under investigation.

**CAUTION:** When executing injected sinus procedures, care should be taken to see that the injected substance is not expelled. In case the patient reports to the x-ray department with the contrast medium already injected, exposure should be made immediately upon his arrival, if possible.
Section VII. SOFT TISSUE RADIOLOGY

4-40. INTRODUCTION

Soft-tissue radiography is a procedure whereby the associated technical factors are so balanced as to produce a radiograph that provides optimum demonstration of the essential details within the soft-tissue structure under consideration. Since a radiograph of any part of the body is a study of the differences in density within the area exposed, a practical knowledge of the related technical factors influencing the range or magnitude of these differences in density is very useful in accomplishing soft-tissue radiography. Many factors that influence radiographic quality have already been considered in detail in another subcourse. When applied to soft-tissue radiography, some differences of emphasis among the various factors become necessary, depending upon the part or parts of interest. The principal aim is to achieve maximum contrast based on the differences in density of the tissues in question. Some parts of the body lend themselves more readily to this procedure than others. Anatomical parts or areas having great differences in tissue density are less difficult and allow for wider latitude in exposure factors. On the other hand, when a body of soft tissue consists of adjacent-lying structures with each differing in density to an extent approaching imperceptibility, it is necessary to employ the most exacting technique if maximum diagnostic quality is to be obtained.

4-41. USES

Some of the situations and conditions wherein soft-tissue radiography techniques may be needed are listed below.

a. **Muscles.** You may be required to perform work showing anatomic outlines of specific muscle structures, areas of calcification, ruptures, or areas of muscular ossification.

b. **Blood Vessels.** Radiographs demonstrating various forms of calcification, varicose veins, phleboliths, or thrombi may be needed.

c. **Breast.** You may make exposures to locate possible tumors of the breast.

d. **Tumors.** Radiographs that demonstrate the extent, location, and characteristics of various cartilaginous or nonosseous tumors may be required.

e. **Gas Gangrene.** You may be asked to do work demonstrating the presence and extent of involvement of gas gangrene.

f. **Foreign Bodies.** Various nonmetallic foreign bodies may need to be located.

g. **Fracture Sites.** Soft-tissue techniques are needed to demonstrate early callus development at fracture sites.
4-42. TECHNICAL FACTORS AND PROCEDURE

a. General. The vital principle of soft-tissue radiography is that full advantage is taken of all factors that contribute to the optimum differentiation of soft-tissue details.

(1) The technique must be selective. For a specific body of soft tissue to be x-rayed, all the associated technical variables should be "correct" for only that particular part under examination. The part or area of interest must be definitely circumscribed as to zone, extent, thickness, and density. It is impractical to attempt to combine structures of varying thickness and densities on the same radiograph with the part that is the focal point of diagnostic interest.

(2) The soft-tissue part must be adequately penetrated. The main objective is to produce differentiation of details within the soft-tissue structure and not merely the semblance of an outline. The practical kVp range is from 40 to 70, but each case must be judged on the thickness and density of the part. Use the lowest kVp necessary for adequate penetration.

(3) The radiograph should exhibit relatively high (short-scale) contrast graduated over the entire image pattern. The emphasis on short-scale contrast should be solely for the purpose of causing the finer image details to be demonstrated clearly. A radiograph presenting a chalky appearance, areas devoid of silver, or areas of excessively dense silver deposits is of little or no diagnostic value.

b. Factors. To obtain the quality of radiographic contrast suitable for soft-tissue radiography, the following factors must receive consideration.

(1) A relatively high mAs ratio with as low a kVp as is consistent with adequate penetration for the particular soft-tissue structure under examination should be used.

(2) Non-screen film in a cardboard holder is useful when referring to the detail factor and the exposure latitude involved. However, the use of intensifying screens aids in obtaining contrast and reduces the exposure time. The use of a cassette with a single screen (back) may prove especially advantageous at the very low kVp ranges where the front screen might absorb too much of the remnant radiation. In the majority of cases, however, satisfactory results can be obtained by the use of double screens.

(3) Best results are achieved when filtration of the primary x-ray beam is at a minimum, especially if the tissue thickness is very small.

(4) Beam-restricting devices are especially useful because they limit the amount of irradiation to the part, with consequent lessening of fogging SR.
(5) The processing of the exposed film is more critical than in conventional radiography. Time-temperature development in fresh solutions of proper strength is imperative. Safe lighting must conform to proper standards of darkroom illumination. The film emulsion must be fresh and have unimpaired quality.

c. X-ray Unit. A full-wave rectified x-ray unit of sufficient capacity and equipped with a rotating anode tube is preferred. With this type of unit, it is possible to minimize the effects of motion unsharpness by the use of shorter exposure times.

d. Positioning. Positioning of the part is the same as for routine radiography. Modification in positioning or in the alignment of the CR may be necessary to circumvent overlying bone or other structures that may obscure the site of interest.

e. Basic Technique. The basic technique factors given below (see table 4-2) should prove of value as a starting procedure and are listed solely for the guidance of the x-ray specialist. They are based on the average-sized adult using a full-wave rectified unit and par speed intensifying screens. If a trial exposure is indicated to determine the characteristic behavior of the x-ray unit or intensifying screens, a small portion of the site to be demonstrated should be selected and the surrounding areas marked off with suitable radiopaque materials prior to making the exposure. Examination of the test exposure should enable the x-ray specialist to make the necessary adjustments. If the exposed area on the film is excessively dense, the mAs (milliamperes-seconds) value should be reduced; if it is blank or devoid of image details, the kVp should be increased. The following techniques should prove useful as those suitable for average adult exposures.

<table>
<thead>
<tr>
<th>PART</th>
<th>kVp</th>
<th>mAs</th>
<th>SID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hand and wrist</td>
<td>52</td>
<td>2*</td>
<td>40&quot;</td>
</tr>
<tr>
<td>Elbow and ankle</td>
<td>58</td>
<td>3*</td>
<td>40&quot;</td>
</tr>
<tr>
<td>Humerus</td>
<td>65</td>
<td>4*</td>
<td>40&quot;</td>
</tr>
<tr>
<td>Leg</td>
<td>62</td>
<td>3*</td>
<td>40&quot;</td>
</tr>
<tr>
<td>Knee</td>
<td>66</td>
<td>5*/10</td>
<td>40&quot;</td>
</tr>
<tr>
<td>Thigh</td>
<td>70</td>
<td>12</td>
<td>40&quot;</td>
</tr>
<tr>
<td>Neck</td>
<td>70</td>
<td>12</td>
<td>40&quot;</td>
</tr>
<tr>
<td>Neck, lateral</td>
<td>75</td>
<td>12</td>
<td>72&quot;</td>
</tr>
</tbody>
</table>

* NG-Non-grid

Table 4-2. Basic technical factors.
4-43. INTRODUCTION

At times, it is necessary to perform radiographic examinations outside the radiology department. One common site for these examinations is in the patient's room on the ward (sometimes called nursing unit). He may be seriously ill, in isolation, in traction, or incapacitated in some other way that prevents him from coming to the department. Another place where portable equipment procedures are frequently accomplished is in the surgical suite. In this case, the examinations are performed in conjunction with surgical procedures. Two examples of this mechanical fixation are fractures and cholecystectomy.

4-44. PORTABLE X-RAY MACHINES

a. Portable x-rays units vary considerably from hospital to hospital. They differ in tube capacity, rectification, design, and so forth; therefore, this section will not attempt to describe any particular portable units. The x-ray specialist should become familiar with the unit in his department by studying the manufacturer's operational instructions. A portable x-ray machines are shown in figures 4-17 and 4-18.

b. Ensure all radiographic equipment use spark proof plugs to prevent explosions or fires. This safety precaution cannot be overemphasized because of the hazard that exists with flammable or explosive gases used in hospitals. Even a tiny spark is enough to cause an explosion that would be dangerous for the patient and operating room personnel. If there is any doubt as the reliability in this regard of the equipment to be used, discuss the situation with the anesthetist and the medical equipment repairmen. Do not assume the equipment is safe just because it has been used without incidence in the past.

4-45. RADIATION PROTECTION

a. General. The radiation hazard in portable radiography is potentially greater than the conventional exposure room in the radiology department. This hazard is greater because portable examinations are usually conducted in areas that have no protective barriers. For this reason, exposure to the x-ray specialist will be increased somewhat over exposures received in the department. The x-ray specialist can, however, keep exposure down to a minimum for himself, the patient, and others who are in the area by following a few simple rules. Most of these measures are not limited to portable equipment radiography, but should be practiced in the radiology department as well.
Figure 4-17: General Electric AMX 4, Portable radiographic equipment.

Figure 4-18. Modern portable x-ray machines.
4-16. TOMOGRAPHIC SYSTEMS

Radiography of a layer or section of the body is known by many names such as tomography, stratigraphy, laminography, and planigraphy. As a general rule, the names were applied to the patented apparatus. However, the basic principles of operation are the same. To standardize the nomenclature, the International Commission on Radiological Units and Measurements (ICRU), in Handbook 89, recommends that tomography be used to describe all body-section techniques. Handbook 89 further classifies the systems according to the methods involved. This study guide describes two moving tube systems, called rectilinear and pluridirectional.

a. **Linear.** The tube and film move in a straight line. This movement can be described as plane-parallel. Some tomographic apparatus will only perform a linear movement longitudinally to the long axis of the table. Others will perform crosswise and diagonal movements with respects to the long axis of the table. See figures 4-7 and 4-8. Linear movements are often adequate for tomograms of the lungs, kidneys, and simple bony structures.

b. **Pluridirectional.** Pluridirectional (multidirectional) systems, as a general rule, produce better tomograms of areas that require maximum blurring, such as the optic canal, inner ear, and complicated bone structures. In polytomography, the term is usually used for pluridirectional system in which there is a wide variety of movements. They include circular, elliptical, hypocycloidal, spiral, sinusoidal, and random movements. The first three of these are discussed below.

   (1) **Circular.** Although the circular movement is the simplest of the polytomographic movements, it offers complete blurring. Circular movement is accomplished with the tube tilted 20° to 40°. The pattern is beneficial for views of the lumbar spine.
4-46. FILM HOLDERS AND GRIDS

a. **General.** The choice of film holders can play an important role in the quality of the finished radiograph made by portable examination. SR, as it affects film quality, must also be considered when examinations are not limited to small parts, the chest, or other areas where SR is not a problem.

b. **Film Holders.** As a general rule, portable equipment examinations should be done using screen technique. One reason for this is that minimum exposure times are possible when using intensifying screens. Since patients involved in these examinations are frequently not able to cooperate by remaining motionless, fast exposure times can be a valuable asset in improving the clarity of the radiograph. Another reason cassettes are advantageous is mAs required for non-screen exposures might exceed the capacity of the unit. Finally, cassettes can better withstand the weight involved in some portable equipment examination.

c. **Grids.** Grids (either portable or grid cassettes) should be used for all examinations where SR might pose a problem. An unfocused grid is recommended for general use because you frequently are unable to use the SID required by a focused grid. This is not to say that a focused grid cannot be used. On the contrary, these will produce excellent results when you are able to determine the SID ahead of time and bring the proper grid. For general use, however, when the exact circumstances are not known beforehand, an unfocused or parallel grid should be used.

4-47. BEDSIDE RADIOGRAPHY

a. It is difficult to establish definite procedures for bedside examinations because of the unpredictable conditions of patients. A procedure that works perfectly for one patient may not work for another. Therefore, the x-ray specialist must decide upon the best course of action depending on the circumstances. Some common sense rules, however, will apply in most cases.

b. It is good practice, when the patient's condition permits, to go into the room and introduce yourself to the patient before bringing in the portable unit. At this time, ensure you have the correct patient by checking the armband or by checking with the nurses' station. The abrupt entrance of an x-ray specialist propelling a large, strange machine may alarm some patients unless they have been told to expect this.

c. If intravenous (IV) fluids are being administered, use care in preparing the patient and the bed for the examination. Rough handling of either may cause the needle to dislodge from the vein and the fluid to infiltrate the surrounding tissue. Be extra careful with other devices that may be in use—suction apparatus, traction device, and so forth.
d. If the patient is receiving oxygen, ensure you use care in preparing the patient and the bed for the examination. Do not disconnect the oxygen. If you need to remove an oxygen mask, obtain a nurse's permission before removing the mask. If possible, have the nurse turn off the oxygen and remove the mask. While oxygen alone does not burn, it most certainly supports combustion.

e. When positioning the patient, make modifications in accordance with his condition and the limitations of the portable unit. For example, to project a lateral knee on a patient who cannot rotate the leg into the ordinary position, raise the knee slightly and support it with a pillow; then place the cassette on edge and align the tube from a horizontal position.

f. When a bedside examination is accomplished on a patient in isolation, the portable unit and all accessory equipment must be cleaned afterwards. The ward will provide the solution, a hospital-approved disinfectant.

4-48. SURGICAL RADIOGRAPHY

a. General. On occasion, radiographic procedures are part of a surgical routine. Such surgical procedures as cholecystectomy (removal of the gall bladder) or the reduction and/or mechanical fixation of a fracture usually require radiographic support. In such cases, the radiographic examinations are conducted in the operating room under sterile conditions.

b. Location of Power Source. The power source in the operating room is located between 4 and 4 1/2 feet above floor level to provide an added safety factor. The anesthetic gases are heavier than air and, in case of leakage, settle to the floor. An electrical spark at floor level, as would be the case with conventionally placed floor-level receptacles, could produce a devastating explosion or fire.

c. Surgical Attire. When working in the operating room, the x-ray specialist must be clean and as free from bacteria as possible, short of sterilization. Consequently, he changes into surgical clothes, which consist of shirt, trousers, cap, mask, and conductive boots. Female attire consists of a one-piece cotton dress that snaps up the back and is belted by cotton ties. Since one purpose of the cotton dress is to prevent the build-up of static electricity, nylon undergarments are not worn.

d. Cleaning the Machine. The portable unit must be cleaned before it is taken into the operating room. This cleaning consists of washing it down with an antiseptic agent. Wescodyne or 70 percent isopropyl alcohol may be used. When washing the unit, give special attention to the tube housing, the accessory devices on the tube housing, and to the tube arm. These portions of the machine will be over the sterile field, so they must be completely clean.
Performing the Examination. As with bedside radiography, it is difficult to establish set procedures for radiographic work in surgery. Different surgeons require different projections, variation in numbers of film, and so forth. The requirements also vary with identical examinations, depending upon the suspected pathology. The x-ray specialist, therefore, must vary his procedure according to the desires of the surgeon. Some of the following principles will apply in certain cases.

1. Offer lead aprons to all members of the surgical team. If the team member must work under sterile conditions, it will be necessary for him to remove his apron before putting on the sterile gown. Some members of the team may not want a protective apron, but each person should be offered one.

2. Make a scout film whenever possible. This will help to ensure that the patient is properly positioned and that the exposure factors are correct.

3. Coordinate the exposure with the anesthetist. Remember, he controls the patient’s breathing, so he must stop the breathing before the exposure.

4. Process the films as quickly as possible and return them to the surgeon.
EXERCISES, LESSON 4

INSTRUCTIONS: Answer the following exercises by marking the lettered response that best answers the question or best completes the incomplete statement.

After you have completed all the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the material referenced with the solution.

1. The virginal breast consists primarily of __________ tissue.
   a. Fatty.
   b. Muscular.
   c. Fibroglanular.
   d. Calculus.

2. One of the important factors to consider in mammography is focal spot size. If the large focal spot is used, it may adversely affect detail; but if the small one is used:
   a. The exposure factors must be low enough.
   b. Penetration of the rays may be too low.
   c. More irradiation damage may result.
   d. The radiograph may lack density.

3. For a mammography study, if the kVp is 25 and the mAs 1600, three views would generate __________ HU.
   a. 40,000.
   b. 80,000.
   c. 120,000.
   d. 240,000.
4. For voltages under 50 kVp, the minimum filtration equivalent is:
   a. 0.3 mm aluminum equivalent.
   b. 0.5 mm aluminum equivalent.
   c. 1.0 mm aluminum equivalent.
   d. 1.5 mm aluminum equivalent.

5. Frequently, the larger breast will require less technique rather than more. This is because the larger breast:
   a. Is more muscular.
   b. Has more glands.
   c. Often has more fatty tissue and lies flatter.
   d. Is more dense.

6. In the craniocaudad breast position, the patient is to put her hand behind her back and:
   a. Sit up straight.
   b. Lean to one side.
   c. Cough.
   d. Bend slightly backward.

7. For a mediolateral breast projection, the patient is in what position?
   a. Laterally recumbent.
   b. Prone.
   c. Erect.
   d. Supine.
8. The greatest problem the x-ray specialist has in producing acceptable radiographs of infants and children is the:
   a. Indifference of parents.
   b. Interference of parents.
   c. Adverse effects of motion.
   d. Unpredictable absorption qualities inherent to children.

9. In gastrointestinal examinations of infants, how should the contrast medium be administered?
   a. Spoon.
   b. Nursing bottle.
   c. Syringe.
   d. Eyedropper.

10. Tomography depends upon:
    a. Focusing x-rays.
    b. Blurring out unwanted structures.
    c. OFD.
    d. SID.

11. Where there is a choice of the type of tube and film movement, which of the following would be used in tomography of the skull?
    a. Rectilinear.
    b. Circular.
    c. Elliptical.
    d. Hypocycloidal.
12. Amplitude affects the thickness of the section demonstrated on a tomogram. Another factor that controls thickness is:

   a. OFD.
   b. mAs.
   c. SID.
   d. kVp.

13. Because tube movement has the effect of increasing part thickness, an increase of ________________ in mAs over the normal technique for the part is needed for tomography.

   a. 50 to 75 percent.
   b. 50 to 100 percent.
   c. 75 to 150 percent.
   d. 100 to 150 percent.

14. A particular body section unit is set for a tube amplitude of 24 inches and a rate of 12 inches per second. What exposure time (in seconds) should be set?

   a. 0.5.
   b. 1.5.
   c. 2.0.
   d. 2.5.

Check Your Answers on Next Page
SOLUTIONS TO EXERCISES, LESSON 4

1. c (para 4-2c(1))
2. a (para 4-3)
3. d (para 4-4) (1600 x 25 x 3 x 2)
4. b (para 4-5)
5. c (para 4-8f)
6. d (para 4-9a(6))
7. a (para 4-9b(1))
8. c (para 4-13c)
9. b (para 4-14e(1))
10. b (para 4-15b)
11. d (para 4-16b(3))
12. c (para 4-18)
13. b (para 4-19)
14. c (para 4-20a)