LESSON ASSIGNMENT

LESSON 3
Respiratory, Cardiovascular, and Nervous Systems.

TEXT ASSIGNMENT
Paragraph 3-1 through 3-31.

LESSON OBJECTIVES
After completing this lesson, you should be able to:

3-1. Choose proper radiographic and fluoroscopic procedures involving the respiratory system.

3-2. Choose proper radiographic and fluoroscopic procedures involving the cardiovascular system.

3-3. Choose proper radiographic and fluoroscopic procedures involving the nervous system.

SUGGESTION
After completing the assignment, complete the exercises at the end of this lesson. These exercises will help you to achieve the lesson objectives.
3-1. INTRODUCTION

Advances in technology take place every day. The bronchographic studies are being used less and less, replaced by other modalities. Computed tomography is used primarily, as well as pulmonary angiography, nuclear medicine, and magnetic resonance imaging. These are now the preferred modalities for imaging the respiratory system. Of all the organs and structures that comprise the human body, the lungs are most frequently examined by radiologic means. The major components of the respiratory system are generally demonstrated via standard PA (posterior-anterior) and lateral chest projections. However, certain respiratory diseases and bronchial conditions require detailed examination of the bronchial tree before a definite diagnosis can be made. The radiographic study of the bronchial structures using a contrast medium is called bronchography. Computed tomography is the modality of choice and has replaced bronchography.

3-2. ALTERNATIVE MODALITIES OR PROCEDURES

a. Computed Tomography (CT). CT is most frequently used to examine and identify masses or other pathology in either the mediastinum or in the lung.

b. Bronchography. CT is the modality of choice and has replaced bronchography. Bronchography, performed in the past to examine the bronchial tree and lungs after introduction of a catheter and positive contrast media into the bronchi (see figures 3-1 through 3-5). PA, lateral, and frequently obliques were then taken to rule out pathologies such as obstructions, fistulas, carcinoma, bronchitis, or bronchiectasis.

c. Sonography (Ultrasound). Ultrasound may be used to detect pleural effusion (fluid within the pleura space) or for guidance when inserting a needle to aspirate the fluid (thoracentesis).

d. Nuclear Medicine. Certain nuclear medicine procedures involving radionuclides can be used to evaluate and diagnose pulmonary diffusion conditions or pulmonary emboli.

e. Magnetic Resonance Imaging (MRI). Cardiovascular MRI procedures can be used to demonstrate and evaluate certain pathology such as congenital heart disorders, graft patency, cardiac tumors, thrombi, pericardial masses, and evaluation of aortic dissection and aneurysms.
Figure 3-1. Bronchogram, PA.

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<tbody>
<tr>
<td>1.</td>
<td>Trachea</td>
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<tr>
<td>2.</td>
<td>Carina</td>
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<tr>
<td>3.</td>
<td>Left main bronchus</td>
</tr>
<tr>
<td>4.</td>
<td>Right main bronchus</td>
</tr>
<tr>
<td>5.</td>
<td>Right upper lobe bronchus</td>
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<tr>
<td>6.</td>
<td>Right middle lobe bronchus</td>
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<td>7.</td>
<td>Right lower lobe bronchus</td>
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<tr>
<td>8.</td>
<td>Bronchus to segment of right lower lobe</td>
</tr>
<tr>
<td>9.</td>
<td>Left upper lobe bronchus</td>
</tr>
<tr>
<td>10.</td>
<td>Left lower lobe bronchus</td>
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</table>
Figure 3-2. Bronchogram, PA right oblique.
Figure 3-3. Bronchogram, left lateral.

Figure 3-4. Catheters for pulmonary angiography. Left to right: the Nyman, Grollman, and straight pigtail catheters, and the balloon occlusion with side-holes distal to the balloon (Berman type).
(A) Straight body pigtail catheter and tip deflecting wire. (1) The pigtail catheter is placed in the right atrium. (2) The wire is deflected to point toward the right ventricle. (3) The wire is fixed, and the catheter is advanced over it into the right ventricle. (4) The tip deflection is released. (5) Counterclockwise rotation of the catheter swings the pigtail anteriorly. Simultaneous advancement of the catheter places it into the main pulmonary artery. Advancing the catheter further usually takes it into the left main pulmonary artery. The tip deflecting wire is utilized to direct the catheter downward and to the right for right main pulmonary artery catheterization.

(B) Angled pigtail catheter. (1) The pigtail catheter is placed in the right atrium. (2) Advancing the catheter places the tip in the right ventricle. (3) Clockwise rotation, with simultaneous advancement places the tip in the main pulmonary artery.

(C) Balloon catheter. The balloon is inflated under fluoroscopic guidance in the common iliac vein. It is advanced under observation through the right heart and into the main pulmonary artery. Selection of right and left pulmonary arteries is assisted with conventional or tip-deflecting wires. If a pigtail catheter is needed after use of a balloon catheter, 260 cm Rosen wire is used for the exchange.

Figure 3-5. Techniques for pulmonary artery catheterization.
Section II. THE VASCULAR SYSTEM

3-3. INTRODUCTION

a. Angiography (or vasography) is the radiographic investigation and study of the blood channels in selected portions of the circulatory system after injection of a radiopaque contrast medium to render them visible. Images are captured with digital fluoroscopy and digital printers are capable of printing multiple images on each film. The unprinted digital image is still available on the image archiving system. There are three basic divisions of angiography.

NOTE: Many examinations of the vascular system are now replaced by other modalities such as computerized tomography (CT) and magnetic resonance imaging (MRI).

(1) Arteriography. Arteriography is the radiographic examination of the arteries during injection of a radiopaque contrast medium.

(2) Venography. Venography (or phlebography) is the radiographic examination of the veins during the injection of a contrast medium. Venography may be done in one of two ways. In direct venography, the contrast medium is injected directly into the lumen of the veins and radiographs are exposed the instant a given portion of the venous system is filled with the contrast medium. In direct venography, the contrast medium is introduced into a selected portion of the arterial system and radiography of the analogously related venous channels is done at the time the contrast medium is passing through the veins on its return flow.

(3) Capillariography. Capillariography is the radiographic examination of the capillaries after they have been filled with a contrast medium (nephrography is a form of capillariography).

b. The terms below apply to specific types of angiographic examinations.

(1) Angiocardiography. Angiocardiography is the radiographic examination of the heart and great vessels of the thorax during the venous injection of an opaque contrast medium.

(2) Aortography. Aortography is the radiographic examination of the aorta after injection of a contrast medium.

(3) Cardiac catheterization. Cardiac catheterization is a procedure wherein a catheter is introduced into the heart via selected blood vessels under fluoroscopic control to obtain samples of blood from the various chambers of the heart for determination of the cardiac output.
(4) Selective catheterization or direct angiography. This is a procedure wherein a contrast solution is introduced directly into specific chambers of the heart of particular blood channels (via a catheter in vivo) and the structures are x-rayed during radiopacification.

(5) Cerebral arteriography. Cerebral arteriography, also known as arterial encephalography or cerebral angiography, is the radiographic visualization and study of the intracranial arterial channels during induced radiopacification.

(6) Intra-osseous venography. Intra-osseous venography is a special procedure for the radiographic investigation of selected venous pathways during radiopacification following the introduction of a contrast medium via the intramedullary or intraspongious route.

(7) Portal venography. Portal venography is the radiographic examination of the venous circulation in the spleen and related blood channels during induced radiopacification.

3-4. THE X-RAY SPECIALIST'S ROLE

The x-ray specialist must have an integrated concept of the essential elements and procedural mechanics common to the most frequent angiographic examinations. The importance of this cannot be overemphasized. Only the basic elements of the techniques in the different procedures are described. All of these procedures are subject to variation since each patient undergoing an angiographic examination is regarded as a special case. Except in emergencies, all angiographic examinations are scheduled in accordance with the established clinical procedure.

NOTE: To broaden his knowledge, the specialist should refer to pertinent texts and professional journals dealing with angiography.

3-5. PATIENT PREPARATION

a. Premedication. Premedication of the patient will depend upon clinical dictates.

b. Control of Eating and Drinking Prior to the Examination. This is governed largely by the type of examination and the judgment of the examiner.

c. Check Laboratory Results. Check laboratory results for blood urea nitrogen (BUN), creatinine (Cr), hematocrit/hemoglobin (Hct/Hgb), prothrombin time (PT), partial thromboplastin time (PTT), platelets, etc. The values are checked to determine any possible reaction to iodide compounds even though non-ionic contrasts are primarily used.
d. **Anesthesia.** Local anesthesia is usually administered by the examiner. If general anesthesia has been administered, the patient will be unable to control his respiration or cooperate in assuming or maintaining certain positions.

e. **Preparation of the Intended for Injection.** The injection site is prepared by the examiner or by a designated individual under his direct supervision, usually just prior to making the injection.

### 3-6. SOLUTIONS

The principal solution is the contrast-producing agent. Usually, this consists of one of the sterile aqueous solutions of 60 percent to 76 percent diatrizoate meglumine injection, or iotalmate injection. The choice of an intravascular contrast agent depends on its opacity, osmolality, viscosity, lack of toxicity, and expense. The substitution of meglumine (methylglucamine) for most or all of the sodium of the earlier tri-iodized contrast compounds has resulted in greater patient comfort and less induced, localized, and systemic absorption. The contrast solution must be clear of sediment, sterile, and (unless otherwise specified) maintained at body temperature prior to examination. In some instances, the specialist may be required to fill the syringe(s) with the contrast solution. It is imperative that he use sterile technique and make certain that the right solution goes into the right syringe. This is of vital importance.

NOTE: There are many other types of contrast-producing agents. Consult a practicing radiologist for the desired types of contrast-producing agents.

### 3-7. MATERIALS AND APPARATUS

These items are frequently made up into special sets or layouts for specific procedures (for example: angiography, venography of the lower extremities, cardiac catheterization). Representative items in this category may include any of the following.

a. **Syringes.** Luer-lok type, number and sizes are required.

b. **Needles.**

   (1) Needle-stopcock unit, type suited to the particular requirements or the preference of the examiner.

   (2) Needles of the particular gauge, length, or design for solution transfer.

   (3) Hypodermic needles.

c. **Tubing.** Sterile pieces of tubing are required in suitable calibers and lengths.
d. **Flow Switch.** This is a device attached at the end of the tubing that allows the examiners to stop the back-flow of contrast once contrast injection has stopped.

e. **Catheters.** Fascial dilators are used to slowly expand the access site. There is a wide range of sizes from 4.5 to 28 French. They should be readily available during the procedure.

f. **Sterile cups.** The projected number needed of sterile cups should be included.

g. **Forceps.** Sterile forceps are included in the type(s) and size(s) needed.

h. **Scalpel.** A sterile scalpel and blades are laid out in the size and number required.

i. **Towels and Drapes.** Sterile towels and drapes should be included.

j. **Gloves and Gowns.** A supply of sterile gloves and gowns will be needed.

k. **Gauze Squares.** Include sterile gauze squares in sizes likely to be needed.

l. **Tourniquet.** Lay out a tourniquet, adhesive tape, and bandage.

m. **Table.** Be sure there is a table or instrument stand for arranging layouts.

3-8. **SPECIAL ANGIOGRAPHIC EQUIPMENT**

a. **Needles.** There are many styles of needles employed for angiography. Some are listed and described below.

   (1) The venipuncture needle has the sharpest bevel of the needles employed. It is very satisfactory for percutaneous vein puncture; however, its sharpness is a disadvantage with arterial puncture because of the danger of making too deep an insertion.

   (2) The arteriographic needle, such as the Seldinger style, has a protruding obturator with a low profile bevel and central stylet. It is designed to be inserted when assembled. Most modern arteriographic needles have a blunt tip with a sharp protruding obturator and matching protruding blunt obturator. The advantage of this needle is that the lumen of a vessel can be identified by the flow of arterial blood once the central stylet is removed. The blunt obturator can then be reinserted, restricting the flow of blood.
(3) Sheath needles are a variation on the arteriographic design with a flexible plastic sheath fitted over the needle slightly shorter than the bevel. Once the lumen is encountered after insertion, the needle is withdrawn and the sheath remains. This can be threaded into the vessel. The needle should not be reinserted into the sheath except under direct vision since the needle can cut the plastic sheath.

b. Catheters. If a catheter is to be introduced, the decision as to type will be made by the examiner. The first cardiac catheters were an adaptation of ureteral catheters. A relatively thin-walled, more supple design was forthcoming. There are many different types and shapes of catheters. The barium-loaded polyethylene catheter (ductile and malleable in water, steam, or air at 75°C) allows the operator to readily form a tip design and catheter shape or change design to fit the anatomic circumstances (see figure 3-6). Factory preformed catheters are available in sterile disposable form. This type of catheter will perform ninety percent of clinical angiographic studies. Table 3-1 shows characteristics of some of the available catheter materials.

c. Injection Apparatus. An automatic injection apparatus is used. The automatic type is set and can be adjusted to control the rate of injection and automatically initiate the exposure at a predetermined time after the commencement of the injection.
Table 3-1. Comparison of various catheter materials.

<table>
<thead>
<tr>
<th></th>
<th>Polyurethane</th>
<th>Polyethylene</th>
<th>Polyvinyl</th>
<th>Teflon</th>
<th>Metal Braid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Friction of usual finish</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>Curve retention</td>
<td>Excellent</td>
<td>Good</td>
<td>Good</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Kinking tendency</td>
<td>Moderate</td>
<td>Low</td>
<td>Low</td>
<td>Very Low</td>
<td>Low</td>
</tr>
<tr>
<td>Torque response</td>
<td>Good</td>
<td>Fair</td>
<td>Fair</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Resistance to bursting pressure</td>
<td>High</td>
<td>Moderate</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Effect of temperature and moisture of the blood on flexibility</td>
<td>None</td>
<td>Minimal Increase</td>
<td>Moderate Increase</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Sterilization</td>
<td>Autoclave</td>
<td>Cold</td>
<td>Autoclave</td>
<td>Cold</td>
<td>Cold</td>
</tr>
</tbody>
</table>

3-9. RADIOGRAPHIC EQUIPMENT

a. Type of Equipment Used for Direct Radiography.

(1) Stationary (combination radiographic-fluoroscopic or non-fluoroscopic) or mobile conventional x-ray unit.

(2) Multiple C-arm setup hooked up with digital image capturing and archiving system rapid exposures. See figure 3-7.

(3) Two-tube setup, the most common, with simultaneous biplane exposure apparatus hooked up with a digital image capture system; however, rapid cassette-changing devices are still used.

(4) Two-tube setup equipped with apparatus for making rapid-sequence, biplane, and capturing the images digitally. For older systems, a synchronized exposure on a large roll film is still used.
A. Biplane radiology equipment used in the cardiac catheterization laboratory.
B. Modern single-plane digital catheterization with "smart handle" technology.

Figure: 3-7. Equipment used for direct radiography.
b. **Type of Equipment Used for Indirect Radiography or Photofluorography.**

For this method, digital subtraction images are captured and the x-ray unit is equipped with a digital image intensifier.

c. **Tube Heat Capacity.** This factor is of prime importance in angiography, especially when it is necessary to make rapid-sequence exposures of very short duration (1/30 sec (second) or less) and relatively high energy levels. Tube and generator capacities from 300 to 1200 mA are commonly used in angiocardiographic examinations. When relatively high milliamperage values are used, careful consideration must be given to the appropriate tube-rating chart. For example, if the tube-rating chart stipulates an upper limit of 1/10 second exposure time at 500 mA and 100 kVp, this would permit six rapid-sequence exposures at 1/60 second, or three such exposures at 1/30 second. This means that the sum of any serialized increments of exposure time (in rapid sequence) is not to exceed the safe limits stipulated in the tube-rating chart for the given mA-kVp value. Where it is not feasible to use the upper range of mA values, the lower mA values, with compensatory increase in kVp, may be used.

d. **Accessory Devices.**

1. Grid-front cassettes or tape-on grid mounted on a movable stand that can be adjusted.

2. Protective devices especially designed for, or easily adaptable to, the particular needs of the given situation, such as leaded shields, lead-impregnated gloves and aprons, and thyroid shields. These items are required for the protection of all personnel against direct or stray radiation.

3. Special timing and sequencing device (or program selector). This may consist of a thyraonic rapid-recovering timing unit or a timing unit that embodies a type of high-voltage switch, tube, and condenser arrangement. These devices are used for making exposures of 1/1000 to 1/500 second in rapid sequence at predetermined intervals. They are especially suited for serialized studies showing the progressive phases of the transport of the opacifying agent through specific portions of the vascular system (for example, the various chambers of the heart or the great vessels).

4. Immobilization and supportive devices, such as bands and straps, clamps, bags filled with sand or shot, folded towels, adjustable stools, and foot and shoulder rests.
3-10. POSITION OF PATIENT

a. Position of Patient During Injection of the Contrast Medium.

(1) The position is determined by the examiner. The decision will be influenced by the nature or type of examination, the condition of the patient, the preferred methodology of the examiner, the nature and extent of any existent or suspected pathology and/or anomaly, and the degree of adaptability of the available equipment.

(2) Before starting the procedure, the examiner tells the specialist whether the patient is to be placed in the supine, prone, sitting, standing, or lateral (right or left) decubitus position for the injection. Strict attention on the part of the specialist concerning this point cannot be overstressed. The technique is exacting and demands perfect coordination and timing; following the injection, there is only a very short interval in which to maneuver the necessary equipment into place, adjust controls, and (if necessary) change the position of the patient or part for the exposure.

(3) In some instances, angiographic examinations have to be conducted without a preplanned or set routine. The specialist must be constantly on the alert as the examiner will give impromptu or "on-the-spot" directions.

b. Position of the Patient During Exposure of Angiograms. The examiner may have the patient remain positioned as for the injection procedure or he may have him placed in a different position for the radiography.

3-11. SITE OF INJECTION

a. The site of injection is selected by the examiner. The site selection will depend upon such factors as the specific portion of the blood channels under examination, the existent or suspected pathology, the type of procedure, and the preference of the examiner.

b. If possible, the position of the patient should be oriented so that the site of injection will be same as the working side of the table.

c. If the venous channels of an extremity are injected, the position of the film, with respect to the part, should be adjusted so that maximal coverage will be obtained of those structures that lie distal to the injection site.
3-12. METHOD OF INJECTION

Determined by the examiner, the injection may be made by the percutaneous method or by the insertion of a needle, cannula, or catheter into a selected blood vessel after surgical exposure and under local or general anesthesia. If a special injection apparatus is used, the specialist should anticipate moving the apparatus into position, checking out the electrical connections, disassembling and cleaning the apparatus after usage, and similar tasks.

3-13. RATE OF INJECTION

Since time is an all-important factor, the rate of injection ties in with the need for working out in advance signals or cues for making each desired exposure at the optimal instant. For example, when a relatively large amount of contrast solution (usually of a heavy concentration) is rapidly injected into the aorta, a delay of even one second in making the exposure may render the projection valueless.

3-14. USE OF A TOURNIQUET

A tourniquet is used by many examiners, especially in examinations of the extremities, to force the contrast agent into the deeper blood channels. The specialist must be very careful while adjusting the position of the patient or exchanging cassettes for serialized exposures to make sure that he does not disturb the tension of the applied tourniquet or cause it to snap loose.

NOTE: In some instances, an inflatable cuff may be used in lieu of the customary rubber tubing.)

3-15. PROJECTIONS

The projections to be taken for any specific examination are determined by the examiner, usually at the time the examination is begun. It is necessary for the specialist to know:

a. What projections are to be made (for example: AP, lateral, oblique).

b. What area or areas are to be included in given projections.

c. Number of films to be exposed per projection and the time interval between exposures.

d. How the patient is to be positioned for stereoscopic exposures, if indicated.
3-16. SIZE OF FILM

Images are captured with digital fluoroscopy. Digital printers are capable of printing multiple images on each film. In addition, the unprinted digital image is still available on the image archiving system. In selecting the size of film, the following factors must be considered:

a. The particular region to be radiographed and the extent of coverage desired.

b. The size of the patient. In an angiocardiographic examination, for example, an 8 x 10-inch film may suffice for an infant, but a large film (usually 14 x 17-inch) would be required for an adult.

3-17. THE CR

a. If, in a given situation, the subject to be radiographed is placed in a specified position with the objective of accomplishing a certain radiograph, the projection can be made only according to the following CR relationships:

(1) With the CR directed from a vertical relationship.

(2) With the CR directed from a horizontal relationship.

b. Assume, for example, that the patient is in the supine position on the x-ray table and it is desired to obtain AP and lateral projections of the leg with the position of the patient and the part remaining unchanged throughout the procedure. This necessitates the use of two types of CR projections: a vertical CR projection for the AP and a horizontal CR projection for the lateral. However, if the patient is in the standing position and the same projections (AP and lateral) are required, a horizontal CR projection must be used in each case.

3-18. RADIOGRAPHIC EXPOSURE FACTORS

a. As a general rule, the exposure technique for angiographic examinations will require an increase of about 10 percent over the kVp values normally used for comparable radiographs in routine radiography. The mAs values should be adjusted to produce the desired film density. The shortest practicable exposure times should be used.
b. The exposure technique is vital to the success of the examination. Nothing must be taken for granted. If there is the slightest doubt regarding the technique factors (for instance, if the patient is above or below average in size), a test or control film should be exposed and developed prior to the injection of the contrast medium. In this connection, it is extremely important that the specialist have a sound working knowledge of conversion factors. This might include such things as changes from non-grid to grid technique or vice versa, or compensating for changes in SID or mAs-kVp relationships.

3-19. ANGIOGRAPHIC EXAMINATION OF THE UPPER EXTREMITIES

a. Arteriography.

(1) Patient preparation and administration of sensitivity test. This is covered earlier in this section (para 3-5).

(2) Preliminary procedure.

(a) After ascertaining whether the right or the left extremity is to be examined, the specialist will adjust the patient in the supine position on the x-ray table, with the arm abducted and supinated.

(b) Images are captured with digital fluoroscopy with new digital printers printing multiple images on each film. The unprinted digital image is still available on the image archiving system.

(c) The groin is the site most frequently used for injection. The actual site depends upon two factors--a strong presence of a pulse and the presence of any vessel disease.

(d) The site of injection is rendered aseptic and from 1 to 2 cc of 0.5 percent procaine solution is injected into the skin and subcutaneous tissues over the site.

(e) From 10 to 15 cc of the contrast solution is warmed to body temperature and placed in the syringe.

(3) Injection of contrast medium and radiography.

(a) The specialist selects the radiographic, technique factors and adjusts the controls of the x-ray unit. Normally, routine (nongrid) factors for the part will suffice, but the exposure time should be as short as possible. With everything in readiness, the specialist assumes the "Ready" position so that the exposures can be made without delay when the examiner gives the signal.
(b) The groin is the most common access site. The contrast is injected and the first exposure is made when the examiner gives the signal. The patient should have been instructed beforehand to remain absolutely motionless at the time the exposure is being made.

(c) For additional exposure, the procedure described above is repeated.

(4) Variations.

(a) When specific or localized areas of the extremity are the objects of clinical interest (for example, a given region of the hand or forearm), pronation of the part may be indicated. Lateral projections may also be included.

(b) Rapid-sequence exposures may be made if the necessary apparatus is available.

(c) A collateral result of arteriography is sometimes achieved by delaying the time of exposure so that the contrast medium enters the analogously related venous channels on its return flow (indirect venography).

(5) Precautions.

(a) Since the examiner usually works in close proximity to the field of exposure, proper safeguards must be employed for his protection; for example, a leaded screen positioned near the x-ray table will provide a relatively safe shelter during the time the films are being exposed. Collimation should be used to keep the field of irradiation within the necessary limits.

(b) A technical difficulty frequently encountered is the mistiming of the exact instant of exposure. Perfectly coordinated teamwork is vitally important to the success of the examination.

b. Venography. See figure 3-8.

(1) Patient preparation and administration of sensitivity test. These have been covered earlier in this section (para 3-5).

(2) Preliminary procedure.

(a) As soon as the patient is received at the x-ray clinic, the specialist will ascertain from the examiner the site of injection and the particular portion of the extremity to be examined.

(b) The patient is adjusted in the supine position on the x-ray table, with the arm abducted and supinated.
(c) If the examination is localized to any specified region lying distal to the proximal third of arm, again digital images are captured and digital subtraction is applied to the images.

(d) If the object of the examination is to demonstrate the venous channels of the upper portion of the arm, axillary, shoulder girdle, or upper thoracic regions, then the position of the patient should be adjusted in relation to the midline of the x-ray table so that the desired coverage will be obtained. Digital subtraction images are captured. Identification markers are preferably placed on the tabletop.

(e) The site of injection is rendered aseptic and local anesthesia is administered.

(f) The injection needle is then inserted into a vein (for example, the antecubital vein or the basilic vein for views of the hand).

(3) Injection of contrast medium and radiography.

(a) From 20 to 40 cc of the contrast solution, similar to that used for arteriography, is injected at a rate of from 5 to 20 cc per second.

(b) When given the signal by the examiner, the specialist makes the first exposure. The exact time at which this exposure is made may vary from the instant the injection is completed to 5 or more seconds afterwards.

(c) Additional exposures are made by direction of the examiner.

(4) Control of respiration during exposure of films.

(a) In some cases, the patient may be instructed to suspend respiration while the exposure is made. In other cases, he may be allowed to breathe naturally.

(b) Under certain conditions, special methods of respiration control may be employed. For example, the patient may be instructed to inhale against the closed glottis (Muller's maneuver) or to execute forced expiration against the closed glottis (Valsalva's maneuver) while the exposure is being made.

(5) Digital subtraction radiography. Digital subtraction radiography is used with automatic exposure control. With digital technology, a highly sophisticated computer "subtracts" or removes certain anatomic structures so that the resultant image demonstrates only the vessel(s) of interest containing contrast media. A subtracted image appears as a reversed image and may visualize diagnostic information not apparent on a conventional non-subtracted image.
The top projection demonstrates the right subclavian artery injected, demonstrating iatrogenic occlusion of radial artery (arrow).

The bottom is a normal right upper venogram.

Figure 3-8. Venography.

3-20. ANGIOGRAPHIC EXAMINATION OF THE LOWER EXTREMITIES

a. Arteriography.

(1) Preparation. Digital subtraction is used to demonstrate any part of the lower extremity. Patient preparation and administration of sensitivity test is covered earlier.

(2) Preliminary procedure.

(a) As soon as the patient is received at the x-ray clinic, the specialist will ascertain from the examiner the area(s) of the extremity to be examined. If the examination is concerned with any part lying distal to the region of the knee, then non-grid technique is normally employed. Bucky technique may be indicated when the arterial channels in the thigh region (exclusively) or in the leg and thigh regions are to be examined. With the latter, it is possible to obtain simultaneous coverage of both the leg and thigh portions with a single exposure, by using several cassettes (placed end-
to-end with their adjacent edges overlapping) or by the use of a special 36-inch cassette adjusted underneath the part. When full-length coverage is required, it may be necessary to increase the normal SID to accommodate the area of interest to the exposing x-ray beam. To equalize the exposure between the thinner region of the leg and the thicker region of the thigh, the x-ray tube should be positioned with the cathode end toward the thigh. The use of a compensating filter should also be considered.

(b) The patient is assisted onto the x-ray table, and the lower extremity under consideration is adjusted to the AP position. A 14- x 17-inch cassette is placed beneath the extremity and centered to the region to be examined if nongrid technique is used. With grid technique, the cassette is placed in a Bucky tray and the part or area under consideration is aligned to the midline of the x-ray table.

(3) Injection of contrast medium and radiography.

(a) After the administration of local anesthesia, the examiner inserts the catheter into the lumen of the common femoral artery just distal to the inguinal (Poupart's) ligament.

(b) An automatic injector is loaded with 60 cc of the contrast solution. The examiner gives the "Ready," signal and then rapidly injects the contrast solution. At the same time, the examiner (or an assistant) applies manual or mechanical pressure on the femoral artery proximal to the injection site.

(c) Additional exposures are made according to the examiner's instructions; for example, lateral or oblique. When it is undesirable to change the position of the patient, it may be necessary to use an extra machine, such as a mobile unit, for the lateral projections with the use of a horizontal CR.

(4) Radiographic exposure factors. The kVp is usually increased 10 percent over other exposures of the same part and the mA adjusted to hold density constant.

b. Venography.

(1) Preparation. Patient preparation and administration of sensitivity test have been covered earlier. Digital subtraction is used to demonstrate any part of the lower extremity.

(2) Preliminary procedure.

(a) As soon as the patient is received at the x-ray clinic, the specialist will ascertain from the examiner the area(s) of the extremity to be examined.
(b) For venography in the horizontal position, the patient is assisted onto the x-ray table and adjusted in the supine position. The lower extremity to be studied is aligned to the midline of the x-ray table if a Potter-Bucky diaphragm is to be used. For nongrid technique, the region of interest is adjusted over a suitable film-changing tunnel.

(c) For venography in the erect or the semi-erect position, the patient stands facing the x-ray tube on a footrest that has been fastened to the x-ray table. The x-ray table is tilted 65 to 80 degrees from the horizontal position. The footrest should be adjusted to a high enough elevation to permit the examiner to have reasonably easy access to the working site. An immobilization band should be placed over the patient's chest, just beneath the armpits, to provide support. The part to be examined is aligned to the image intensifier for digital capture. A 14 x 14-inch cassette is placed in the fluoroscopic machine.

(d) An infusion set for saline solution should be placed in a location that is safe and reasonably convenient to the part under examination.

(e) The site of injection is rendered aseptic and local anesthesia is administered.

(3) Injection of contrast medium and radiography.

(a) Injection may be made by the percutaneous method or by "cutting down" and surgically exposing a vein (which is rarely done anymore). The site of injection may be in either the retromalleolar region or the dorsum of the foot.

(b) A butterfly needle is primarily used, usually connected to a length of plastic tubing with an adapter attached. It is inserted in the vein and secured in position by adhesive tape.

(c) When indicated, venoclysis with normal saline solution is initiated. In some instances, venoclysis is done in both extremities.

(d) A rubber-like tourniquet is applied around the mid-calf or above the knee and tightened to impede the circulation in the superficial venous system.

(e) From 20 to 40 cc of a contrast solution is injected at rate varying from 1 to 5 cc per second.

(f) The examiner signals the specialist when the first exposure is to be made, anywhere from less than 5 seconds to more than 120 seconds following the injection. Venograms of the leg are shown in figure 3-9.
(4) Variations. There are numerous methods for venography of the lower extremities. Certain variations frequently resorted to are:

(a) Stereoradiography. Since the transport of the injected contrast material in the venous channels is relatively slow, stereoscopic projections are practical. Stereoscopy, however, requires the use of a suitable film-changing tunnel or the Bucky technique. The tube-shift should be made in a crosswise direction in relation to the long axis of the part under consideration.

(b) Projections. Because of superimposition of the tibia and fibula with certain venous channels, oblique projections (made with the leg rotated either internally or externally as directed by the examiner) or laterals may be especially indicated.

(c) Coverage. In certain cases, the first exposure is made to demonstrate the most distal portion of the extremity; subsequent exposures are made with each cassette positioned progressively nearer the regions, which lie proximally. Since the timing of these exposures and the order in which they are made is an extremely important factor, the specialist must carry out the instructions of the examiner with utmost exactness.

(d) Proximal injection method. The principal object of this method is to introduce the contrast medium into the proximal portion of the venous system of the lower extremity. The injection may be done in one of several ways. For example, the contrast solution is injected into either the median superficial or the lateral superficial vein of the penis in the case of the male patient or into the superficial circumflex iliac vein in the case of the female patient. The solution may also be introduced by direct-needle injection of the femoral vein in the region just below the crease in the groin or by
the insertion of a catheter into the saphenous vein in the region of the fossa ovalis after the vein has been surgically exposed. In practically every case, the patient is adjusted in the erect or the semi-erect position on the tilted x-ray table and facing the tube. The reason this position is used is to allow the injected contrast medium to gravitate into the dependent veins in retrograde fashion to the level of competent venous valves. Exposures of the pelvic and upper thigh regions are made immediately after the completion of the injection and, thereafter, as indicated by the examiner.

(5) Radiographic technique factors. The kVp is usually increased 10 percent over other exposures of the same part and the mA adjusted to hold density constant.

3-21. ANGIOCARDIOGRAPHY

a. Patient Preparation and Administration of Sensitivity Test. This is discussed earlier in this section (para 3-5).

b. Preliminary Procedure.

(1) An angiocardiographic layout and the necessary solutions are prepared.

(2) Pre-examination or control films are made and developed to establish the proper technique factors and to permit the examiner to select the most favorable position. These films are made as soon as the patient arrives at the x-ray clinic.

(3) The patient is positioned over a specially constructed device equipped with digital imaging capture systems (figure 3-7). Older systems have a roll-film (for example, Fairchild) magazine which is mounted on an adjustable and mobile stand.

(4) The site of injection is rendered aseptic and then local anesthesia is administered.

(5) A tourniquet is applied around the upper region of the patient's arm. Then, a suitable injection needle (for example, Robb-Steinberg, 12 to 15 gauge) is inserted into the antecubital vein, either percutaneously or after surgical exposure of the vein. Following this, the tourniquet is removed. In some instances, however, a special type of catheter is used for introducing the contrast medium. The catheter may be inserted into the external jugular vein and advanced through the femoral and iliac veins into the vena cava.
(6) In the absence of rapid-sequence, serializing-recording apparatus, it may be necessary to perform circulation-time tests to ascertain the relationship of the time interval between the commencement of the injection of the contrast medium and the occurrence of opacification of specific blood channels. A substance such as ether, sodium dehydrocholate (Decholin), sodium cyanide, fluorescein, or calcium gluconate is injected into the vein and specific reactions (such as bitter taste, odor of breath, yellowish coloration of the lips) manifested by the patient are noted and timed by a stopwatch. This provides a reliable means for predicting when maximum opacification of specific blood channels will occur and when the exposures should be made.

NOTE: If fluorescein is to be used, the specialist must take the necessary steps to darken the x-ray room and see that a Wood's lamp is on hand so that the fluorescent coloration of the patient's lips can be detected the moment it occurs.

(7) When indicated, the examiner, the patient, and the specialist (including any assistants) will rehearse the critical aspects of the injection procedure.

c. Positioning the Patient. The patient is usually placed in the horizontal position, either prone or supine (see figure 3-10). If he is obliqued and supporting material is used, the material must be free of any opaque substance. At the discretion of the examiner, the patient may be placed in the upright position.

![Figure 3-10. Position of patient and examiner preparatory to injecting the contrast medium for angiocardiography.](image-url)
d. **Projections.** The projections to be made for angiocardiography are determined by the examiner and will depend upon the nature of the given case. The specialist is concerned about the exact order and specific time the required films are to be exposed and, in the case of the obliques, also the degree of rotation to be used. As a rule, when rapid-sequencing recording apparatus in combination with a biplane exposure setup is used, simultaneous AP and lateral projections only are made.

e. **Injection of Contrast Medium and Radiography.**

(1) When everything is in complete readiness, participants alerted, x-ray unit turned on, technique factors selected, and the tube anode actuated to "exposure-rotation," the examiner draws about 10 to 15 cc of blood from the patient's vein into the syringe.

(2) The examiner instructs the patient to suspend respiration at the end of exhalation.

(3) Next, the patient is told to inspire rapidly and deeply and then to hold his breath.

(4) Simultaneously with the inspiration, 40 to 50 cc of the contrast solution is injected at a rate of about 25 to 35 cc per second. At the exact instant the injection is begun, the specialist starts the stopwatch.

(5) With his eyes on the stopwatch and his hand on the exposure controls, the specialist makes the first exposure at the predetermined instant.

(6) Additional exposures are made as ordered by the examiner.

f. **Radiographic Technique Factors.**

(1) The kVp is usually increased 10 percent over other exposures of the same par, and the mA adjusted to hold density constant.

(2) Special consideration should be given to the following:

   (a) Exposure time. Due to the relatively rapid transport of the contrast medium in angiocardiography, the shortest practicable exposure time should be used. Exposure time for the average adult patient should not exceed 1/15 second. For a small child, it should not exceed 1/30 second. Under average conditions, exposure times of 1/30 second for the adult patient and 1/60 second for the small child patient are usually adequate. When allowed a choice, it may be preferable to use exposure times shorter than those given above.
(b) Kilovoltage, mAs. As compared to the kVp values for routine radiography of the chest of similar size and for comparable radiographs, an increase of about 15 percent is necessary for angiocardiography. When a grid is used, a tube tension of about 100 kVp is a sound starting value. The mAs values should be adjusted so as to obtain the desired density and contrast of the opacified structures, more or less disregarding the pneumatized lung fields. Whenever there is an element of doubt, it is better to favor overexposure than to risk underexposure.

(c) SID. An SID of 40 inches is generally used with interventional C-arms, but can be slightly greater with larger units.

3-22. CARDIAC CATHETERIZATION

a. Patient Preparation and Administration of Sensitivity Test. This has been covered earlier in the section. Figure 3-11 demonstrates a cardiac catheterization with the injection of contrast during diastole and systole.

b. Preliminary Procedure.

(1) A combination radiographic-fluoroscopic unit (and television, if available) is put in operative order by the specialist. The table unit is adjusted in the horizontal position and, when indicated, a soft synthetic rubber mattress is placed on the tabletop to ensure the comfort of the patient.

(2) When the patient arrives at the x-ray clinic, he is placed on the x-ray table in the supine position and sterile draped.

(3) A cardiac catheterization layout is prepared.

(4) The site of insertion (for example, antecubital fossa) is made aseptic, local anesthesia is administered, and a selected vein is surgically exposed. A size 8 or 9 French ureteral-type catheter, 100 to 125 cm long, connected to a regular saline infusion set by a stopcock complex and adjusted for continuous saline perfusion, is inserted into the vein through the surgically induced opening. The fluoroscopic apparatus and spot-film assembly are moved into position over the patient's chest, adjusted to the required height, and locked in place. The specialist should make certain that the self-recording time clock is in the catheter in the heart, fluoroscopic circuit and is set to accurately tally the total exposure.

c. Fluoroscopic and Spot-Film Procedure. The examiner advances the catheter into the initial position in the heart under fluoroscopic control. Samples of blood are aspirated into a syringe connected to the stopcock complex and transferred into special containers for laboratory analysis. Usually, spot films are exposed to record the catheter in the various positions. The spot films are numbered to correspond to the numbered samples of blood.
A. An example of midcavitary catheter position for left ventriculography using a pigtail catheter: before the injection of contrast (A-1), at end-diastole (A-2), and at end-systole (A-3).

B. Left ventricular inflow tract catheter position for right anterior oblique using a pigtail catheter: before the introduction of contrast (B-1), at end-diastole (B-2), and at end-systole (B-3).

Figure 3-11. Cardiac catheterization with the injection of contrast during diastole and systole.
d. Selective Catheterization or Direct Angiocardiography.

(1) Patient preparation has been covered earlier in this section.

(2) Procedure.

(a) Immediately after completion of cardiac catheterization, the patient is positioned for exposure of the angiocardiographic films.

(b) The stopcock complex is readjusted so that the contrast medium will flow from the previously filled syringe through the lumen of the catheter. Any equipment previously used for cardiac catheterization and not needed for this procedure will be disconnected and moved out of the way.

(c) Injection of the contrast medium and radiography are essentially the same as for intravenous angiocardiography with the execution of the exposure-timing phase being somewhat more critical. However, this difficulty is usually overcome by the use of an automatic injection device and a serial film changer.

3-23. ABDOMINAL ANGIOGRAPHY

a. Aortography, Translumbar Percutaneous (Direct) Method. See figure 3-12.

(1) Preparation. Patient preparation and administration of sensitivity test. This has been covered earlier in this section. Digital subtraction is used to demonstrate any part of the lower extremity.

(2) Preliminary procedure.

(a) A sterile layout consisting of the necessary instruments and materials is prepared.

(b) The X-Ray table is adjusted in the horizontal position.

(c) The patient is placed in the prone position on the x-ray table. An abdominal film (14x17-inch) is exposed and immediately developed. This film serves to check the adequacy of the pre-examination preparation of the patient's bowels, the most favorable centering of the film with respect to the area under examination, and the correctness of the technique factors.

(d) If the vascular structures in the pelvic region are to be studied, the examiner may request that sphygmomanometer cuff be adjusted around the proximal portion of both thighs and inflated to about 200 mm (millimeters) Hg (mercury).
Figure 3-12. Aortogram that shows opacification of aorta and tributaries.

(e) The patient is anesthetized by the intravenous administration of sodium pantothal.

(f) The area in and around the injection site is made aseptic and then sterile draped.

(g) The skin just below the 12th rib and approximately 7 cm to the left of the spinous processes is punctured with a relatively short thick needle. A special type of needle (15 cm in length and fitted with a stylet) is then passed through the puncture hole and directed toward a point just anterior to the body of the twelfth thoracic vertebra. Upon approach of the needle point to the aortic wall, the stylet is removed and the needle is then cautiously advanced until characteristic physical manifestations indicate entry of the needle in the lumen of the aorta.
(h) The needle is then connected to the plastic tubing and syringe filled with sterile saline solution. The ease of flow throughout the injection route is checked by means of barbotage.

(i) The stopcock is then closed. The syringe is disconnected and filled with approximately 20 cc of the contrast solution. The syringe is reconnected and the stopcock complex adjusted. To make sure that the needle is well within the lumen of the aorta, the examiner may request an exploratory exposure the instant after injection of a relatively small amount of the contrast solution. This film must be processed immediately and presented to the examiner for reading.

(3) Injection of contrast medium and radiography.

(a) The examiner withdraws a few cubic centimeters of blood into the barrel of the syringe.

(b) When everything is in complete readiness, all participants alerted, x-ray unit energized, cassette in the Bucky tray, and technique factors set, the examiner gives the "Ready," signal to the specialist and starts the injection. At that instant, the examiner gives the signal "Now," or "Shoot," and the specialist makes the first exposure.

(c) The injection needle is removed by the examiner and the x-ray specialist (or an assistant) changes cassettes.

(d) Subsequent exposures are made at predetermined intervals. Exposures made from 2 to 4 seconds after completion of the injection will usually demonstrate the venous return.

(e) To obtain optimum radiographic quality in the aortogram, grid technique must be used. The exposure time should not exceed 1/10 second. Increase the kVp 10 percent above that which would be used for a similar projection without contrast medium, adjusting the mA to keep density constant. A pilot film should be made to check technique.

b. Aortography--Retrograde Method.

(1) Patient preparation and preliminary procedure. In general, the preparation of the patient and the preliminary procedure are the same as for the translumbar percutaneous method described above, with the following exceptions:

(a) The patient is adjusted in the supine position on the x-ray table.

(b) After aseptic preparation and local anesthesia, the femoral artery is the region of Scarpe's triangle located.
(2) **Injection of contrast medium and radiography.**

(a) Before starting the injection procedure, a final check is made of all apparatus for operative readiness.

(b) From 60 to 120 cc of the contrast solution is put into the auto-injector syringe.

(c) The syringe is connected to the injection system and the stopcock complex is adjusted.

(d) The examiner gives the "Ready," signal to the specialist and then starts the injection.

(e) When all but a few cubic centimeters of the contrast medium have been injected, the examiner will give the signal "Now," or "Shoot," and the specialist makes the first exposure.

(f) Subsequent exposures are made at predetermined intervals.

(g) The patient will control his respiration according to the instructions of the examiner.

c. **Venography of the Inferior Vena Cava (Cavagram).**

(1) **Patient preparation and administration of sensitivity test.** This has been covered earlier in this section (para 3-5).

(2) **Preliminary procedure.** Digital subtraction is used to demonstrate any inferior vena cava.

(a) The patient is placed in the supine position on the x-ray table.

(b) Pre-injection films (14x14-inch) are sometimes made to include an AP projection exposed with a vertical CR and a lateral projection exposed with a horizontal CR. Grid technique is used for both. These films are processed immediately and presented to the examiner for reading.

(c) While the projection films are being developed, the injection needle is inserted percutaneously into the lumen of the femoral vein. A plastic tube is then connected to the needle. Adhesive tape is used to hold the needle in place.

(d) In the absence of a simultaneous biplane exposure setup, the examiner will signify whether the AP or the lateral is to be exposed first.
(3) **Injection of contrast medium and radiography.**

(a) Approximately 120 cc of the contrast solution is put into the syringe. The syringe is then connected to the automatic injection system and the necessary adjustments of the stopcock complex are made.

(b) The examiner gives the "Ready," signal to the specialist and then starts the injection of the contrast solution at a rate of about 10 cc per second.

(c) The specialist makes the first exposure at the instant the examiner gives the signal.

(d) Subsequent exposures are made according to the instructions of the examiner.

d. **Portal Venography.**

(1) **Methods.** The methods of performing portal venography vary principally in the way the contrast medium is introduced.

(a) Operative method. The contrast medium is introduced through one of the tributaries (for example, right gastroepiploic, superior mesenteric) of the portal vein while exposed during abdominal laparotomy. This method is the only one that will be described here.

(b) Occlusal method. The vena cava is momentarily occluded at a specific level by means of a special type of balloon-catheter during the injection. The catheter is inserted via the femoral and iliac route into the vena cava.

(c) Percutaneous transhepatic method. The injection needle is inserted through the abdominal wall just below the xiphoid process of the sternum and then advanced through the liver into the portal vein.

(2) **Patient preparation.** The specific mode of patient preparation depends upon the method of injection and the demands of the clinical situation.

(3) **Preliminary procedure.**

(a) This examination should be done primarily in an interventional radiologic suite that has a digital subtraction capability. At the appointed time, the specialist will proceed to the designated operating room with a mobile x-ray unit and portable Bucky or gridfront cassettes. When the latter are to be used, a suitable cassette-changing tunnel may be required. The specialist must change into attire appropriate for operating room environment before he enters the sterile operating area. He must inquire of the surgeon in charge regarding the most favorable location for setting up the x-ray equipment.
(b) The patient is placed on the operating table in the supine position and draped for surgery. The specialist placed the portable Bucky grid or the cassette tunnel underneath the patient and centers the film in line with the siphoid process of the sternum and slightly to the right of the midline.

(c) A preliminary film (10 x 12-inch or 14 x 17-inch) is exposed and immediately processed. This film is used to check the centering of the film and the correctness of the technique factors.

(d) Anesthesia is induced and the operating field is prepared for surgery.

(e) After surgical exposure, a plastic catheter is inserted into one of the tributaries of the portal vein, advanced into the portal, and then tied in place.

(4) Injection of contrast medium and radiography. See figure 3-13.

(a) An automatic injector syringe filled with 60 to 120 cc of a contrast solution is attached to the exposed end of the catheter. Meanwhile, the specialist will move the x-ray unit in place and center the tube over the area indicated by the surgeon. Before positioning the tube, the surgical site must be covered with a sterile towel or the tube assembly wrapped with a suitable sterile material.

(b) With all participants alerted, the surgeon gives the "Ready," signal to the specialist and then starts injection of the contrast solution at a rate of 10 to 15 cc per second. Immediately upon completion of the injection, the first exposure is made. In some instances, the surgeon may instruct the anesthetist to induce apnea for the duration of the exposure in order to help overcome the possible loss of image detail caused by respiratory movement in the patient. This is especially advantageous in cases where a low-powered mobile x-ray unit is all that is available for use in the operating room. When apnea is induced, two factors are of prime importance.

1. The surgeon must determine the optimum time for the commencement of the injection concurrent with the inducement of apnea

2. The specialist must be prepared to make the exposure at the required instant.

(c) Subsequent exposures are made at predetermined intervals.

(5) Procedural variations. When the contrast medium is introduced by the transhepatic or the occlusal method, operating room facilities are not necessarily required. This is advantageous since it permits the use of automatic rapid-sequence serializing biplane exposure apparatus.
1. Right portal vein.  
2. Left portal vein.  
3. Main portal vein.  
4. Splenic vein.  
5. Superior mesenteric vein.  
6. Inferior mesenteric vein.

Figure 3-13. Portal venogram showing the portal vein and tributaries injected with the contrast solution.

e. **Splenopancreaticoduodenography (Percutaneous).**

(1) **Patient preparation.**

   (a) General anesthesia may be administered either in the operating room or in the designated x-ray room. Only the latter situation will be described here.
(b) The patient is placed in the supine position on the x-ray table, and adjusted so that the sagittal plane located 1 1/2 to 2 inches medial to the midclavicular line is aligned to the midline of the x-ray table. A 10 x 12-inch or a 14 x 17-inch cassette is placed in the Bucky tray, positioned crosswise in relation to the midline of the patient, and centered to the level of the xiphoid process.

(c) A preliminary film is exposed and immediately processed. The film is used to check the adequacy of intra-abdominal preparation and the correctness of the technique factors.

(d) The anesthetist then induces general anesthesia and performs endotracheal intubation. In the meantime, the site of injection is made aseptic and sterile drapes are placed.

(e) The examiner inserts the injection needle in the midaxillary line (left side) in the 9th and 10th intercostal space. As the examiner advances the needle into the bulb of the spleen, he instructs the anesthetist to induce apnea.

(2) Injection of contrast medium and radiography (figure 3-13).

(a) A 50 cc syringe is filled with a contrast solution and then attached to the injection needle.

(b) With all participants of the medical team alerted and the x-ray apparatus adjusted and energized, the examiner again instructs the anesthetist to induce apnea and gives the "Ready," signal to the specialist.

(c) The examiner will now inject the contrast solution at a rate of 10 to 15 cc per second. Immediately upon completion of the injection, the injection needle is withdrawn and the first exposure is made.

(d) Subsequent exposures are made at predetermined intervals. In the event that rapid-serial radiography is used, the exposures are generally made at a continuous rate of one per second for 10 to 15 seconds.

3-24. CEREBRAL ARTERIOGRAPHY

a. Patient Preparation. This has already been discussed in this section (para 3-5).

b. Preliminary Procedure.

(1) The patient is placed in the supine position and centered to the midline of the x-ray table.
(2) Preliminary films of the skull (AP and lateral) are exposed according to the examiner’s instructions. These films are processed immediately and presented to the examiner for reading.

(3) A sterile layout consisting of the instruments and materials required for cerebral arteriography is prepared.

(4) Radiation protection shielding should be arranged so as to provide the necessary safety and yet afford optimum freedom of movement for each member of the medical team.

(5) If the injection is to be carried out by the percutaneous method, the examiner palpates the femoral vein in the groin area to determine the best site for puncture.

(6) The examiner inserts the injection needle into the selected lumen of the vein and then engages the needle with the adapter in the injection system (figure 3-14).

Figure 3-14. Showing relationships of the inserted injection needle, adapter, syringe, and stopcock complex for selectively directing the flow of contrast medium in the injection continuum.

c. **Injection of Contrast Medium and Radiography.** See figures 3-15 and 3-16.

   (1) The specialist adjusts the patient's head in the AP position. The CR is aligned parallel to the glabellomeatal line and directed to a point midway on line approximately 2 cm superior to the tragi.

   (2) A syringe filled with approximately 20 cc of warmed contrast solution is attached to the stopcock complex.
1. Cavernous portion of internal carotid artery
2. Anterior cerebral artery
3. Middle cerebral artery

Figure 3-15. Cerebral arteriography, AP view.

1. Cavernous portion of internal carotid artery.
2. Anterior cerebral artery.
3. Middle cerebral artery.

Figure 3-16. Cerebral arteriography, lateral view.
(3) With all participants alerted and the x-ray unit in readiness for instant exposure (the rotating anode must be at exposure speed), the examiner gives the "Ready," signal to the specialist and injects the contrast solution at a rate of approximately 10 cc per second. Just as the final cubic centimeter leaves the syringe, the examiner gives the signal "Shoot," and the specialist makes the first exposure.

(4) In the absence of rapid-sequence serializing exposure apparatus, the specialist (or an assistant) will rapidly exchange cassettes and then expose the second film as quickly as possible. The pressure on the opposite side of the injection site is now released. The second exposure, when executed 3 to 5 seconds after injection, will represent the radiopaque medium passing through the venous phase of circulation. This film is actually a type of cerebral venogram.

(5) The manner in which the next step of the procedure is carried out depends largely upon the decision of the examiner. For example, he may order that fronto-occipital and/or lateral projections be made addition to the AP.

(6) Exposure time should not exceed 1/4 second. The timing of the exposures in relation to the time of injection is a vitally important point.

(7) All exposed films should be processed immediately and placed in an illuminator for viewing by the examiner before the patient is removed from the table.

d. Variations. When direct percutaneous injection of the contrast substance is made into the vertebral artery, the procedure is called vertebral arteriography. With certain exceptions, the procedure is similar to that for cerebral arteriography by carotid injection (supine position). In this case, the patient does not lie directly on the table surface. Instead, a firm cushion (approximately 6 inches high) is placed beneath the thoracic and pelvic regions and the head is hyperextended so that vertex of the skull rests on the table surface. Submentovertical projections are exposed during the first injection and such other projections as the examiner may direct during subsequent injections.

e. Cerebral Arteriography by Use of Special Equipment. Special equipment is used in various installations throughout the Army, such as automatic biplane C-arm image intensifiers, with a digital subtraction capability used to demonstrate any part of the cerebral anatomy. Notwithstanding the complexity of this type of apparatus, the procedural principles are basically the same as when conventional equipment is used.
3-25. CEREBRAL VENOGRAPHY AND SINUS VENOGRAPHY

a. General. Cerebral venograms may be produced incidental to cerebral arteriography when exposures are made during the venous phase of circulation. Certain diagnostic situations, however, demand a more detailed demonstration of specific venous channels than is afforded by this type of venogram (which is actually the result of indirect venography); for example, when it is desirable to obtain a more selective filling of specific venous channels with accompanying lack of dilution of the contrast substance. The preparation of the patient, preliminary procedure, positioning technique, and radiography are, for the most part, the same as for cerebral arteriography. The principal difference lies in the methods of introducing contrast medium.

b. Injection Method for Superior Sagittal Sinus Venogram. With the patient in the supine position on the table, the examiner makes an incision at the hairline in the mid-forehead area after having induced local anesthesia. A burr hole is made, then a ureteral-type catheter is inserted. The exposed end of the inserted catheter is connected to the stopcock complex and the usual infusion apparatus. Approximately 15 cc of the contrast solution (sterile aqueous type containing 35 percent iodine compound) is injected at a rate of approximately 5 cc per second. The first exposure is made at the completion of injection. Subsequent injections and views are made in accordance with clinical dictates.

c. Injection Method for Retrograde Jugular Venogram. The patient is placed in the supine position on the x-ray table. After aseptic preparation and administration of local anesthesia, an antecubital vein is surgically exposed. A cardiac catheter is inserted into the selected vein and then advanced to the desired level in the jugular vein under fluoroscopic control. The patient's head is positioned for the lateral view. Approximately 25 cc of contrast medium is injected through the catheter at a rate of 10 to 15 cc per second. The first exposure is made just as the last of the contrast medium leaves the syringe. In some instances, the examiner may have an assistant exert manual pressure on both jugular veins during injection. Subsequent injections and/or exposure are made in accordance with clinical dictates.

3-26. INTRA-OSSEOUS VENOGRAPHY

In this method of venography, the contrast medium is introduced into selected venous pathways via the intramedullary or intraspongious route. In some situations, this technique may offer certain advantages over those previously described. The specialist should consult standard textbooks on this subject.
3-27. LYMPHANGIOGRAPHY

a. This is a radiographic procedure, which will allow visualization of the lymph nodes and lymphatic channels by the use of contrast media. The lymph vessels and nodes of the extremities as well as the retroperitoneal areas can be visualized by this technique.

b. The examiner injects 6 cc Ethiodol (ethyl ester of iodized poppyseed oil containing 37 percent iodine) in the upper extremity or 12 cc into the lymphatic vessels of the lower extremities. For infants and children, the total amount injected is one-third to two-thirds that for adults. At the completion of the injection, the exposures are made. For lymphangiograms of the lower extremities, AP projections are taken of the legs, thighs, pelvis, abdomen, and chest. For the upper extremities, AP projections include the forearm, arm, shoulder, and chest.

Section III. THE CENTRAL NERVOUS SYSTEM

3-28. INTRODUCTION

The central nervous system consists of the brain and spinal cord. Because there is insufficient difference in densities of the tissues to allow for satisfactory visualization of the various structures of the central nervous system by conventional radiography, specialized radiographic techniques must be used. The attending physician and the radiologist determine the specific method.

3-29. VENTRICULOGRAPHY

Ventriculography is a diagnostic procedure whereby several radiographs are made of the head in various positions following the removal of all or a certain portion of the cerebrospinal fluid and its replacement with a suitable contrast medium. The ventricles are reached with hollow needles through small trephine openings in the skull.

a. Patient Preparation and Scheduling. Except in emergency, the examination is scheduled. Usually, the patient is sedated the evening before and again on the morning of the examination according to the directions of the responsible clinician. Breakfast is withheld on the morning of the examination.

b. Preliminary Procedure.

(1) The patient is taken to the designated operating room, where he is placed in a sitting position with his chin resting on a suitable support. After aseptic preparation and administration of local anesthetic, two small openings are made with a trephine in the skull, 6.5 cm to 7 cm above the occipital protuberance, and 3 cm lateral to the midline. A needle or cannula is introduced into each of the trephine openings, and then advanced into the ventricular cavities. A mercury manometer is used to
measure the intracranial pressure. Approximately 1 cc of indigo carmine is injected into one of the ventricles and allowed to diffuse for a period of several minutes. The cerebrospinal fluid is allowed to drain slowly from the two ventricles and is carefully collected in a graduate for measuring. To promote drainage, the patient's head is positioned so that the exposed portions of the cannulas are dependent. The patient's head is then positioned so that one cannula is lower than the other to permit the cerebrospinal fluid to drain from the lower cannula while air (the contrast medium) flows into the ventricular system through the upper cannula. This procedure is continued until approximately 25 to 30 cc of the cerebrospinal fluid has been withdrawn and replaced with air.

(2) This phase of the examination may vary. For example, drainage of the cerebrospinal fluid may be accomplished by means of a syringe (Luer type) attached to the cannula with flexible tubing. In this method, small quantities of cerebrospinal fluid are withdrawn (5 to 10 cc at a time) and replaced with carbon dioxide (CO₂). This procedure is continued until gas instead of fluid is returned upon aspiration.

(3) When the injection of the contrast medium has been completed, the cannulas are removed, the scalp is sutured, and a dressing is applied. Immediately following this, the patient is brought to the x-ray room for the ventriculographic examination.

c. Radiographic Procedure.

(1) Basic routine. Ordinarily, AP, PA, and right and left lateral projections of the skull are first made with the patient in a horizontal position. Then a similar set is made with the patient in an upright (sitting) position. The exposure factors are usually the same as those used for routine skull examinations.

(2) Central ray-part relationships. For the sagittal (axial) projections (that is, AP and PA), the vertically or horizontally projected CR is directed along the IOML (infraorbitalmeatal line) and in line with the midsagittal plane of the skull. The laterals are made similarly to routine laterals of the skull.

(3) Additional positions and projections. Additional projections may be taken in various positions with various CR relationships to include any one or several as shown in Table 3-2.
<table>
<thead>
<tr>
<th>View</th>
<th>Patient-part position</th>
<th>Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right and/or Left lateral.</td>
<td>Supine decubitus, brow-up; film-plane vertical.</td>
<td>Horizontal.</td>
</tr>
<tr>
<td>Right and/or Left lateral.</td>
<td>Prone decubitus, brow-down; film-plane vertical.</td>
<td>Horizontal.</td>
</tr>
<tr>
<td>Right and/or Left lateral.</td>
<td>Supine decubitus, head inclined backward and downward (with hyperextension of neck) and extending over and below the end of the table, so that Reid's Base Line (RBL) assumes a horizontal relationship. Film-plane vertical.</td>
<td>Horizontal.</td>
</tr>
<tr>
<td>Right and/or Left lateral.</td>
<td>Prone decubitus, head inclined forward and downward (with flexion of the neck) extending over and below the end of the table with the coronal plane of the head approximately 5º to 10º from the vertical relationship. Film-plane vertical.</td>
<td>Horizontal.</td>
</tr>
<tr>
<td>Right and/or Left lateral.</td>
<td>Horizontal (prone or supine), head extending beyond end of table (or litter) and held in place beneath horizontal film-plane by a suitable supportive device.</td>
<td>Vertical CR projected from below.</td>
</tr>
</tbody>
</table>

Table 3-2. Additional projections of ventricles (continued).
<table>
<thead>
<tr>
<th>View</th>
<th>Patient-part position</th>
<th>Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anterior-Posterior.</td>
<td>Right and left lateral decubitus; film-plane vertical.</td>
<td>Horizontal.</td>
</tr>
<tr>
<td>Anterior-Posterior.</td>
<td>Prone decubitus, head extending beyond end of table (or litter) and held in place beneath horizontal film by a suitable supportive device.</td>
<td>Vertical CR projected from below.</td>
</tr>
<tr>
<td>Posterior-Anterior.</td>
<td>Right and left lateral decubitus; film-plane vertical.</td>
<td>Horizontal.</td>
</tr>
<tr>
<td>Posterior-Anterior.</td>
<td>Supine decubitus, head extending beyond end of table (or litter) and held in place beneath horizontal film by a suitable supportive device.</td>
<td>Vertical CR projected from below.</td>
</tr>
<tr>
<td>Occipital-Frontal.</td>
<td>Upright (sitting position), facing Vertical film, head inclined forward, neck and body flexed coronal plane of head approximately $45^\circ$ to $50^\circ$ from the vertical relationship (Waggoner-Clark position).</td>
<td>Horizontal CR directed midsagittally approximately $1^\circ$ above level of external auditory meati.</td>
</tr>
</tbody>
</table>

Table 3-2. Additional projections of ventricles (concluded).

(4) **Stereoradiography.** Stereoscopic exposures are frequently made. These are exposed in pairs and usually include both laterals and one or both sagittal projections. It is extremely important that the specialist know in advance the exact positions in which the stereo pairs are to be made. Normally, the tube is shifted longitudinally for the sagittal projections and transversely for the lateral projections.

(5) **Grid technique.** When possible, grid technique should be used for all ventriculographic exposures. If a special head unit is not available, it may be necessary to use grid-front cassettes or a wafer-type grid for the right angle projections. Customarily, two right-angle projections are made for each head position used. Ideally, each pair should be made without changing the position of the patient's head since even a slight deviation in position may change the distribution of the cerebrospinal fluid and the contrast medium within the ventricular system, resulting in dissimilarity of object-representation between the sagittal and lateral projections.
(6) **Precautions.** To obtain the best results, the patient must be properly immobilized and must suspend respiration during exposure of the films. The positioning of the head and the centering of the CR must be done with extreme care and exactness. The mAs selected should be such as to allow use of the shortest possible exposure time. Arrangements must be made for the films to be processed immediately and presented to the radiologist for reading before the patient leaves the x-ray department. The entire procedure must be under aseptic conditions.

d. **Variations of Technique.**

(1) **Ventriculo-encephalography.** This technique is used to demonstrate structures in the posterior fossa that cannot be shown clearly by regular ventriculography. A certain amount of cerebrospinal fluid is withdrawn by spinal puncture (spinal tap) and replaced with air or other suitable gas. As soon as the required amount of fluid has been drained off and replaced with air, the various exposures are made at the direction of the examiner.

(2) **Radiopaque contrast ventriculography.** In this method, a radiopaque contrast medium is introduced into selected portions of the ventricular system of the brain and a series of radiographs made utilizing several positions. If indicated, this procedure is usually performed immediately following gas ventriculography.

(a) The patient is seated in the erect position in front of a vertical fluoroscopic table unit for lateral viewing of the skull by the examiner.

(b) The patient's neck and body are flexed so that the foramen magnum is at higher level than the vertex of the skull. The head is then rotated so that one of the trephine openings is uppermost.

(c) Using a syringe with needle attached, the examiner introduces approximately 2 cc of contrast medium (for example, Pantopaque) into the lateral ventricle via the upper trephine opening.

(d) The examiner signals the specialist to engage the fluoroscopic unit and then proceeds to maneuver the contrast agent into the third ventricle by postural manipulation of the patient's head, neck, and body.

(e) When the contrast agent is in the third ventricle, the examiner will signal the specialist to prepare for the required radiography.

(f) Usually, the prescribed sagittal and lateral projections are made without changing the position of the patient's head or body. Additional projections may be made in various other positions according to the directions of the examiner.
(g) Arrangements should be made for the films to be developed and presented to the radiologist for reading immediately upon completion of the exposures.

(h) If additional films are not required, the examiner will posturally manipulate the patient (with the help of the specialist or an assistant) in such a way as to cause the contrast medium to collect in the dural sac for subsequent removal by spinal puncture.

3-30. MYELOGRAPHY

a. General.

(1) Myelography is a procedure for the investigation of the spinal cord and subarachnoid spaces following the introduction of contrast medium into the spinal canal.

(2) Pantopaque (ethyl iodophenylundecylenate), an oily iodinated organic compound, is the preferred contrast medium; however, in some localities or in special situations, substances in the sterile aqueous category (for example, Hypaque) may be used. The following concerns techniques in which Pantopaque is used. When air or oxygen is used for the contrast medium, the procedure is termed pneumomyelography.

(3) Since the majority of myelographic studies are concerned with the lumbar region of the spine, emphasis is placed on the techniques used in studies dealing with that region (commonly termed lumbar myelography). Not infrequently, however, it is the thoracic or the cervical region that is the site of prime diagnostic interest. For pertinent technical details relating to thoracic myelography and cervical myelography, see g and h below; otherwise, the essential technical details are the same as those described for lumbar myelography.

b. Patient Preparation and Scheduling. Except in emergencies, myelographic examinations are scheduled according to the established clinical procedure. Sedation is administered by the responsible clinician approximately one hour prior to the procedure.

c. Preliminary Procedure.

(1) Upon arriving at the x-ray department, the patient is properly gowned for the examination and the pertinent aspects of the procedure are explained to him.

(2) The patient is placed on the horizontally adjusted radiographic-fluoroscopic tilt-table unit, either prone or on his side depending upon the preference of the examiner. If preliminary radiography is not required, the positioning procedure is as follows:
(a) Patient prone (figure 3-17). The patient is adjusted in the prone position with the midline of the body aligned to the center of the table; the head may be turned to either side. The patient is then instructed to grasp the edge of the tabletop with his hands at the level of his shoulders or to grasp the shoulder brace with one hand. To straighten the lumbar curve to the required degree, a bolster (made by rolling a small pillow or other suitable object into the desired shape) is placed under the lower abdomen. The patient's feet are placed firmly against the footrest.

(b) Patient lying on his side (figure 3-18). The patient lies on his side, with his back toward the examiner. A suitable bolster is placed under the thoracic region to straighten the spinal column in relation to the midsagittal plane and make it parallel with the tabletop. The patient's neck, body, and lower extremities are then brought into flexion so that the knees are drawn toward the chin and arms and shoulders are drawn forward.

(3) A sterile-packed myelographic layout is set up near the examiner.

(4) The injection site is made aseptic and local anesthesia is administered.

(5) The radiographic and fluoroscopic factors are determined according to the size of the patient. If necessary, test exposures are made and developed for immediate inspection. The specialist should prepare the radiographic room for the examination so that every item needed will be in place. A sufficient number of films of the required sizes should be available both for spot-filming and for other radiography. Appropriate identification markers should be made before any radiography is done.

Figure 3-17. Head-end of tilt-table unit raised during myelographic examination.
d. **Introduction of Contrast Medium, Fluoroscopy, and Radiography.**

(1) Sterile and aseptic precautions are observed throughout the entire procedure.

(2) The examiner inserts an 18- or 20-gauge lumbar-puncture (short-beveled) needle into the subarachnoid space exactly in the midline and in the region of the vertebral interspaces between L3 and L4, L4 and L5, or L5 and S1. The stylet is removed from the needle and approximately 3 to 5 cc of cerebrospinal fluid are withdrawn and collected in a test tube for laboratory analysis. When indicated by the examiner, the Queckenstedt test is performed for the determination of possible block in the vertebral canal. In the absence of an assistant, the examiner may direct the specialist to assist him in this maneuver (carotid artery compression). In this case, the specialist must carry out the examiner's instructions (however simple they may seem) with exacting care. The cerebrospinal fluid pressure is recorded at this stage of the procedure.
(3) The head-end of the table is now raised approximately 10 to 20 degrees from the horizontal (figure 3-18). If the patient is lying on his side, he must be adjusted in the prone position. The injection site is covered with sterile gauze or a towel. The fluoroscopic apparatus and spot-film device are then brought into operative position over the injection site. Proper precautions must be taken to avoid disturbing the position of the needle. The specialist should be sure that the fluoroscopic apparatus is locked and the locking mechanism is absolutely safe. In some instances, a safety-bar may be used as an additional safeguard. The safety-bar may be contrived of an ordinary piece of wood or metal that is sturdy enough to serve the purpose. It is advisable to have safety-bars made up in several lengths to accommodate patients of varying sizes. If necessary, the safety-bar can be tied, taped, or clamped onto the upright support assembly that maintains the fluoroscopic apparatus and spot-film device.

(4) Fluoroscopy and spot-film radiography are then carried out. In some instances, however, the examiner may forego the latter aspect of the examination and proceed to inject the contrast medium instead.

(5) A syringe filled with the contrast medium (3 to 4 cc) is attached to the needle. The subsequent steps of the procedure depend upon the amount of contrast medium (with specific reference to Pantopaque) used.

   e. Technique in Which a Relatively Small Amount (2 to 6 cc) of Contrast Medium is Used.

(1) After the introduction of the contrast medium into the subarachnoid space, the syringe is disengaged from the needle, the stylet is replaced, and the injection site is covered with sterile gauze or a towel. The bolster is removed from beneath the abdomen and placed under the patient's lower extremities, as needed.

(2) The fluoroscopic apparatus and spot-film device are brought into working position over the injection site. The apparent shape, location, and behavior of the body of injected contrast medium is studied by the examiner under fluoroscopic control as the table unit is raised or lowered according to his instructions. The position of the patient in relation to the tabletop may be changed at intervals. For example, the patient may be obliqued either to the right or the left, or postured on his side. In handling the patient, great care must be taken to see that the needle does not hit the fluoroscopic apparatus.

(3) Spot-film exposures are made at various intervals and in different positions. The patient should be instructed beforehand that he is to immediately suspend respiration at a given signal from the examiner or the specialist. In addition to the spot-films, PA (figure 3-19) and lateral projections (figure 3-20) may be made without changing the position of the patient. For the lateral projection, a horizontal CR is preferable. Spot obliques and/or stereoscopic exposures are made as indicated by the examiner.
Figure 3-19. Patient positioned on tilt-table unit, head lowered, for pneumomyelography.

Figure 3-20. Equipment used in an interventional radiography suite.
(4) Radiopaque markers may be taped to the patient's body (or to the grid) to indicate anatomical relationships or landmarks. In any case, at least one of the radiographs out of each group (exposed at right angles to each other) should provide sufficient coverage to facilitate positive identification of the pertinent relationships between the position of the lumbar-puncture needle, the contrast medium situated in the spinal canal, and the important anatomical landmarks.

f. Technique in Which a Relatively Large Amount (6 to 21 cc) of Contrast Medium is Used. This is sometimes referred to as "full-column myelography," erect-method myelography," or "total myelography."

(1) Upon completion of the preliminary phases of the procedure, the patient is adjusted in a lateral recumbent position on the tilt-table unit. The spinal-puncture needle is inserted, a cerebrospinal pressure reading is recorded, and cerebrospinal fluid is collected for laboratory analysis.

(2) The head-end of the table is now raised approximately 10 to 20 degrees from the horizontal. The contrast medium is injected into the subarachnoid space in the lumbar region after withdrawal of a similar amount of cerebrospinal fluid. The lumbar-puncture needle is then removed and the patient is adjusted in the same position with his feet placed firmly against the footrest.

(3) After properly alerting the patient, the table is brought into the vertical relationship. Additional fluoroscopy, spot-filming, or radiography is carried out according to the directions of the examiner. The table is then returned to the horizontal relationship and the patient lies in the supine position. Further fluoroscopic and radiographic studies may be carried out, if indicated.

(4) Upon completion of the examination, the spinal-puncture needle is reinserted for subsequent removal of the contrast medium.

g. Thoracic Myelography.

(1) Patient prone. The patient is placed in the prone position on the tilt-table unit with the head fully extended. Some examiners may prefer to elevate the lower back by placing a suitable bolster under the lower abdominal region. The contrast medium and the manner of its introduction are essentially the same as in lumbar myelograph. In some instances, however, the contrast medium may have to be injected. Under fluoroscopic control and by slowly lowering the head-end of the table, the column of radiopaque control medium is made to flow into the subarachnoid space of the thoracic spine. Spot-films are taken in various positions as indicated. Conventional radiographic technique may be used for the sagittal and lateral projections. With the lateral projection, a horizontal CR is preferred.
(2) **Patient supine.** This technique may be used when a relatively large amount of contrast medium is injected. After completion of the injection, the needle is withdrawn and the patient is placed in the supine position on the tilt-table unit. The table is tilted and desired. The flow of the contrast medium is observed fluoroscopically and spot-films are taken in various positions as indicated.

(3) **Removal of contrast medium.** When the examination has been completed, the head-end of the table is raised so that the patient is brought to the vertical (or near-vertical) position, thereby pooling the contrast medium in the lumbar subarachnoid space for subsequent removal.

(4) **Incidental blockage.** In the event of incidental blockage of the spinal canal due to pathologic condition in the thoracolumbar region, it may be necessary for the examiner to inject the medium by means of cisternal puncture. In this case, the tilting procedure is the reverse of that used for the lumbar-puncture method.

h. **Cervical Myelography.** The patient is placed in the prone position on the tilt-table unit, with the head fully extended. The head must be fully extended to prevent the contrast medium from entering the cranial cavity. Contrast medium is introduced into the lumbar subarachnoid space in a manner similar to that in lumbar myelography. By lowering the head-end of the table, the examiner maneuvers the column of contrast medium from the lumbar region toward the cervical subarachnoid space. This is done under fluoroscopic control. Spot-film exposures are made for the sagittal projections. Lateral projections of the cervical region are obtained with the radiographic tube and a horizontal CR. After completion of the examination, the contrast medium is pooled under the lumbar-puncture needle for subsequent removal.

i. **Removal of Contrast Medium from the Subarachnoid Space of the Spine.** Removal of contrast medium is done only under fluoroscopic control. Two methods are described below.

(1) In one method, the patient is placed in the prone position on the tilt-table unit. By appropriate tilting of the table and under fluoroscopic control, the column of contrast medium is pooled under the spinal-puncture needle. An unused sterile syringe is then attached to the needle and the contrast medium is carefully aspirated. In case the needle was withdrawn immediately after the introduction of the contrast medium, a second spinal puncture is performed over the area and the contrast medium is removed as described above. Before the needle is withdrawn, a radiograph, or a fluoroscopic examination should be made to determine if satisfactory removal has been accomplished. If satisfactory removal is confirmed, the needle is withdrawn and the patient is returned to the ward.
In the second method, the procedure is the same as outlined above until the contrast medium is pooled under the needle, but differs thereafter. When the contrast medium has been pooled under the needle, the stylet is removed but, in this case, no syringe is attached. Instead, the patient is instructed to do the Valsalva maneuver in which he takes in a deep breath and carries out forced expiration against a closed glottis. This aids in causing the contrast medium to flow out through the needle. The maneuver is repeated until all (or most) of the contrast medium has been removed. Before the needle is withdrawn, a radiograph, or a fluoroscopic examination should be made to see if satisfactory removal has been accomplished. If satisfactory removal is confirmed, the needle is withdrawn and the patient is returned to the ward.

3-31. DISKOGRAPHY

Diskography is the radiographic investigation of selected intervertebral fibrocartilages (disks) during radiopacification by a contrast medium. Examinations of this type are normally done in the operating room or interventional radiology suite using a C-arm. See figure 3-20.

a. Preparation of Patient Scheduling. The examination is scheduled according to the established clinical procedure. Sedation is usually administered one hour prior to the procedure.

b. Preliminary Procedure (Lumbar Diskography).

(1) When indicated, pre-injection radiographs are made of the area(s) of diagnostic interest.

(2) For lumbar diskography, the patient is usually placed on his side (laterally recumbent) on a tilt-table unit with his body in flexion (as for routine spinal anesthesia). In some instances, the examiner may prefer to have the patient placed in the prone position.

(3) The lumbar area is made aseptic and local anesthetic is administered.

(4) Under sterile precautions, the examiner inserts a No. 19 needle (1 1/2 inches long) in the midline aiming at the center portion of the intervertebral disk to be punctured. A lateral projection is then obtained to check the exact location and alignment of the needle.

(5) When it has been established that the No. 19 needle is properly aligned, a smaller caliber needle (No. 22, 4 inches long) is inserted into the No. 19 needle. The smaller needle is then advanced into the lumbar subarachnoid space. At this point, cerebrospinal fluid may be withdrawn and collected for laboratory examination.
(6) Next, the smaller caliber needle (No. 22) is advanced until its tip enters the nucleus pulposus of the intervertebral disk under consideration. In some cases, a lateral projection is made to check the precise position of the needle. If necessary, additional pairs of needles may be inserted in one or more of the adjacent intervertebral spaces.

c. **Introduction of Contrast Medium and Radiography.**

(1) A syringe (for example, Luer-Lok, 10 cc) filled with approximately 5 cc of the contrast medium consisting of one of the sterile aqueous solutions (for example, Hypaque) and containing from 35 to 50 percent iodine compound is then attached to the smaller caliber needle.

(2) After the specialist has readied the radiographic apparatus and placed a cassette in the Bucky tray, the examiner injects the contrast medium into the intervertebral disk. In the case of a normal disk, approximately 0.5 to 1 cc of the contrast solution may be injected. If abnormal conditions are encountered, more contrast solution may be injected—usually from 2 to 5 cc (or more).

(3) PA and lateral projections (figure 3-21) of the injected disks are obtained as soon as possible following the injection. These radiographs are made without changing the position of the patient. This technique usually requires a portable Potter-Bucky diaphragm or grid-front cassettes for the horizontal CR.

(4) The examiner now removes the needles and an appropriate dressing is applied to the puncture site. The patient is then placed in the supine position and the spinal column is flattened by flexion of the knees. AP projections (figure 3-22) are obtained. Stereoscopic exposures are made according to the instructions of the examiner.

(5) The table is then brought to the vertebral relationship, and lateral projections are obtained with the patient in the standing (weight-bearing) position.

(6) All exposed films should be developed and presented to the examiner for inspection before the patient is returned to the ward.

(7) If additional projections (for example, oblique) are required, they must be exposed as quickly as possible; otherwise, absorption of contrast medium may diminish radiopacification to such a degree that satisfactory radiographs cannot be obtained.
Figure 3-21. Diskography—lateral view. Needle localization with contrast injection.

Figure 3-22. Diskogram sagittal view.
d. **Cervical Diskography.** For cervical diskography, the technical procedure closely follows that described for lumbar diskography with the following exceptions:

1. The patient is placed in the supine position on the tilt-table unit. Pre-injection radiography is carried out according to the demands of the situation.

2. The antero-lateral aspect of the patient's neck on the side of interest (or the most suitable site of access) is made aseptic and local anesthetic is administered.

3. The examiner inserts the injection needle(s) into the tissues lying in the antero-lateral aspect of the cervical region and directs it toward the intervertebral disk(s) under consideration. A single 21-gauge, 9-cm spinal needle, or a pair of needles, consisting of a No. 20 (2 inches long) through which a smaller caliber (No. 25, 2 1/2 inches long) needle is passed may be used.

4. Before the injection needle(s) is/are advanced into the nucleus pulposes of the intervertebral disk, AP and lateral projections are exposed without changing the position of the patient. These films are made to check the exact position and alignment of the needle(s).

5. The patient is cautioned not to move; cough, or talk while the needle is in place. A syringe filled with the contrast medium (sterile aqueous solutions containing 50 percent iodine compound) is attached to the needle and approximately 0.2 to 0.5 cc of the contrast medium is injected into each of the intervertebral disks to be studied.

6. AP and lateral projections (also oblique projections, if indicated) of the cervical region are obtained without changing the position of the patient. The films are processed for immediate inspection.

7. If injection of additional contrast solution is not required, the injection needles are removed and further radiography is carried out according to the instructions of the examiner. Stereoscopic exposures are made as indicated.

8. All exposed films should be developed and presented to the examiner for inspection before the patient is returned to the ward.

Continue with Exercises

Return to Table of Contents
EXERCISES, LESSON 3

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 sharpest angiographic needle is:
   a. Plastic sheath type.
   b. Seldinger style.
   c. Venipuncture type.
   d. Arterial catheter.

2. One very important factor needed in angiographic equipment is:
   a. Low mA capacity.
   b. High tube heat capacity.
   c. Slow-speed timing unit.
   d. Tri-plane setup.

3. For angiography, the CR is usually directed:
   a. Vertically only.
   b. Horizontally only.
   c. Both vertically and horizontally.
   d. 20º caudad.
4. Angiographic examination usually requires about ________ kVp than that normally used for a given part.
   a. 10 percent less.
   b. 5 percent less.
   c. 5 percent more.
   d. 10 percent more.

5. What is the usual position of the arm for the start of arteriography of the upper extremity?
   a. Flexed with hand on abdomen.
   b. Adducted and pronated.
   c. Adducted and supinated.
   d. Abducted and supinated.

6. Where is the site of injection for the contrast medium in arteriography of the upper extremity?
   a. Over the cisterna magna.
   b. Over the brachial artery.
   c. Over the carotid artery.
   d. Over the femoral artery in the groin.

7. In venography of the upper extremity, what position does the patient assume initially?
   a. Supine.
   b. Prone.
   c. Sitting.
   d. Lateral recumbent.
8. Valsalva's maneuver and Muller's maneuver are actions that are performed by the:
   a. X-ray specialist.
   b. Radiologist.
   c. Injector.
   d. Patient.

9. In arteriography of the lower extremity, what technique is used to equalize exposure between thicker and thinner ends of the extremity?
   a. Reduce SID.
   b. Flex lower leg.
   c. Increase kVp.
   d. Place cathode end of tube nearest thigh.

10. In an upright venographic examination of the lower extremity, what supportive device should be used for the safety of the patient?
    a. Immobilization band.
    b. Sandbags.
    c. Shoulder rest.
    d. Head clamps.

11. Which of these areas would be a possible site for the injection of medium in a venographic study of the lower extremity?
    a. Popliteal.
    b. Intercondylar.
    c. Suprastellar.
    d. Retromalleolar.
12. In angiocardiography, what pair of views is usually performed with the biplane rapid film unit?
   a. Right and left laterals.
   b. AP and PA.
   c. AP and lateral.
   d. PA and PALO.

13. In the retrograde method of aortography, the patient is placed in what position?
   a. Supine.
   b. Fowler.
   c. Trendelenburg.
   d. Erect.

14. For vertebral arteriography, in what position is the patient placed?
   a. Supine, with head hyperextended.
   b. 20º Trendelenburg.
   c. Ventral decubitus.
   d. 45º Fowler.

15. In vertebral arteriography, what view is the basic projection?
   a. AP.
   b. Submentovertical.
   c. PA.
   d. Oblique.
16. Lymphangiographic study of the lower extremities will include radiographs of the:
   a. Abdomen and chest.
   b. Skull and sinuses.
   c. Cervical and thoracic spines.
   d. Auditory ossicles and hyoid bone.

17. In the routine ventriculographic procedure, what contrast medium is used?
   a. Mercury.
   b. Pantopaque.
   c. Visciodol.
   d. Carbon dioxide.

18. In the Waggoner-Clark position for ventriculography, the coronal plane of the head is angled ____________ degrees from the vertical.
   a. 85 to 90.
   b. 70 to 75.
   c. 45 to 50.
   d. 10 to 15.

19. What general technical consideration would be in effect for all exposures made during ventriculography?
   a. Supervoltage technique.
   b. Horizontal CR.
   c. Short exposure time.
   d. SID 6 to 7 feet.
20. What is the purpose of the Queckenstedt test performed in myelography?
   a. Determine spinal fluid pressure.
   b. Determine intracranial pressure.
   c. Determine if a block is present in vertebral canal.
   d. Rule out osteomyelitis.

21. When the contrast medium is being aspirated in myelography, what action by the patient aids the flow?
   a. Forcing head against knees.
   b. Rocking on his abdomen.
   c. Forcing breath against closed glottis.
   d. Forcing head back against hands.

Check Your Answers on Next Page
SOLUTIONS TO EXERCISES, LESSON 3

1. c (para 3-8a(1))
2. b (para 3-9c)
3. c (para 3-17a)
4. d (para 3-18a)
5. d (para 3-19a(2)(a))
6. d (paras 3-19a(2)(c), (3)(b))
7. a (para 3-19a(2)(a))
8. d (para 3-19b(4)(b))
9. d (para 3-20a(2)(a))
10. a (para 3-20b(2)(c))
11. d (para 3-20b(3)(a))
12. c (para 3-21d)
13. a (para 3-23b(1)(a))
14. a (para 3-24d)
15. b (para 3-24d)
16. a (para 3-27b)
17. d (paras 3-29b(1), (2))
18. c (table 3-2)
19. c (para 3-29c(6))
20. c (para 3-30d(2))
21. c (para 3-30i(2))