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In this final volume of the Z4R051 course, you will learn about the special imaging areas of the diagnostic imaging career field. The volume begins with a look at the various types of radiographic contrast media in use and potential adverse patient reactions to contrast media administration. The first unit continues to outline how to perform venipuncture and in-turn monitor patients under your care.

Unit two discusses contrast studies of the digestive system while reviewing the anatomy and physiology of the alimentary tract.

Unit three is devoted to the genitourinary tract where you will learn about the contrast studies of the urinary tract and radiographic considerations of the female reproductive system.

In unit four, the lessons will discuss the central nervous system and endocrine system.

In unit five, the lessons will discuss the cardiovascular system and muscular system.

Unit six closes up the volume and the course with applicable information about scanography and arthrography.

A glossary is included for your use.

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NOTE:

In this volume, the subject matter is divided into self-contained units. A unit menu begins each unit, identifying the lesson headings and numbers. After reading the unit menu page and unit introduction, study the section, answer the self-test questions, and compare your answers with those given at the end of the unit. Then complete the unit review exercises.

Page

Unit 1. Contrast Media and Reactions, Venipuncture, and Patient Monitoring

FROM THE EARLIEST DAYS OF RADIOGRAPHY, scientists have experimented with methods of improving radiographic visualization of every part of the body. Unfortunately, routine radiography does not lend itself well to detailed imaging of soft tissue structures because of their similar photon absorption properties. For this reason, the pioneers in the field began experimenting with substances that could be introduced into the body to enhance the contrast of various structures and organs, and thereby improve their radiographic visualization; thus, contrast media was invented.

Over time, the quality of contrast media has improved greatly and its use has subsequently expanded. The technologist's role in radiographic contrast procedures has also expanded. Today technologists are called upon to evaluate the patient, select the appropriate contrast media and dosages, and in many instances, administer contrast media under the supervision of a physician.

For this reason, this first unit of the special procedures volume introduces contrast media. In this unit, we will discuss the properties of the various types of contrast media, types and treatment of contrast media reactions, venipuncture; and how to monitor patients and their vital signs.

1–1. Contrast Media

The earliest types of contrast media used in radiography were highly toxic. Because of this, their use was restricted to imaging cadavers. In the early 1900s substances were found that could be safely introduced into live patients, and the field of special procedures was born. Through much experimentation, it was discovered that substances could be used to enhance the radiographic contrast of nearly every major organ and system in the body. In this section, we look at the general properties of contrast media and discuss the various types of contrast media used today.

801. Classification of contrast media principles

All contrast media must possess certain properties that make them useful as contrast agents. Based on these properties, contrast agents are divided into categories.

General properties

All contrast agents must possess two basic properties to be useful for radiographic imaging. First, they must be nontoxic. Contrast media agents would be of no benefit if we were to introduce a substance into the body that enabled us to diagnose a disease, but killed the patient in the process. Second, the agent must alter photon absorption. This is the key to changing a structure's contrast enough to make it visible on a radiograph. By altering photon absorption, we mean the contrast agent either increases or decreases the absorption of X-ray photons by the body part. This change in photon absorption will allow either more or less radiation to reach the image receptor, rendering the structure clearly visible on the radiograph.

Categories of contrast media

Contrast agents are categorized according to the manner in which they alter photon absorption. On this basis, they are either positive or negative contrast agents.

Negative contrast agents

Contrast media that *decrease* photon absorption are called *negative contrast agents*. Common examples of negative contrast agents are air, oxygen, and carbon dioxide. For example, carbon dioxide is produced in the stomach when you give a patient sodium bicarbonate crystals during an upper gastrointestinal (GI) series. The presence of this gas reduces the density of the stomach, and therefore, reduces the photon absorption. This, in turn, causes the stomach to appear darker on the radiograph. Another example of the use of a negative contrast medium is introducing air into the colon during an air-contrast barium enema (BE). Because the risk of gas embolization is high, negative contrast agents are not used within the vascular system.

Positive contrast agents

Contrast media agents that *increase* photon absorption are called *positive contrast agents*. These agents alter photon absorption by increasing the molecular density of the structure(s) into which they are introduced, thereby increasing photon absorption. This, in turn, causes the structure to appear *lighter* on the finished radiograph.

There are many different types of positive contrast agents. Positive contrast agents are made from a variety of substances with high atomic weights, such as iodine, bromine, and barium. They also come in a variety of forms suitable for different routes of administration. Positive contrast agents may take the form of powders, liquids, pastes, or tablets.

802. Types of contrast media principles

The many different types of positive contrast media are classified according to their physical properties and/or their route of administration. The four commonly accepted groups are: oral/rectal, water-soluble injectable, water-soluble non-injectable, and oily/viscous. Within each of these groups there are further distinctions and subdivisions. As we discuss them, examples of manufacturer’s name brands are provided to help you assimilate your experience with this text. This is not meant to be an endorsement of these specific products. The products used at your facility are determined by your radiologists and established supply procedures.

Oral/rectal

Oral/rectal contrast media are used to enhance the alimentary tract and, as the name implies, can be introduced by either orifice. These contrast media agents are used whenever detailed anatomic information of the alimentary tract is required such as during an upper GI, BE, or abdominal computed tomography (CT) exam. This group is subdivided according to the chemical composition of the contrast agents.

Barium sulfate

By far the most common oral/rectal contrast agents in use are those made from barium sulfate. Barium sulfate is an inert inorganic salt of the element barium. Barium sulfate preparations are available under many different brand names. Some examples are Barosperse, Barotrast, Oratrast, E-Z-Paque, and Polibar. These agents are used for visualization of the pharynx, esophagus, stomach, small bowel, and colon. Barium sulfate preparations may come in a powder form that must be mixed with a specific amount of water (to obtain the desired amount of thickness, *viscosity*) or they may come premixed as creams, pastes, or liquids.

Advantages of barium sulfate preparations are: (1) they are relatively inexpensive; and (2) when in powder form, they are flexible enough to be made into thin or thick preparations simply by varying the amount of added water. When made into a thin mixture, the motility of the alimentary tract is evaluated whereas a thick mixture is used to adhere to the mucosa during studies of the esophagus.

The primary disadvantage of barium sulfate preparations is they are *not* water soluble. Although they may be mixed with water, they do *not* dissolve. For this reason, they should *not* be used when bowel perforation is suspected. If barium leaves the alimentary tract through a perforation; it adheres to the external surface of the intestines and other peritoneal structures. Also, because barium is hygroscopic in nature (the tendency to attract water), it continually tries to absorb water and can solidify. Patients who are administered barium preparations should be instructed to drink large amounts of water for one or two days following their examination to prevent the barium from dehydrating and blocking the intestines. Barium has no flavor except to have a chalky taste that some patients find difficult to swallow. Patients tend to find barium easier to swallow when administered cold and with a drinking straw. Since barium sulfate is an inert compound, allergic reactions typically are not a concern and side effects are very minimal. If flavoring additives are mixed with barium sulfate, patients should be screened for possible allergies to the additive.

Water-soluble

In instances where barium sulfate is contraindicated, a water-soluble oral contrast is used. These agents are made from iodine compounds like the injectable media, but have been modified to make them suitable for ingestion. Oral Hypaque, Gastrografin, and Gastroview are three common examples. These agents usually come in liquid form that may be used straight or diluted further with water depending on the type of exam and the preference of the radiologist. Because these agents are water-soluble, if they exit the alimentary tract through a perforation, they simply are absorbed by the body.

One *contraindication* for the water-soluble oral contrast agents is when a tracheoesophageal fistula is suspected. A fistula is an abnormal tube-like passage from one normal cavity to another. When such a passage occurs between the trachea and esophagus, items swallowed by the patient can pass into the bronchial tree. Water-soluble contrast agents are extreme irritants to the bronchial passages and can cause significant complications for the patient to include pulmonary edema and pneumonitis. Therefore, in instances where a tracheoesophageal fistula or swallowing difficulties are suspected, it is better to use the barium sulfate preparations.

Many water-soluble oral contrast agents, like the water-soluble injectable agents, have a characteristic known as high *osmolality*. Osmolality refers to a substance's tendency to disassociate into charged particles when dissolved in a liquid. High osmolar contrast material such as Gastrografin or Gastroview should *never* be administered to children without a radiologist's supervision. Intravenous (IV) fluid support is required in infants because this type of contrast medium has a dehydrating effect on the intestines.

Oral cholecystopaques

We have grouped oral cholecystopaques into the oral/rectal category because of their route of administration. However, the similarities with other oral contrast media types end here. Cholecystopaques are contrast media used to enhance visualization of the gallbladder *and* biliary tree ("cholecyst" is Greek for "gall bladder"). Some examples of oral cholecystopaques are Bilopaque, Oragrafin, and Telepaque. They are supplied in tablet, capsule, or powder form (to be mixed with water). Once ingested, they are carried from the small intestine to the liver through the portal venous system. In the liver they are secreted with the bile into the biliary ductal system, where they concentrate in the gall bladder.

Cholecystopaques also come in a less commonly used injectable form. An example of an injectable cholecystopaque used for IV cholecystography or IV cholangiography is Conray or Hypaque 76.

Operative, T-tube, and transhepatic cholangiograms are usually performed using a water-soluble injectable medium, such as Conray or Renografin.

Water-soluble injectable

Water-soluble injectable contrast agents have a variety of uses, but are most commonly used to enhance visualization of the cardiovascular and urogenital systems. When used for these purposes, they are generally administered intravenously (except when performing arteriography). Contrast media administered intravenously can be delivered slowly (high-volume IV drip) or at a fast pace (bolus). Automatic pressure injectors are typically used in CT and interventional radiography to inject IV contrast at a higher rate of speed up to 5 to 6 cubic centimeters (cc) per second.

Water-soluble iodine contrast media agents all share one common characteristic; they are carbon-based organic compounds. So what exactly does this mean? It means this type of contrast media is comprised of molecules that not only contain iodine but also combinations of other atoms. Certain characteristics of strength and chemical make-up directly affect a product's ability to perform in the clinical setting. The characteristics are iodine concentration, osmolality, viscosity, and toxicity.

Iodine concentration

The concentration of iodine in the water-soluble contrast media determines the amount the medium will attenuate or absorb the useful beam. Higher concentrations of iodine in the contrast media will create a higher degree of positive radiographic contrast. When deciding what concentration level to use, you must consider what amount of media will be diluted by bodily fluids. For example, when imaging the aorta, a higher iodine concentration is needed due to the large volume of blood in the part being imaged. If the part being imaged is of veins and smaller arteries, then a lower concentration is typically all that is needed. One thing to keep in mind though, higher iodine concentrations increase the media's viscosity, osmolality, and toxicity.

Osmolality

As stated previously, osmolality refers to a substance's tendency to disassociate into charged particles when dissolved in a liquid. Human blood has an osmolality rate of approximately 300 milliosmoles per kilogram (kg); however, water-soluble contrast media has an osmolality range from 300 to 1000 milliosmoles per kg. Injecting human blood with an agent of higher osmolality than blood causes problems which we will discuss in more detail later in this unit. In general though, using a lower osmolality definitely reduces the risk for adverse reactions. Some molecules of certain contrast media types will dissociate into two charged particles when combined with another liquid (like human blood). Molecules that dissociate in this manner are termed *ionic*.

Ionic

Ionic contrast agents are the traditional type of injectable media. Developed in the 1930s, they were the only form of injectable media available until the 1980s. The *ionic* agents are composed of salts of organic iodine compounds. As salts, they consist of an *anion* (negatively charged particle) and a *cation* (positively charged particle) which *disassociate* when dissolved in water; hence, their name—"ionic" contrast agents.

Another characteristic of the ionic contrast agents is their relatively high osmolality. Osmolality controls a substance's ability to pass through a semipermeable membrane. Specifically, we are concerned with its ability to pass through the *blood-brain barrier*. The blood-brain barrier is the anatomic/physiologic aspect of the brain that separates the parenchyma (organ tissue) of the central nervous system from the blood. Its purpose is to prevent certain damaging substances from reaching the brain tissue. The high osmolality of ionic contrast agents is thought to be the cause of many of the serious allergic reactions resulting from IV contrast medium administration.

Ionic compounds use either sodium or meglumine as the cation and a form of benzoic acid that has been iodinated as the anion. Each salt has slightly different characteristics and the potential to affect the patient differently. Examples of ionic injectable media are Conray, Renografin, and Hypaque. The specific iodine content of the compound is expressed in milligrams (mg) per milliliter (ml). For example, a vial of Conray 60 percent has 282 mg of iodine per ml, or *28 percent iodine content*. Renografin 76 percent has 370 mg/ml, or *37 percent iodine content*.

You may be asking yourself, "What does the 60 stand for in Conray 60?" It stands for the weight-by-volume concentration of the iodine compound. In other words, in a vial of Conray 60, approximately 60 percent of the weight of the liquid in the vial is the iothalamate meglumine molecule. The other 40 percent of the weight is from water and other agents. However, because only a portion of the iothalamate meglumine compound is iodine, only about 28 percent of the solution is actually iodine. On the contrary, to ionic contrast media agents are *nonionic* agents.

Nonionic

Nonionic contrast agents were developed in the 1980s because of the high osmolality of the ionic agents and their link to adverse contrast reactions. The basic structure of nonionic agents is very similar to their ionic counterparts. However, nonionic agents have been chemically designed in such a way to *prevent ionization* (separating into cations and anions) when mixed with water. In other words, nonionic media molecules stay together when combined with another liquid. Since osmolality is determined by the number of charged particles in the solution, nonionic contrast agents have a much lower osmolality than ionic agents.

Thus, the primary advantage of nonionic agents is a far lower incidence of adverse contrast media reactions. Patients also experience less of a burning sensation from the nonionic agents, which can be a significant factor in procedures that require the patient to remain motionless during the injection. Rather than classifying these agents by weight per volume of the iodine compound like the majority of the ionic agents, they are generally listed by the mg/ml concentration of the iodine itself. For instance, Omnipaque 300 contains 300 mg of iodine per ml of solution, or 30 percent iodine.

Viscosity

Viscosity refers to how much resistance is present to the flow of fluid, in this case, contrast media. As stated earlier, higher concentrations of iodine typically are more viscous. Viscosity must be considered when choosing the IV catheter size, the flow rate, and injection time. In addition, it is a standard of practice to warm contrast media to body temperature prior to injection to reduce its viscosity.

Toxicity

Contrast media toxicity as it relates to body tissues and organs is determined by the media's chemical configuration, concentration of iodine, injection rate, osmolality, and amount injected. Typically, nonionic contrast media agents have a lower osmolality, which results in a decreased chance of an adverse reaction.

Low-osmolar

When introduced in the 1980s, low-osmolar contrast agents were actually ionic compounds that combine characteristics of ionic and nonionic agents. One of the first multi-purpose low-osmolar contrast agents was Hexabrix. Many low-osmolar contrast agents in use today are now nonionic. Isovue, Omnipaque, and Visipaque are examples of low-osmolar contrast agents. Visipaque is an extra special type of nonionic contrast media agent in that it is isosmolar. *Isosmolar* means the agent's osmolality is equal to that of human blood. Isosmolar agents are less toxic, easier on the patient (by producing less of a heating sensation), and are the contrast media of choice when mild to moderate renal insufficiency is indicated because isosmolar agents have a lower nephrotoxicity. When first introduced to the market, nonionic and low-osmolar agents were very costly however, now they are priced more reasonable making them the mainstay contrast media in most radiography departments. Isosmolar contrast media (Visipaque) is the more expensive agent today therefore is typically only used for patients with a high allergy risk or patients with kidney or cardiac function issues.

Water-soluble noninjectable

Another group of positive contrast agents is the water-soluble noninjectable. This group consists simply of noninjectable contrast media with a manufacturer added antibiotic. The antibiotic makes this type of contrast media unsuitable for intravascular use, but does offer one important advantage; it helps prevent infection when performing retrograde studies of the urinary tract. Retrografin and Cystokon are common examples of water-soluble noninjectable agents.

Oily/viscous

The last group of contrast agents we will discuss is the oily/viscous agents. As the name of this group implies, these agents are generally oil-based and/or very thick (high viscosity). These types of agents are designed for use in areas of the body that require either contrast media that do not absorb readily or extremely thick contrast. Since this group of contrast media is probably the least frequently used, many of the oily/viscous contrast agents are no longer produced. A few examinations still call for oily/viscous contrast media: they are sialography (a contrast study of the salivary glands), hysterosalpingography (a contrast study of the uterus and fallopian tubes), and lymphangiography (a contrast study of the lymphatic vessels and lymph nodes). Ethiodol and Sinografin are two examples of oily/viscous contrast agents still available today.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

801. Classification of contrast media principles

1. What two basic properties *must all* contrast media possess?

2. What are the two main categories of contrast media?

3. List three examples of negative contrast media.

4. Why are negative contrast agents not used within the vascular system?

5. How do positive contrast agents alter photon absorption?

6. Name three substances used to make positive contrast agents.

802. Types of contrast media principles

1. What are the four groups of positive contrast media?

2. What is the primary disadvantage of barium sulfate preparations?

3. List one reason a barium sulfate preparation *should not* be used.

4. Why is an allergic reaction typically not a concern when using barium sulfate?

5. What type of contrast medium should be used if barium is contraindicated?

6. What are cholecystopaques?

7. What type of contrast is used to enhance the cardiovascular and urogenital system?

8. What characteristic determines the amount the medium will attenuate or absorb the useful beam?

9. Why are some water-soluble injectable media agents called “ionic” contrast agents?

10. What is thought to be the cause of many of the serious allergic reactions resulting from IV contrast administration?

11. What does the 60 stand for in Conray 60?

12. What is the primary advantage of nonionic contrast agents?

13. Why is it a standard of practice to warm contrast media to body temperature prior to injection?

14. What are low-osmolar contrast agents?

15. What does it mean if a contrast media agent is isosmolar?

16. Name two examples of oily/viscous agents still available today.

1–2. Contrast Media Reactions

As technologists gain more responsibility in the area of contrast administration, we must heighten our awareness and understanding of the potential adverse reactions to the various types of contrast media. Contrast media reactions are generally rare, and when they do occur, are usually mild. However, the potential always exists for a life threatening reaction, whether it is the first or the fifth time a patient has received contrast. In most instances, the technologist is the only person in the exposure room to monitor the patient after the contrast has been administered. Therefore, you must be alert for the earliest signs of a reaction. Your prompt response may be the only thing standing between life and death for the patient.

803. Principles for the pre-injection evaluation of the patient

You cannot predict which patient is going to have a contrast media reaction. You can better identify which patients may be more susceptible to having an allergic reaction or renal problem caused by the contrast media by asking a few detailed patient history questions and ensuring the appropriate labs have been drawn and processed (when applicable).

Patient medical history

Each radiology department develops its own protocol of questions that must be asked of every patient before IV contrast media is administered. Below are some standard questions most often asked to the patient to evaluate for a potential reaction to contrast media. Routine screening of your patients prior to IV contrast media administration is necessary to effectively reduce the possibility of an adverse reaction and if a reaction occurs, it helps in the emergency management of a reaction.

NOTE: Always follow your department protocol for screening patients prior to injection of IV contrast media.

Ask the following questions:

1. *Have you ever been injected with IV contrast media (X-ray dye) before*? If a patient has received IV contrast media before, ask if there were any adverse reactions. Patients who have had previous allergic reactions to contrast media may need to be premedicated prior to any subsequent contrast media injections. (Remember though, a patient who had contrast media injected and did not experience a negative reaction *can* have a reaction *without* any *prior* issues or specific indicators.)
2. *Do you have kidney problems*? Contrast agents are eliminated from the body by the kidneys. A patient with renal insufficiency may require the radiologist to change the type of contrast media to an isosmolar agent, like Visipaque, and/or reduce the quantity administered.
3. *Are you a diabetic?* Diabetic patients sometimes take medications such as Glucophage, Glucovance, Metaglip, or Avandamet. Each of those four medications contain metformin hydrochloride which when mixed with the contrast media can cause kidney damage or in worse case scenarios, acute kidney failure. Metformin products should be stopped the day the contrast media is given and for 48 hours after the injection of contrast media. In addition, patients are typically instructed to contact their physician prior to resuming their metformin therapy regimen.
4. *Do you have heart disease or have you had heart failure?*
5. *Do you have asthma? Do you have any food or drug allergies?* Patients with asthma and/or certain food or drug allergies may have an increased chance of having a contrast media reaction.

6. *What other medical conditions do you have?*
7. *What medications and doses are you currently taking?*

If a patient answers *yes* to any of the above conditions, *alert* the radiologist *prior* to administering IV contrast media.

Lab results

Many departments require a blood chemistry test on patients of a certain age (typically somewhere between 40 to 50 years of age and older), with certain specific medical conditions (e.g., renal insufficiency or history of renal failure) or other qualifying factors prior to the administration of IV contrast media. There are *three common* blood tests used to measure how well the *kidneys* are functioning. They are serum creatinine, blood urea nitrogen (BUN), and glomerular filtration rate (GFR). The type of lab test used to check renal function before injecting IV contrast is determined by your radiologist therefore make sure to follow your departments specific policies. No matter the test, if the lab result is outside of the normal range, notify the radiologist prior to contrast media administration. The normal adult range for the three types of *renal* function lab tests discussed are as follows:

1. Serum creatinine is 0.6 to 1.5 milligrams per deciliter (mg/dL).
2. BUN is 6 to 20 (mg/dL).
3. GFR is 90 to 120 milliliters per minute (ml/min).

It is typical for your radiologist to set a more strict acceptable range for both types of blood tests. For example, the acceptable range for a BUN test may be 6 to 15 mg/dL and for a serum creatinine, the acceptable range may be 0.6 to 1.3 ml/dL.

Remember this:

- Get a lab test for everyone who meets your departments prequalifying factors.
- Notify the radiologist of any result not within the acceptable range *prior* to injection.

Premedications for patients with a prior contrast reaction

Sometimes a contrast-enhanced study is necessary even though the patient has experienced a prior contrast-induced allergic reaction. In situations like this, the patient’s requesting physician prescribes a prophylaxis treatment (premedication) and then the patient picks up the medications from the local pharmacy. For routine contrast media studies, the *prophylaxis* treatment is a *13-hour* preparation. A prescribed medication (normally methylprednisolone/prednisone) is taken three times by the patient; (1) 13 hours before the expected injection, (2) seven hours before the expected injection, and (3) one hour before the expected injection. Also at one hour before the expected injection, the patient takes a dose of diphenhydramine (Benadryl). When a patient is premedicated, it is important that their exam and injection be performed at their scheduled time in order for the prophylaxis treatment to be most effective.

804. Types and treatment of contrast media reactions principles

Whether you are injecting contrast for an excretory urography exam, angiography exam, or any of the many enhanced CT exams, you must be aware of the normal reactions as well as the adverse reactions associated with a contrast media injection. In this lesson, you will learn some specific symptoms to look for and learn what to do to save your patients life potentially.

Background information

Researchers are still unsure what actually causes a patient to have an allergic reaction to the iodinated contrast media but there is no doubt, there is a risk associated with every injection of contrast media. Approximately 1 in 14,000 contrast media injections results in a severe allergic reaction and though quite rare, 1 in 40,000 contrast media reactions can result in patient death. The bottom line; injections of intravascular contrast media can cause acute adverse reactions in a very short amount of time. You must be aware of the potential symptoms of an adverse reaction and you must not take for granted that every injection will go off without an issue. Your patient's life depends on your knowledge and ability to respond in a crisis.

Most contrast media reactions happen *within* one to three minutes after beginning the contrast injection; however, it is still possible for delayed reactions to take place 30 minutes to hours after the contrast media injection. It is very important that you are comfortable talking to your patient about what to expect from the contrast media injection as well as what could happen without causing your patient any additional anxiety. Your "bedside" manner will likely make or break how well your patient reacts to the normal sensations that coincide with the injection.

Normal reactions

Most patients when injected with iodinated contrast media at a high rate of speed (generally considered 1.6 cubic centimeters [cc] per second and above) will feel one or all of the following "normal" reactions (sensations):

- A metallic taste in the mouth.
- A warming sensation throughout the body for the duration of the injection.
- A more intense warming sensation in the groin area that gives the patient a feeling they need to void.

  NOTE: This is typically a false sensation of needing to void unless the patient's bladder was already full upon beginning the injection.

No matter what the rate of injection, always talk to the patient prior to the injection of iodinated contrast media and inform them of the "normal" sensations. As a result of talking to the patient, it will help to ease your patient's anxiety level, ensure a successful injection, and increase the probability of obtaining a quality diagnostic examination.

In other instances, patients may get nauseated; that may or may not lead to actual vomiting. If a patient gets nauseated, open and give the patient a standard alcohol pad and instruct them to hold it in front of their nose while breathing *in* through the nostrils and *out* through the mouth. Most of the time, this technique will alleviate the patient's nausea sensation. If the patient progresses to the point of vomiting, carefully roll them to their side to avoid causing the patient to aspirate the vomit into the trachea. A good practice is to have an emesis basin in close proximity for use in emergent situations. Once a patient vomits, notify the radiologist to further evaluate the patient for potential symptoms of more adverse reactions. If your injection was being timed to initiate imaging (as in most contrasted CT exams), the timing is now thrown off. For this reason, you attempt to alleviate the nausea sensation first with the alcohol pad technique before rolling the patient on their side.

Psychogenic reactions

Patients seldom check-in to the radiology department feeling their best. Because of this, a patient's anxiety level may already be elevated do to the uncertainty of why they are in your department. Psychogenic reactions are caused by feelings of anxiety; this is quite common for patients undergoing unfamiliar medical examinations or treatments. The overanxious patient may respond to the normal subjective side effects of contrast media administration (the warm feeling or the metallic taste in the mouth) with an autonomic response. The autonomic nervous system controls involuntary body functions such as heart rate, vasoconstriction/dilation, adrenalin production, and so forth.

One common type of psychogenic reaction is *vasovagal syncope*. Vasovagal syncope is sudden fainting due to hypotension induced by the response of the nervous system to abrupt emotional stress, pain, or trauma. It may be accompanied by pallor, sweating, hyperventilation, and bradycardia. To treat a vasovagal episode, you place the patient in the supine position, elevate their feet/legs approximately 20 degrees, and place a pillow under their head raising it a slight degree. Notify the radiologist for further evaluation.

While you may think that these types of responses are all in the patient's mind, they are very real and can be quite severe. When a patient is nervous, most of the time you can detect their increased anxiety ahead of time. At that moment, how you respond to the patient can make or break the success of your examination. Your bedside demeanor should be calm and reassuring while clearly explaining what to expect from the exam and the injection. If you ignore their anxiety, more problems typically arise and cause an undesirable ending to the completion of the exam. Don't let the fact you may be behind in handling your scheduled patients, it's time for your lunch break, or it's the end of your duty day get in the way of taking care of your patient.

Anaphylactic reaction

Anaphylactic shock reactions result when the patient is *allergic* to the contrast medium. As with any other reaction, they can be mild or severe. Anaphylactic shock may cause respiratory or cardiac arrest and, sometimes seizures. Signs and symptoms of anaphylactic reactions include urticaria (hives), which are elevated patches on the skin that are redder or paler than the surrounding skin. Generalized itching also may occur, which may or may not be accompanied by urticaria. Tightness in the chest, sneezing, and wheezing (audible breathing) also may be present. Breathing difficulties or irregularities may be present—such as labored breathing and high or low respiration rates, or breathing may cease altogether. Watery or reddened eyes are also signs of an anaphylactic reaction.

When an anaphylactic shock reaction is suspected or actually happening, you must act quickly to first notify your radiologist and second retrieve your emergency medications for possible administration if the radiologist determines intervention is necessary. If the patient stops breathing or becomes pulseless, call a code (code blue) immediately! Typical drugs used to counteract anaphylactic shock reaction to contrast media are epinephrine, corticosteroid injections (Solu-Cortef or Solu-Medrol), diphenhydramine (Benadryl), and the H-2 inhibitor cimetidine (Tagmet). Your radiologist determines which medications are stocked in your X-ray suites emergency medication kit. Your radiologist (or other qualified physician) is the one who determines which medications are given to the patient and in what dosage. As a reminder, if not promptly treated, anaphylactic shock could be fatal.

Evaluation of reactions

Once IV contrast media is administered, you must pay attention to your patient and under *no circumstances*, ever leave the patient unattended. Subtle actions like the patient sneezing or having an itching sensation on any part of their body are reasons to engage and ask if the patient is feeling ok. If you must leave the patient alone, even for a moment, get another technologist to remain with the patient.

If such symptoms as urticaria, hypotension, hypertension, difficulty in breathing, abnormal pulse, cyanosis, or equal reactions occur, notify the radiologist immediately. If a patient sneezes or randomly scratches himself or herself, it could be a sign of a mild reaction or it could be alerting you to the fact that a more severe reaction may be imminent. Either way, you should talk to the patient and observe him or her closely for additional symptoms. Depending upon the patient's response to your questions, you will determine how urgently you need to notify your radiologist of the symptoms. The following table summarizes the type of reaction, patient symptoms, and possible treatments.

Evaluation of Reactions		
Type of Reaction	**Symptoms of Patient**	**Possible Treatment**
Mild / Normal	Warming sensation, flush feeling, metallic taste in mouth, and possible nausea.	Typically, no treatment is necessary.
Moderate	Erythema (skin redness), urticaria (hives), and bronchospasm (breathing difficulty).	Typically, diphenhydramine (Benadryl) or albuterol is administered if determined necessary by the radiologist/physician.
Intermediate (vasovagal)	Diaphoresis (excessive perspiration), hypotension (decreased blood pressure), and bradycardia (slowed heartbeat).	Typically, place patient supine with legs raise at 20 degree angle. IV fluids and atropine if determined necessary by the radiologist/physician.
Severe (anaphylactic shock)	Tingling, itchy palms/soles of feet, and inflammation of the trachea; progresses to respiratory distress, cardiac arrest, and possibly seizures.	Call a code (code blue), maintain open airway, typically epinephrine and/or other emergent medications are administered by the radiologist or physician.

Emergency equipment, supplies, and medications

Every radiology department using injectable contrast media must have readily available the appropriate equipment, supplies, and medications to treat a severe contrast media reaction. These items are made available through an emergency medication kit and an emergency cart.

Emergency medication kit

The emergency medication kit (fig. 1–1) is a small clear plastic container typically attached to the wall of an X-ray suite that routinely is used to inject IV contrast media. The kit contains some basic emergency medications and supplies needed to administer the medications in an emergency situation. The contents of a typical emergency medication kit include:

- Two 1 milliliter vials of 50 milligram per milliliter injectable diphenhydramine (Benadryl).
- Two epinephrine auto-injectors; one adult and one junior.
- One albuterol sulfate aerosol inhaler.
- Two 1 milliliter syringes.
- Two 18-gauge and two 25-gauge hypodermic safety needles.

Figure 1–1. Emergency medication kit.

Emergency cart

The emergency cart or *crash cart* is a central storage unit on rollers for all emergency supplies and medications that may be needed in the event of a cardiac arrest or severe IV contrast reaction. (fig. 1–2). A crash cart has a defibrillator, portable suction unit, portable oxygen cylinder, adult and child size breathing bag, stethoscope, blood pressure cuff, and a box of latex-free gloves that normally sit on top of or are attached to the cart itself. Within the drawers are other supplies like an emergency medications tray, laryngoscope, and venipuncture supplies.

Your role with the crash cart is to:

1. Know its location and be able to retrieve it on a moment's notice.
2. Be familiar with the pieces of equipment and medications located on and within the cart.
3. Be able to quickly retrieve items from the cart in an emergency situation for the radiologist, physician, or code team.
4. Be able to adjust the settings of the defibrillator, operate the portable suction unit, dispense oxygen, and use the stethoscope and blood pressure cuff to obtain a patient's blood pressure.
5. Be able to perform daily and/or monthly inventory of the entire crash cart.
6. Be able to restock the crash cart per department or medical treatment facility (MTF) policies as needed.

Figure 1–2. Emergency equipment and medication cart (crash cart).

Emergency medications

As a technologist, you should be familiar with some of the more common drugs used to treat emergency reactions to contrast media. Your awareness of each drug's uses and dosages better enables you to assist in the emergency treatment of a reaction. Three of the more common medications used for treating emergency reactions to contrast media are diphenhydramine, epinephrine, and albuterol.

Diphenhydramine (Benadryl)

Diphenhydramine is an antihistaminic agent. Histamine is a substance in the body released by injured cells. It causes the capillaries to dilate and the surrounding tissue to take on excess fluid as a protective measure against further injury and to promote the healing process. Antihistamine is the substance in the body that inhibits the action of histamine to prevent tissue from taking on too much fluid. During some anaphylactic reactions, a histamine imbalance is produced within the body that can manifest itself in many ways, including urticaria, tracheal or pulmonary edema, itching, watery eyes, localized swelling, and so forth.

Histamine *imbalance* reactions are treated *with* diphenhydramine or some other antihistaminic agent. It may be administered intramuscularly or orally. The normal adult dosage is 25 to 50 mg.

Epinephrine

Epinephrine (also known as *adrenaline*) is a *cardiac* stimulant and vasoconstrictor. It is used to increase cardiac output and elevate blood pressure in cases of ventricular fibrillation and asystole (cardiac standstill). It may be administered by IV, tracheobronchial, or intracardiac injection. When given by IV, the normal adult dose is 5 to 10 ml of a 1:10,000 solution that may be repeated every five minutes.

Albuterol

Albuterol is a bronchodilator medication that relaxes the muscles in the airways and increases airflow to the lungs. An albuterol inhaler is used to treat or prevent bronchospasms. Contrast media reactions can induce bronchospasms (difficulty breathing) in patients similar to that of an acute asthma attack.

Technologist responsibilities

The technologist's role in emergency treatment of contrast media reactions, while limited, is extremely vital. Your primary responsibilities when dealing with IV contrast reactions are to observe the patient for any signs of a reaction, evaluate the severity of the reaction, notify the radiologist to the reaction symptoms, monitor the patient's vital signs, and ensure appropriate emergency equipment and supplies are readily available. Unfortunately, there is no clear guidance as to when a radiologist should be notified; however it is best to be over-cautious.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

803. Principles for the pre-injection evaluation of the patient

1. What are the three common types of blood tests performed prior to IV contrast administration?

2. What are the normal adult ranges for the three tests in question 1?

3. What is the length of the prophylaxis treatment for routine contrast media studies?

804. Types and treatment of contrast media reactions principles

1. How long does it take *most* reactions to happen?

2. Name the three “normal” reactions most patients feel when injected at a high rate of speed.

3. What are the results of talking to your patient prior to the injection?

4. What causes psychogenic reactions?

5. Explain a vasovagal syncope episode.

6. Which type of adverse reaction to contrast media is considered an allergic reaction?

7. What is urticaria (hives)?

8. Once IV contrast is administered, what *must* you do?

9. Match the patient symptom in column B with correct type of reaction in column A. Each item may only be used once.

Column A	***Column B***
____ (1) Respiratory distress and cardiac arrest.	a. Mild
____ (2) Urticaria.	b. Moderate
____ (3) Diaphoresis.	c. Intermediate.
____ (4) Metallic taste in mouth.	d. Severe.

10. What items are found in a typical emergency medication kit?

11. What type of drug is diphenhydramine?

12. What are the routes of administration and normal dosage for diphenhydramine?

13. What type of drug is epinephrine?

14. What are the routes of administration and normal adult dosage for epinephrine?

15. When would an albuterol inhaler be used?

16. What are your primary responsibilities when dealing with IV contrast reactions?

1–3. Venipuncture and Monitoring Patients in Radiology

One of the areas technologists are being called upon to perform more frequently is the actual administration of IV contrast media. In today's busy radiology departments, the radiologist's responsibilities are often overwhelming. For this reason, many departments choose to train their technologists in IV contrast media administration. This section is not designed to bring you to a level of proficiency in IV contrast administration, but it will give you a knowledge base to draw from while receiving hands-on training should you be called upon to perform this duty.

805. Perform venipuncture procedures

After you have obtained the patient's medical history, checked the appropriate lab values, gathered all necessary emergency equipment and supplies, and discussed the contrast medium administration with the radiologist, you are ready to perform the actual injection. Venipuncture is the act of using a needle and a catheter to gain percutaneous access to a blood vessel.

Gathering of supplies

The first step in performing venipuncture is to gather the supplies you will need to complete the task. While learning to perform venipuncture, your trainer may have you gather a slightly different set of supplies; however, the following is a list of some of the basic items you will need to start a peripheral IV line (venipuncture):

- One appropriately sized (18, 20, or 22 gauge) IV catheter (or butterfly needle).
- One connector (referred to as a saline lock, hep lock, or catheter hub).
- Two alcohol pads (or providone-iodine swabs).
- Two 2 by 2 inch gauze pads or one 4 by 4 inch gauze pad.
- One adhesive bandage (Tegaderm over-dressing).
- One 10 cc vial of normal saline flush.
- One pair of disposable latex-free gloves.
- One latex-free tourniquet.

Additional items:

- The appropriate contrast agent (e.g., Omnipaque or Visipaque).
- One or more syringes (typically 60 cc) large enough to hold the volume of contrast medium to be injected.
- An emesis basin.
- If not using a Tegaderm, two strips of silk, latex (if no latex allergy), or paper tape 4-5 inches in length.
- One roll of coban.

Figure 1–3 is a visual example of the basic supplies gathered when preparing to start a peripheral IV line.

Figure 1–3. Basic supplies gathered to start a peripheral IV line.

Intravenous catheter construction and function

The IV catheter device consists of a metal cannula (needle), a flexible plastic catheter situated over the metal cannula, and a clear plastic housing to hold onto and catch the blood return when first gaining access to the blood vessel. During the performance of staring an IV (venipuncture), the metal cannula (needle) is used to pierce the patient's skin and wall of the blood vessel. When the tip of the metal cannula is first inserted into the blood vessel, a small amount of blood is returned through the metal cannula to the plastic housing as "blood return". This signifies you have successfully pierced the wall of the blood vessel. Once the tip of the metal cannula is inside the blood vessel, the plastic catheter is advanced (slid) forward into the patient's blood vessel and the metal cannula is withdrawn leaving only the flexible plastic catheter in the blood vessel.

Selecting the appropriate intravenous catheter size

When selecting the appropriate sized IV catheter, the gauge of the IV catheter references the internal bore's diameter of the plastic catheter that is situated over the needle. The *smaller* the number, the *larger* the diameter is of the IV catheter bore. For example, an 18 gauge IV catheter has a larger bore diameter than a 24 gauge IV catheter. For hand injections, typically an 18 or 20 gauge IV catheter is selected to allow for less resistance when pushing the contrast through the IV catheter. When injecting into a child of less than 10 years old, typically a 25 gauge IV catheter is selected. No matter the gauge selected, IV contrast media is a thick substance and is difficult to hand-pushing through an IV line. The main point to remember when hand-pushing IV contrast media, is to push it through the catheter at as constant-a-pace as physically possible. The following table is provided for easier reference to the common IV catheter gauges used in diagnostic imaging.

IV Catheter Gauges	
Gauge	**Catheter Color**
18 gauge	Green
20 gauge	Pink
22 gauge	Blue
25 gauge	Yellow

When using an automatic pressure injector for CT studies, use the following guidance for selecting the appropriate sized IV catheter. For automatic pressure injection rates of:

- 0.5 cc to 2.0 cc per second, a 22 gauge IV catheter is recommended.
- 2.1 cc to 3.5 cc per second, a 20 gauge IV catheter is recommended.
- 3.6 cc to 5.5 cc per second, an 18 gauge IV catheter is recommended.

NOTE: A larger bore IV catheter is always better when pressure injecting IV contrast media.

Other factors to consider when selecting an appropriate IV catheter size is the perceived size of the patients veins, the location of the vein (back of the hand versus the anterior elbow region), and typically the age of the patient (less than 10 years old or greater than 60 years old).

Starting an intravenous line

There are a number of reasons why a peripheral IV line may need to be started on a patient. In diagnostic imaging, IV lines are started most often to inject a contrast media agent for an intravenous urogram (IVU), enhanced CT examination, radioactive dosing in nuclear medicine, or a gadolinium injection in magnetic resonance imaging. Venipuncture is a skill you should master with on-the-job training as soon as possible in your career. Make sure to have the patient fill out your departments IV contrast media questionnaire and check for any applicable laboratory results before proceeding to start an IV line. While pre-screening the patient for a potential contrast allergy or renal function problems, you may find a reason for which the injection portion of the exam would be postponed or cancelled.

The following outlines the basic steps in *performing* venipuncture (starting an IV line):

1. *Gather all needed supplies*. Unpackage everything so each item is ready to be used.
2. *Greet the patient and confirm at least two patient identifiers* (matching the identifiers to the radiology exam request) to ensure you have the correct patient. No IV can be started on a patient without a doctor’s order. The order for you, as a radiology technologist, comes from the radiologist. When a radiology exam is requested by a physician, the radiologist reviews the request and if he or she determines the radiology exam is necessary, he or she will write the exam type to be performed (protocol) on the printed radiology request. If applicable to the exam requested, the protocol from the radiologist is your authorization to start an IV line.
3. *Position the patient* appropriately (whether supine or possibly in a chair specially designed for starting IV lines).
4. *Explain the procedure to the patient* in basic terms, answering any questions he or she may have.
5. *Wash your hands.*
6. *Apply the tourniquet* approximately 4-5 inches proximal to the projected IV site. Over a period of 20-30 seconds, survey the veins distal to the tourniquet by palpating (feeling) for the largest vein available. Press on the skin over the vein. As the tourniquet restricts the flow

of venous blood, the vein should get visibly larger and should feel spongy (as you press on the vein). During this step, it may be necessary to let the patients arm hang towards the floor with the tourniquet in place. Once you select the vein, place the patients arm back up on a level surface.

SAFETY NOTE: Once the tourniquet is applied, the whole procedure should take *no more than 3 minutes* to complete. Once the tourniquet is engaged for 3 minutes, release the tourniquet so the patient's arm is allowed to relax and normal blood flow is resumed. *Vein selection* is a very important step in performing venipuncture. It is best to start an IV line in the largest vein possible to improve your ability to get the IV line started and to make it easier to push the contrast media into the patient. The most common area to find larger veins is the antecubital (anterior elbow) region. The median cubital, cephalic, and basilic veins are typically larger, easier to locate, and easier to access with a catheter. Other common IV sites include the lateral wrist region (cephalic vein) and the veins on the posterior aspect of the hand and forearm (cephalic and/or basilic veins).

8. *Don latex-free disposable gloves.*
9. Once you have selected a vein, use one of the alcohol prep pads to *disinfect the skin directly above the vein.* Wipe the skin gently but thoroughly starting directly over the vein working out in a circular motion to ensure an even application of rubbing alcohol. Repeat this step with the second alcohol prep pad. Allow the skin to dry (typically about 10 seconds). When selecting a vein, antecubital veins (at the anterior bend of the elbow) are generally the easiest to access. While these veins are not recommended for long term venous access because patients tend to bend their arm and kink the catheter, they are ideal for short term contrast administration.

WARNING: Make sure the vessel you select is indeed a vein and *not* an artery. If you are palpating the vessel and you feel a pulse; you have located an artery. *Do not perform venipuncture on an artery!*

10. Using your non-dominate hand, *stabilize the patient's arm and gently pull the skin taut* just below (approximately 1-2 inches) the proposed IV sight.
11. *Insert the needle* (metal cannula) with the bevel facing up at approximately 20 to 40 degree angle to the vein and directly in line (parallel) to the vein. Once the tip of the needle is through the skin and into the vein, reduce the angle of insertion slightly as you advance the needle into the vein approximately one-quarter of an inch (or one centimeter). If the tip of the needle is indeed in the vein, you will see blood (flashback) where you are holding the needles plastic housing. If you see blood, you are in typically in the vein. If you do not, apologize to the patient and explain that you will need to try again. Always be empathic to the patient because this process can cause pain and anxiety for the patient.
12. Once you have confirmed you are in the vein, retract *only* the needle approximately one-quarter of an inch (or one centimeter); *advance the plastic catheter forward and into the vein.* Finish retracting the needle back into the plastic housing. Be care not to retract the catheter with the needle; the catheter must stay in the patients vein in order for the venipuncture procedure to be a success.
13. At this point the catheter is in the patient's vein and the needle housing is still connected to the female end of the catheter. Get the hep lock (IV hub) or extension tubing in your dominate hand. Use your non-dominate hand to press down firmly where the proximal end of the catheter is estimated to be in the vein. This technique is designed to control bleeding when you remove the needle housing from the catheter. In one swift motion, use your dominate hand to remove the needle housing from the catheter and immediately *connect the*

IV hub (or tubing) to the female end of the catheter. Because you have retracted the needle into the plastic housing, you do not need to worry about getting stuck by the metal cannula.

14. *Release the tourniquet.* Advise the patient to keep their arm still. Secure the catheter and IV hub using the Tegaderm (or tape). Discard the needle in an appropriate sharps disposal container. Clean up any blood that leaked onto the patients arm.
15. Get the 10 cc syringe of normal saline. Bleed (prime) the syringe over a trash can pushing ½ to no more than 1 cc of saline through the neck of the syringe. Connect the syringe to the IV hub (or tubing); pull back on the syringe plunger slight so a small amount of blood enters into the syringe. Keep the syringe fairly upright at the same 20 to 40 degree angle (but don't bend the IV catheter) to allow any free air in the syringe to rise to the top. *Flush the IV catheter* by pushing the saline and blood mixture through the IV catheter at a rate of 1 to 2 cc per second. Use the remaining normal saline in the syringe to flush the IV catheter. Never push air into the catheter (or vein) therefore make certain to stop pushing the syringe plunger before inducing any air into the IV hub or catheter. When flushing the catheter, very little resistance should be felt. If resistance is felt, you may not be in the patient's vein. Also, ask the patient if he or she feels anything when you push the saline through the catheter. The patient should feel the fluid flow and possibly a cool sensation. No pain should be felt.
16. The last step is to pick up after yourself; throw away all trash and if not already done, dispose of the needle (metal cannula) in an appropriate sharps container and *wash your hands.*

Venipuncture is a skill that requires a lot of practice to master. Each patient presents a different set of veins and a different medical condition that you have to account for in order to perform the act of starting an IV successfully. Never attempt venipuncture unless you have been trained and certified by a qualified individual. In addition, make sure your ability to perform venipuncture is properly documented in your training record.

Intravenous line complications

IV lines are widely considered a very safe procedure; however, there is still risk involved. Do not let complacency distract you from preventing complications while injecting IV contrast media in your patient. When problems do arise, it is important that you react quickly and appropriately.

Extravasation and infiltration of the injection site

An extravasation or infiltration is when the contrast material is injected (or leaks) outside of the vein into the tissues surrounding the blood vessel. Extravasation specifically refers to fluid that is outside of the blood vessel. Infiltration specifically refers to fluid outside the vein that has diffused (spread out) into the surrounding tissue. When contrast media leaves the blood vessel, it typically causes pain and swelling at the site of injection. The best way to avoid contrast media infiltration at the injection site is to ensure adequate blood return when testing the IV line before beginning the injection. Most exams allow for you to be next to the patient while the contrast media is being injected; this allows you to appropriately monitor the injection site for any problems.

Patients who experience an extravasation or infiltration may complain of stinging, burning, or pain at the site of injection. In other cases, patients may feel little or no discomfort. For this reason, always monitor your patients closely during an injection. If using an automatic pressure injector, like in CT or interventional radiography, as the injection rates increase, so do the chances of extravasating or infiltrating the patient's vein.

Unfortunately, there is not a clear consensus on how to treat an extravasation or infiltration. Some literature states to use a warm compress while others state a cold compress. In general, a cold compress tends to better relieve the pain associated with an extravasation and a warm compress tends to improve contrast media absorption into the surrounding tissue. You prepare the warm or cold compress by soaking a towel in hot or cold water for approximately 30-60 seconds. Ring out the excess water and then wrap the towel around the affected area of extravasation or infiltration.

Your responsibility in an extravasation is to:

- Quickly recognize the initial symptoms.
- Stop the injection.
- Notify your radiologist.
- Apply the appropriate warm/cold compress as per your department's policy.
- Accurately estimate the amount contrast media injected into the surrounding tissue and give this information to your radiologist.

Once the radiologist is notified, he or she will evaluate the injection site symptoms. If a radiologist is not available, contact the patient's requesting physician for coordination of follow-up care. Also advise patients to seek emergency care if symptoms around the injection/extravasation site worsen. Worsening symptoms include skin ulcerations, tissue necrosis, and development of declining neurologic or circulatory symptoms to include paresthesia in the limb where the extravasation occurred. In some cases, patients will be referred to the surgical clinic for further evaluation, monitoring, or treatment.

Hematoma

A hematoma is a localized collection of blood that is a result of a break in the wall of a blood vessel. When you attempt to start an IV line and miss the vein, you can cause a hematoma. When you miss and the needle (metal cannula) nicks the blood vessel or you go into and completely through the vein, bleeding occurs causing a pooling of blood (a hematoma). A bruise typically forms on the skin as a result of the hematoma and usually resolves itself within days to a couple weeks.

Embolism

An embolism is caused when air is injected into a vein. As mentioned previously concerning flushing the IV line, it is very important to avoid injecting air into the bloodstream. Children are especially at risk to embolisms. In severe instances, embolisms can cause problems breathing, chest pain, blue skin, lowered blood pressure, and even a stroke. Unfortunately, frequently CT techs have used an automatic pressure injector to inject 100 cc of air into a patient because they forgot to fill the syringe with a contrast medium.

Thrombosis

As mentioned in the steps to performing venipuncture, it is extremely important to ensure you start an IV line in a vein and not an artery. A thrombosis is a condition caused by injecting contrast media into an artery versus a vein. Injecting into an artery can cause severe pain, gangrene, motor skill dysfunction, and possibly loss of the limb where the injection took place.

Removing the intravenous line

When the injection is complete and all images have been acquired, it is time to remove the IV line. Make sure that the IV line is left in place for *a minimum of five minutes post injection* in case it is needed to administer emergency medications. Many technologists get over-anxious to remove the IV line as soon as the injection or images are completed. A better standard of practice is to take your time during the post-injection portion of the exam (especially CT since the injection and exams are completed so quickly) and remove the IV line ideally 10 minutes after the injection of contrast media.

Here are the steps to *removing* an IV line:

1. Don a pair of latex-free gloves.
2. Loosen and remove the Tegaderm or tape from the patient's skin but not necessarily from the catheter and IV hub (hep lock).
3. Fold a 2 by 2 piece of gauze in half twice and place it on the skin/injection site.

4. While holding the gauze with fingers from your non-dominate hand, use your dominate hand to pull out and remove the catheter from the patient's vein/skin.
5. Once you have removed the catheter, apply pressure with the folded gauze pad directly over the injection site for one minute. Whether asked previously during the prescreening phase or asked at this point, find out if the patient is on blood thinners like aspirin or Coumadin. If your patient is on a blood thinner, his or her blood may not clot as quickly; therefore, apply direct pressure with the gauze over the injection site for a minimum of 3-5 minutes.
6. Place a piece of tape approximately four inches in length over the folded gauze and advise the patient to keep the gauze in place for approximately one hour. If available, coban works well to properly secure and cover the folded gauze over the injection site.

   NOTE: It is no longer the standard of practice to have the patient bend his or her arm to keep pressure on the gauze. This practice has been found to increase the likelihood of the patient developing a hematoma at the injection site.
7. Remove your gloves, dispose of them, and wash your hands.

Documenting contrast media administration

A newer practice for radiology techs is documenting the administration of IV contrast media. In 2006, the National Patient Safety Goals of The Joint Commission published guidance that required health care workers to communicate a patient's medications list to the next provider or servicing department. In interpreting this patient safety goal, radiology techs are required to tell the patient's nursing staff about any IV contrast that was administered during a radiographic examination. *Contrast media is considered a medication* because it is prescribed or administered by a physician (or radiologist). How you document the administration of IV contrast media is likely to vary depending upon your duty location.

Charting contrast media for out-patients

Every patient cared for at a MTF has a medical record (no matter if it is paper or electronic). Unfortunately, outpatients do not come to radiology carrying their medical records. After the exam, typically your role is to write the IV contrast media brand name (e.g., Isovue or Visipaque) and quantity injected on the radiology request form that is given to the radiologist for exam dictation.

The exam dictation is the radiologist's interpretation of what pathology is seen or not seen on the radiographic images. The radiologist includes the type and quantity of IV contrast injected into the dictation. The dictation later becomes a *final report* for that image or set of images. The report created from the dictation is then added to the patient's permanent medical record.

Some AF locations have built the documentation area into the Composite Health Care System (CHCS) template of the radiology request form. By adding the documentation area to the CHCS template, it is automatically included with every printed radiology request form whenever IV contrast is indicated to be used. See figure 1–4 for an example of the documentation area on a CHCS template.

It is important to note that a lot goes into injecting contrast into a patient; patients are prescreened for allergies and potential complications, starting an IV is a task that takes on-the-job training and a lot of practice. Only trained technologists will make decisions pertaining to which contrast is chosen for injection (with guidance from a radiologist), and again, only trained technologists will perform post injection evaluations. With that stated, only trained technologists document contrast media injection information.

*** IV Contrast Documentation ***

CR Level: 1.2 GFR Level: 95 Lab Collection Date: 19 June 2015

Contrast Injected: Omnipaque 350 / Isovue 370 / Visipaque 320 Amt Injected: 100 ml

IV catheter size: 20 gauge // Injection Rate: 2 cc/sec

IV location: Right / Left Hand / Wrist / Forearm / Elbow / Foot Other: ____________

If IV not used: MORPHIUS PICC / PURPLE POWER PICC / PURPLE POWER PORT

Injection Notes: Successful / Extravasation / Reaction ________________________

Tech Initials: JGH

NOTE: Example entries have been made in blue font however it is important to note that each facility may use a different means to document IV contrast injections.

Figure 1–4. Sample IV contrast post-injection documentation questions.

Charting contrast media for in-patients

For in-patient charting, facilities typically use paper records that travel with the patient from the ward/intensive care unit to radiology. The patient's paper in-patient record or chart has a section labeled Medications. In this section, the IV contrast media brand name (e.g., Isovue or Visipaque) and quantity injected is recorded. Typically, radiology techs do not write directly in patient charts so make sure to verify your facilities procedures for performing this task. If you are not writing directly into the chart, another option is to report the type and quantity of IV contrast media administered to the patient's nurse. The nurse may then make an entry into the chart to satisfy the national patient safety goal mentioned previously.

806. Operating principles monitoring patients and their vital signs

Whenever a patient comes to see you in radiology, they are typically not feeling well. They may be feeling acute or intermittent symptoms. While the patient is in radiology, you must pay close attention to their overall condition and assess their needs. In this lesson, you will learn what it means to monitor your patient and their vital signs.

Patient history

When preparing for an examination read the radiology request form for the reason the patient is in radiology. The reason for the examination, or otherwise known as the history, is provided to you by the requesting physician. Sometimes the history provided by the requesting physician is very thorough; other times it is not. Radiologists rely on you to observe and gather information from the patient regarding his or her medical history and current condition. If the history on the radiology request form is not thorough, ask the patient some of the following basic questions to respectfully figure out why the exam has been requested:

1. Do you know why your physician has ordered the exam today?
2. When did the symptoms begin?
3. Have you ever felt these symptoms before?
4. Are you in any pain? If so, where is the pain?

5. Using a scale of 1 to 10 (10 being the most severe), what is your pain level today?
6. What makes your symptoms feel better? Feel worse?

If there is ever a concern whether the requested exam is relevant for the patient's condition, discuss it with your radiologist before proceeding.

Assessing the patient

Patient assessment is a constant process of observing your patient, comparing symptoms, and evaluating any changes to their overall condition before, during, and after a radiologic examination. A seasoned technologist can compare the condition of a patient to that of other patients having similar signs and symptoms to determine whether a patient's condition is getting better or worse. You need to look for changes in four areas when monitoring patients in radiology: skin color, skin temperature, levels of consciousness, and breathing.

Skin color

Skin color is one of the easier signs to notice changes in a patient's condition. Red blood cells carry oxygen from the lungs to the body tissues and organs. Cyanosis is a condition created when there is a low content of oxygen in the blood. Cyanosis creates a bluish tint in the skin and is most often first recognized on the patient's lips or the nail beds of their fingers. If a patient becomes cyanotic while in your care, *notify a radiologist or physician immediately*; a cyanotic person requires oxygen and urgent medical attention.

Skin temperature

Skin temperature is another area that can clue you in to a patient's condition. Hot dry skin may indicate a fever caused by an infection where as a cold sweat is the body's response to some form of stress. A cold sweat, or condition of *diaphoresis*, refers to the acute onset of sweating that is not caused by heat or physical exertion. You must understand cold sweats are not an issue of concern; however, they are an indication that a problem exists. Cold sweats can happen for a number of reasons that are not life-threatening. However, if you notice your patient experiencing cold sweats, it may lead to an emergency situation caused by lack of oxygen or a low blood sugar condition known as hypoglycemia. You must urgently treat these conditions and notify a radiologist or physician if an abrupt change in skin temperature is observed.

Levels of consciousness

From the first minute you come in contact with a patient to the last, you must pay attention to the patient's mental state. Sudden changes to a patient's mental state may indicate life-threatening issues. There are basically four levels of consciousness:

1. Conscious and alert.
2. Responsive but drowsy.
3. Unconscious yet responsive to pain.
4. Comatose.

Eyeballing is a term used to observe the level of consciousness in patients. Eyeballing a patient means to take a concerted, good look at them. Eyeball the patient when you first come in contact with them and again and again throughout the radiologic examination. Is the patient alert? Are their eyes open and able to focus? When you speak to the patient, does the patient make eye contact with you? Patients can lose consciousness for many different reasons; as with other symptoms, notify a radiologist or physician immediately if your patient loses consciousness while in your care.

Breathing

Breathing is something the body does involuntarily. Without the act of breathing, oxygen does not enter into the body and carbon dioxide is *not* expelled. Normal breathing is a fairly uneventful task; it is typically quiet and performed easily. When assessing your patient's breathing, note whether they are wheezing, gasping, or coughing repeatedly. Further attention may be required if breathing is a struggle. Again, note your patient's ability to breath many times during their time in radiology. If their ability to breath decreases, whether in depth or rate of respirations, it could be the result of acute respiratory distress or a severe contrast reaction if following a contrast media injection. Notify a radiologist or physician immediately if you observe a notable decrease in your patient's ability to breath.

Everything we have talked about in this lesson revolves around paying close attention to the patient and not leaving him or her alone. You are responsible for the care and monitoring of your patient every moment he or she is in the radiology department.

What are vital signs?

Vital signs reflect the general physical condition and stability of the patient. Your responsibility as a medical care professional includes safeguarding each patient's health and wellbeing while in your X-ray department. You may be called upon to monitor and record patients' vital signs during radiographic exams. This is particularly true if the patient begins to display symptoms of a severe reaction to contrast media. There are four vital signs included in this discussion: pulse, respiration, blood pressure, and temperature.

Pulse

Pulse is the palpable surge of blood through the arteries, resulting from the pumping of the heart. The normal pulse rate for adults is between 60 and 100 beats per minute (bpm). Variations in these rates may be a sign of a contrast media reaction; however, you must also consider the patient's age, present state of health, level of physical activity, and so forth. The normal site for taking a patient's pulse is the radial artery, located on the thumb side of wrist. Place three fingers (not the thumb) over the artery and count the pulsations for a 15 second period, then multiply that number by four to obtain the approximate bpm. An alternate site, such as the carotid, femoral, or dorsalis pedis artery (on the instep of the foot) may be used for obtaining a pulse if the arms cannot be used.

An abnormally rapid pulse, over 100 bpm, is called *tachycardia*. An abnormally slow heart rate, below 60 bpm, is called *bradycardia*. Either of these conditions may indicate the possibility of a hemodynamic reaction to contrast media. If a patient's condition is seemingly deteriorating after an IV contrast media injection, check his or her pulse to determine if there is a circulation issue.

Respiration

Respiration consists of the two phases of the breathing cycle, including inspiration and expiration as one respiration. The normal respiration rate is 12–20 breaths (cycles) per minute for the average adult. A common practice is to check the patient's respiratory rate at the same time that you are monitoring the pulse. Simply watch the chest as it rises during inhalation, and then falls during exhalation. In addition to the rate, you also want to observe the rhythm and depth of each cycle. When a patient begins to experience a contrast media reaction, hyperventilation (rapid, shallow breaths) is a common occurrence. You can usually control this by instructing the patient to take slow, deep breaths through the mouth. The radiologist or attending physician will direct any further necessary action.

Blood pressure

Blood pressure is the force exerted against the arterial walls by the blood as it flows through the vascular system. Two measurements are recorded: systolic pressure—a measurement of the contraction phase of the heart; and diastolic pressure—a measurement of the relaxation phase. Three factors affect the normal blood pressure range for adults: age, weight, and physical status. For adults, the acceptable systolic range is 95–119 millimeter (mm) of mercury (Hg) while 60–79 mm Hg is the acceptable diastolic range. *Hypertension* is a condition in which a patient's systolic blood pressure reading is above 140 mm Hg and the diastolic reading is above 90 mm Hg. *Hypotension* is a condition where the patient's systolic blood pressure reading is below 90 mm Hg and the diastolic reading is below 50 mm Hg.

Some radiology departments require a baseline blood pressure reading be taken prior to any IV contrast media injection. This baseline blood pressure reading is extremely helpful in an emergency scenario because now the before and after values can be easily compared.

A sphygmomanometer (often referred to as a blood pressure cuff) and a stethoscope are the two pieces of equipment required to measure blood pressure manually. Wrap the cuff securely around the upper arm, about one inch above the antecubital fossa. (Avoid placing the cuff on the same arm as an IV line.) Palpate for the brachial artery, rest the bell portion of the stethoscope over it in the antecubital fossa region, and listen for the pulse. Inflate the cuff to a point approximately 30 mm Hg beyond the point where the pulsations are no longer heard (not to exceed 200 mm Hg in most circumstances). Slowly deflate the cuff until you begin to hear the pulse again; this reflects the systolic pressure. Continue to deflate the cuff until the pulsations are no longer heard or become muffled; this represents the diastolic pressure.

Record these pressures as fractional figures, such as 110/70 (pronounced "one-ten over seventy") or 120/85. For future reference, record the patient's pulse, respirations, and blood pressure reading as well as the time that each of these vital signs was checked.

Temperature

Body temperature is the balance between heat produced and heat lost by the body. Heat is produced by metabolic activities, such as exercise, digestion, and fever; and heat is lost through the processes of conduction, convection, radiation, and evaporation.

Temperatures can be measured via the oral, rectal, axillary, tympanic, and temporal artery routes. The average normal body temperature when measured orally is 96.8 degrees Fahrenheit (°F) to 99.8°F (36.0°-38.0 degrees Celsius [°C]). When measuring temperature rectally, the normal range is 0.5°F to 1.0°F higher than when measured orally. On the contrary, the normal axillary temperature range is 0.5°F to 1.0°F lower than that when measured orally. Adult body temperatures in excess of 100.4°F (orally) are called a fever, or *pyrexia*. A fever is an indication of increased energy use in the body and is typically the result of an infection. Subnormal body temperatures are called *hypothermia*. Hypothermia may also be caused by shock or injury to the brain or spinal cord.

Glass thermometers are *not* used anymore because of regulations from the Occupational Safety and Health Administration (OSHA) that *restrict* the use of mercury in the clinical setting therefore oral and tympanic methods are the most common routes practiced for obtaining a patient's temperature.

In radiology, few opportunities tend to arise in which you will need to take a patient's temperature. However, you should be able to competently perform this fairly simple task if asked to do so and be able to interpret the readings when necessary. Obtain a patient's temperature when a radiologist or physician deems it necessary to evaluate the patient's condition. Since a radiology technologist does not commonly perform this task, only the oral method is outlined.

Using a digital thermometer, follow these basic steps:

1. Wash your hands.
2. Don a pair of latex-free gloves.
3. Install a plastic sleeve over the thermometer probe.
4. Power on the unit.
5. Place the probe under the patient's tongue and have the patient close their lips.
6. Remove the probe when the unit makes an audible tone indicating a maximum temperature has been achieved (usually less than one minute).
7. Remove and throw away the plastic sleeve into a trash receptacle.

8. Inform the radiologist or physician of the temperature reading and record it on their radiology request form or other applicable medical documentation form.
9. Power off the thermometer unit, remove/discard gloves, and wash hands.

If the patient is unconscious or uncooperative, you may need to acquire a temperature via the axillary or rectal routes. Using the same style of digital thermometer, follow the same steps as outlined above except place the probe in the patient's axilla so that the skin is in direct contact with the plastic sleeve on the probe. If acquiring a rectal temperature, again, follow the same steps as above except position the patient in the lateral recumbent position. Raise the top fold of the buttocks and slowly insert the plastic covered probe into the rectum just past the anal sphincter. For the axilla and rectal methods, hold the probe in place until the audible sound is heard.

NOTE: If acquiring a rectal temperature, use a chaperone if the patient is of the opposite sex from you.

Electronic monitoring of vital signs

Different electronic devices are available to make your job of taking and monitoring vital signs much easier than their manual counterparts. In radiology, two of these devices are likely already in your duty area: a pulse oximeter and an electrocardiograph monitor.

Pulse oximeter

A pulse oximeter is a device that constantly measures pulse and blood oxygen levels. A pulse oximeter uses a photosensitive cell to determine the difference between deoxygenated and oxygenated hemoglobin. The photosensitive cell is in a clip that is placed over the patient's finger (fig. 1–5) and then a digital reading is displayed regarding the patient's current oxygen perfusion rate. Normal readings vary from 95 percent to 100 percent. Readings below 95 percent mean that the tissues are not receiving enough oxygen perfusion.

Figure 1–5. Pulse oximeter with the clip inserted over a finger.

If the pulse oximeter reading falls below 95 percent, look at the patient. If the patient appears in distress, pale, or is in a cold sweat (diaphoresis); notify a nurse, radiologist, or physician immediately for further evaluation. If the patient is not displaying any problems, check the pulse oximeter and especially the clip to make sure it is positioned securely on the patient's finger. When this device is available and instructed to do so, use it to monitor the patient's oxygen perfusion rate. Relay the percentage rate to the radiologist or physician.

Electrocardiograph monitor

An electrocardiogram (ECG or EKG) machine (fig. 1–6) measures the heart's electrical activity. The device records the electrical activity on a strip of graph paper and on a screen for medical personnel to view live monitoring. Electrodes designed to pick up on electrical signals from the patient are attached to the patient using adhesive pads. Normally three electrodes are utilized; two electrodes are placed in-between the second and third ribs on each side of the sternum. The third electrode is placed on the left side of the patient's chest at the approximate level of the sixth and seventh intercostals rib space. Cables from the monitoring device are then attached to the electrodes. When recording an ECG strip (the graphing of the electrical signal on the graph paper), it is important that the patient holds still for the best reading. With normal patient movement, the electrodes can easily come loose which causes a loss of signal from the patient to the machine. If a flat line is displayed on the monitor and the patient is still breathing, check the cables to ensure they are still attached to the electrodes and also check the electrodes to ensure they are still adhered to the patient's skin.

Figure 1–6. Electrocardiogram machine with an electronic blood pressure cuff and pulse oximeter.

As shown in figure 1–6, ECG machines may also have an electronic blood pressure cuff and pulse oximeter included for one-stop monitoring of a patient. This type of monitoring device is portable and extremely useful in emergencies like contrast media reactions. The information acquired assists radiologists and physicians in determining treatment options for life-threatening situations. With on-the-job training at your duty location, you may learn more on this machine to get you ready for use during an emergency.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

805. Perform venipuncture procedures

1. What is the first step in performing venipuncture?

2. What signifies you have successfully pierced the wall of the blood vessel?

3. Which IV catheter has a larger bore, an 18 gauge or 24 gauge?

4. What gauge IV catheter is recommended for an automatic pressure injection of contrast media at a rate of 1.6 cubic centimeters per second (cc/sec)? At 5 cc/second?

5. What are some other factors to consider when selecting an appropriate IV catheter size?

6. If the tourniquet is engaged for three minutes, what should be done?

7. How is the metal cannula inserted through the skin and into the vein?

8. What is the last step in performing venipuncture?

9. Describe an extravasation.

10. What effect does a cold compress have on an extravasation? How about a warm compress?

11. What causes an embolism?

12. What is the ideal amount of time that should pass after the injection of contrast media before the IV line is removed from the patient? What is the minimum amount of time?

13. Where do you write the IV contrast media brand name and quantity injected into an outpatient?

806. Operating principles monitoring patients and their vital signs

1. When would it be necessary to ask the patient some basic questions to respectfully figure out why the exam has been requested?

2. What is patient assessment?

3. Your patient’s lips and finger nail beds have a bluish tint, what should you do?

4. Why must you pay attention to the patient’s mental state?

5. What do vital signs reflect about a patient?

6. What is the normal average pulse rate for adults and when is it appropriate to check a patients pulse?

7. What is the normal average respiration rate for adults and when is it common to check a patient’s respirations?

8. What is the systolic measurement of blood pressure and its normal range? What is the diastolic measurement of blood pressure and its normal range?

9. What is the normal body temperature range when measured orally?

Answers to Self-Test Questions

801

1. They must be nontoxic, and they must alter photon absorption.
2. Positive and negative.
3. Air, oxygen, and carbon dioxide.
4. Because of the risk of gas embolization.
5. They alter photon absorption by increasing the molecular density of the structure(s) into which they are introduced.
6. Iodine, bromine, and barium.

802

1. Oral/rectal, water-soluble injectable, water-soluble non injectable, and oily/viscous.
2. They are not water-soluble.
3. If bowel perforation is suspected.
4. Because barium sulfate is an inert compound.
5. A water-soluble oral contrast.
6. Contrast media used to enhance the gall bladder and biliary tree.
7. Water-soluble injectable.
8. Iodine concentration.
9. Because as salts, they consist of an anion (negatively charged particle) and a cation (positively charged particle) which disassociate when dissolved in water.
10. The high osmolality of the ionic agents.
11. The weight-by-volume concentration of the iodine compound.
12. They have a far lower incidence of adverse contrast media reactions.
13. To reduce its viscosity.
14. They are ionic compounds that combine characteristics of ionic and nonionic agents.
15. It means the agent's osmolality is equal to that of human blood.
16. Ethiodol and Sinografin.

803

1. Serum creatinine, BUN, and GFR.
2. Serum creatinine is 0.6 to 1.5 mg/dL; BUN is 6 to 20 mg/dL; and GFR is 90 to 120 ml/min.
3. It is a 13-hour preparation.

804

1. Within 1-3 minutes after beginning the contrast injection.
2. A metallic taste, a warming sensation throughout their body for the duration of the injection, and a more intense warming sensation in the groin area that gives the patient a feeling that they need to void.
3. It will help to ease your patient's anxiety level, ensure a successful injection, and increase the probability of obtaining a quality diagnostic examination.
4. Feelings of anxiety.
5. It is sudden fainting due to hypotension induced by the response of the nervous system to abrupt emotional stress, pain, or trauma.
6. Anaphylactic reactions.

7. It is elevated patches on the skin that are redder or paler than the surrounding skin.
8. You must pay attention to your patient and under no circumstances, ever leave the patient unattended.
9. (1) d.
   (2) b.
   (3) c.
   (4) a.
10. Two 1 milliliter vials of 50 milligram per milliliter injectable diphenhydramine (Benadryl); two epinephrine auto-injectors; one adult and one junior; one albuterol sulfate aerosol inhaler; two 1 milliliter syringes; and two 18-gauge and two 25-gauge hypodermic safety needles.
11. An antihistaminic agent.
12. Intramuscularly or orally; 25 to 50 mg.
13. A cardiac stimulant and vasoconstrictor.
14. IV, tracheobronchial, or intracardiac; 5 to 10 ml of a 1:10,000 solution when given intravenously.
15. To treat or prevent bronchospasms.
16. To observe the patient for any signs of a reaction, evaluate the severity of the reaction, notify the radiologist to the reaction symptoms, monitor the patient's vital signs, and ensure appropriate emergency equipment and supplies are readily available.

805

1. Gather the supplies you will needed to complete the task.
2. When a small amount of blood is returned through the metal cannula to the plastic housing as *blood return*.
3. 18 gauge.
4. 22 gauge IV catheter; 18 gauge IV catheter.
5. The perceived size of the patients veins, the location of the vein (back of the hand versus the anterior elbow region), and typically the age of the patient (less than 10 years old or greater than 60 years old).
6. The tourniquet should be released so the patients arm is allowed to relax and normal blood flow is resumed.
7. With the bevel facing up at approximately 20 to 40 degree angle to the vein and directly in line (parallel) to the vein.
8. Pick up after yourself throwing away all trash and if not already done so, dispose of the needle (metal cannula) in an appropriate sharps container and washing your hands.
9. Is when the contrast material is injected (or leaks) outside of the vein into the tissues surrounding the blood vessel.
10. A cold compress tends to better relieve the pain associated with an extravasation; a warm compress tends to improve contrast media absorption into the surrounding tissue.
11. When air is injected into a vein.
12. 10 minutes after the injection of contrast media; 5 minutes.
13. On the radiology request form that is given to the radiologist for exam dictation.

806.

1. If the history on the radiology request form is not thorough.
2. It is a constant process of observing your patient, comparing symptoms, and evaluating any changes to their overall condition before, during, and after a radiologic examination.
3. Notify a radiologist or physician immediately; a cyanotic person requires oxygen and urgent medical attention.
4. Because a sudden change to a patient's mental state may indicate life-threatening issues.
5. The general physical condition and stability of the patient.
6. It is between 60 and 100 beat per minute; if a patient's condition is seemingly deteriorating after an IV contrast media injection.
7. 12 to 20 breaths per minute; at the same time that you are monitoring the pulse.

8. A measurement of the contraction phase of the heart; 95–119 mm of Hg; a measurement of the relaxation phase; 60–79 mm Hg.
9. 96.8°F to 99.8°F (36.0°-38.0°C).

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field Scoring Answer Sheet.

Do not return your answer sheet to Air Force Career Development Academy (AFCDA).

1. (801) Which of these is a characteristic of *negative* contrast media?
   a. Consist mainly of anions.
   b. Increase photon absorption.
   c. Decrease photon absorption.
   d. Are ideal for intravascular use.

2. (802) Which condition, if suspected, is a contraindication for water-soluble oral contrast agents?
   a. Diabetes.
   b. Renal failure.
   c. Bowel perforation.
   d. Tracheoesophageal fistula.

3. (802) Oral cholecystopaques are contrast agents used to enhance visualization of the
   a. gall bladder.
   b. vascular system.
   c. alimentary tract.
   d. urogenital system.

4. (802) Contrast molecules that dissociate into two charged particles after combining with another liquid like human blood are referred to as
   a. ionic.
   b. nonionic.
   c. low-osmolar.
   d. water-soluble.

5. (802) Water-soluble noninjectable contrast agents *differ* from injectable contrast agents because they
   a. do not contain iodine.
   b. have a higher viscosity.
   c. have a lower osmolality.
   d. have an antibiotic added.

6. (803) What information about the patient should be obtained *before* administration of IV contrast media?
   a. Age, list of current medications, and family history of contrast reactions.
   b. Liver function test results, known food or drug allergies, and diabetic history.
   c. Diabetic history, known food or drug allergies, and list of current medications.
   d. Family history of contrast reactions, list of current medications, and liver function test results.

7. (803) How *long* is prophylaxis treatment for routine contrast media studies?
   a. 24 hours.
   b. 13 hours.
   c. 7 hours.
   d. 1 hour.

8. (804) Which type of contrast media reaction is vasovagal syncope?
   a. Technique.
   b. Psychogenic.
   c. Anaphylactic.
   d. Hemodynamic.

9. (804) Which type of contrast media reaction is considered an allergic response?
   a. Technique.
   b. Psychogenic.
   c. Anaphylactic.
   d. Hemodynamic.

10. (804) Which type of intravenous contrast reaction is urticarial (hives)?
   a. Mild
   b. Severe.
   c. Moderate.
   d. Intermediate.

11. (804) Which items are found in a typical emergency medication kit used for intravenous contrast media reactions?
   a. Injectable Benadryl, epinephrine, and a 10-milliliter syringe.
   b. Diphenhydramine, epinephrine, and two 1-milliliter syringes.
   c. Albuterol, two 22-gauge intravenous catheters, and a stethoscope.
   d. An adult auto-injector, a junior auto-injector, and blood pressure cuff.

12. (805) Which intravenous catheter has the *largest* bore diameter?
   a. 18 gauge.
   b. 20 gauge.
   c. 22 gauge.
   d. 24 gauge.

13. (805) What color identifies a 22-gauge intravenous catheter?
   a. Pink.
   b. Blue.
   c. Green.
   d. Yellow.

14. (805) The tourniquet should be applied for *no more than*
   a. 3 minutes.
   b. 5 minutes.
   c. 7 minutes.
   d. 10 minutes.

15. (805) Which venipuncture steps are in order of performance?
   a. Don gloves, select the vein, wash hands, and disinfect the skin.
   b. Wash hands, select the vein, advance the catheter, and connect the hub.
   c. Apply the tourniquet, gather supplies, disinfect the skin, and connect the hub.
   d. Explain the procedure, disinfect the skin, apply the tourniquet, and insert the needle bevel facing up.

16. (805) What is the *minimum* amount of time an intravenous line is left in place *post* injection?
   a. 3 minutes.
   b. 5 minutes.
   c. 7 minutes.
   d. 10 minutes.

17. (806) When do you perform a patient assessment?
    a. Before, during, and after the examination.
    b. Only before and after the examination.
    c. Only when the radiologist requests it.
    d. Only after the examination.

18. (806) What are the four areas you need to observe when assessing the patient?
    a. Pulse, respiration, blood pressure, and temperature.
    b. Pupils, lips, breathing sounds, and extremity movement.
    c. Skin color, skin temperature, levels of consciousness, and breathing.
    d. Consciousness, responsiveness, pain response, and state of comatose.

19. (806) The term “bradycardia” refers to
    a. an enlarged heart.
    b. low blood pressure.
    c. high blood pressure.
    d. an abnormally slow heart rate.

Please read the unit menu for unit 2 and continue ➔

Unit 2. Contrast Studies of the Digestive System

CONVERSION OF FOOD into chemical nutrients usable by the body occurs in the digestive system. Consequently, malfunction of any of the system components results in impairment of the digestive process. When the degree of impairment is sufficient, medical and/or surgical intervention is necessary. Generally, the first step in such professional treatment requires radiographic examination of the affected system component. Because you are responsible for preparing the equipment and assisting with such procedures, you must have an understanding of the anatomy and physiology of the digestive system and be able to assist a radiologist with the radiographic examinations thereof. This unit is discusses the digestive system from top to bottom and outlines the common exams performed.

2–1. Anatomy and Physiology of the Digestive System

The digestive system consists of the alimentary tract or canal and the accessory organs of digestion. The alimentary tract is 29 to 30 feet long and consists of the mouth, pharynx, esophagus, stomach, small bowel, large bowel, rectum, and anus. The accessory digestive organs are the salivary glands, liver, gallbladder, and pancreas. We begin our study of the digestive system with the mouth.

807. Mouth, pharynx, and esophagus principles

Although the mouth, or oral cavity, contains various structures including the teeth, mandible, cheeks, lips, and tongue, our discussion is primarily directed toward the roof of the mouth and the salivary glands.

Roof of the mouth

The hard and soft palates form the roof of the mouth. The stationary hard palate, forming the anterior portion of the roof of the mouth, is comprised of the maxillae and palatine bones, which are covered by mucous membranes. The hard palate joins posteriorly with the soft palate—a fold of mucous membrane that encloses muscular fibers, vessels, mucous glands, and nerves. The soft palate, normally pendant, elevates during the process of swallowing to separate the nasal cavity and nasopharynx from the oral cavity and oropharynx (fig. 2–1).

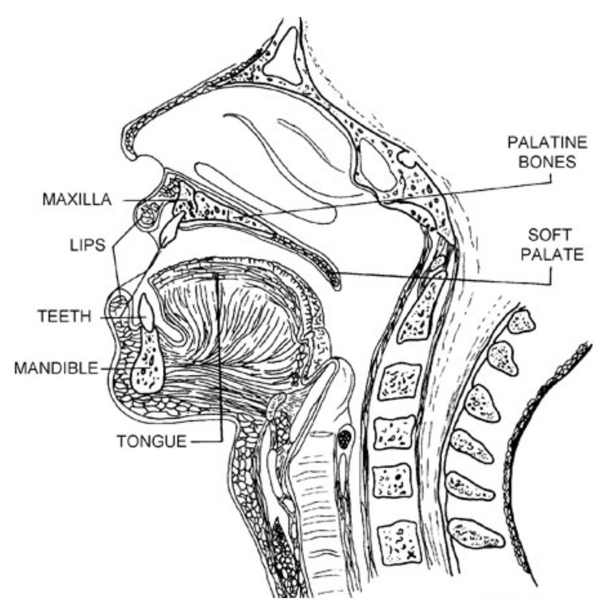

Figure 2–1. Cross-section of the oral cavity.

Salivary glands

Three pairs of salivary glands are located about the oral cavity (fig. 2–2.). They are the parotid, submandibular, and sublingual glands. The function of each of these glands is to secrete saliva into the mouth to moisten food and begin the process of digestion.

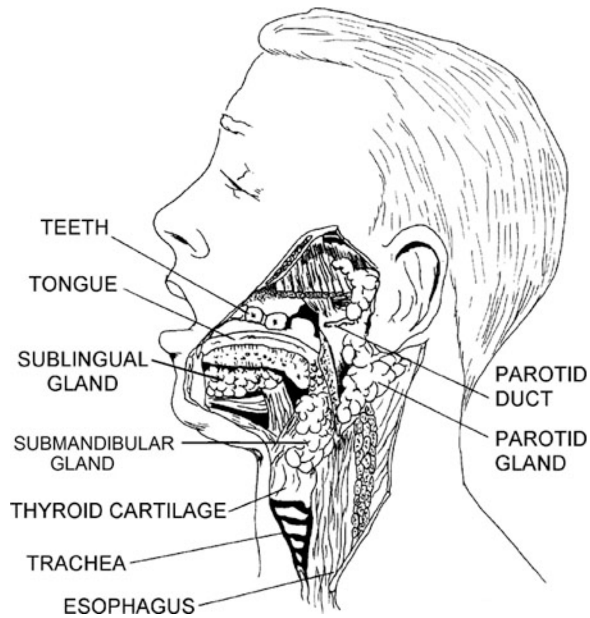

Figure 2–2. Salivary glands and related structures.

The *parotids*, which are the largest of the salivary glands, are located in the superior-posterior aspect of each cheek, below and in front of each ear. By means of the *parotid duct,* parotid secretions are channeled through the muscles of each cheek into the mouth through a small opening adjacent to each upper second molar. The *submandibular* glands are located near the anteromedial aspect of each mandibular angle. Submandibular gland secretions reach the mouth by way of the *submandibular duct*, which opens into the mouth on each side of the frenulum of the tongue. The *sublingual* glands, smallest of the three, are located beneath the mucous membrane of the floor of the mouth on each side of the midline. Saliva from each sublingual gland empties into several small excretory ducts called the ducts of *Rivinus*. Some of the ducts of Rivinus join to form the duct of *Bartholin*. Some empty directly into Wharton's duct, while others empty directly into the mouth on either side of the frenulum of the tongue.

Pharynx

The pharynx (fig. 2–3) is a tube-like structure approximately five inches (13 cm) long, extending from the inferior portion of the skull to the level of the sixth cervical vertebra. It is continuous with the nasal cavity anteriorly and the esophagus inferiorly. The pharynx is divided into three parts: the nasopharynx, oropharynx, and laryngopharynx.

Nasopharynx

The curved nasopharynx is the proximal portion of the pharynx and serves as an air passage from the nasal cavity to the oropharynx. It extends distally to the inferior margin of the soft palate.

Oropharynx

The oropharynx extends from the soft palate to the hyoid bone. It is common to *both* the digestive and respiratory systems because it serves as an air passage from the nasopharynx to the larynx *and* as a food passage from the oral cavity to the laryngopharynx.

Laryngopharynx

The laryngopharynx extends from the oropharynx to the level of the sixth cervical vertebra and the cricoid cartilage, where it becomes the esophagus.

Radiographic considerations

Generally, the nasopharynx and oropharynx can be adequately demonstrated on a soft-tissue lateral radiograph because they are normally filled with air. The laryngopharynx, however, is usually visualized radiographically after the introduction of a contrast medium because it is not a normal air passage.

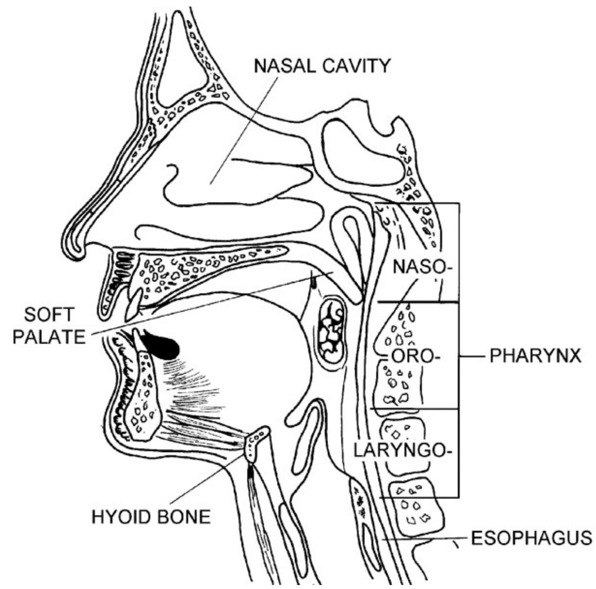

Figure 2–3. The pharynx.

Esophagus

The esophagus, which connects the pharynx to the stomach, is the portion of the digestive system where *peristalsis* begins. It is approximately 10 inches (or 24 cm) long and approximately ¾ inch or 19 mm in diameter (fig. 2–4.). As seen from the front, it looks like a "lazy S." Beginning in the midline, it inclines slightly to the left, back to the right, and then to the left again where it enters the stomach at the level of the eleventh thoracic vertebra.

As seen from the side, it follows the curvatures of the lower cervical and thoracic spines. Notice that the esophagus lies in close proximity to the aorta and the posterior border of the heart. You should see how the location of the esophagus with respect to the aorta and heart can be used to radiographically demonstrate enlargement of these structures. If the esophagus is filled with a contrast medium, an enlarged heart or an aortic aneurysm may show a portion of the esophagus displaced from its normal location.

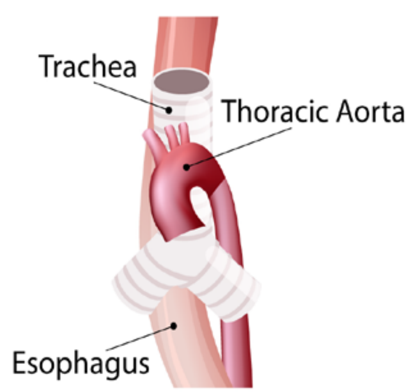

Figure 2–4. The esophagus and related structures.

808. Stomach and intestines principles

The next section of the alimentary tract to discuss is the stomach and intestines.

Stomach

The stomach is the most dilated portion of the digestive system; it extends from the esophagus to the small intestine.

General structure

The stomach has two main borders or curvatures: the greater curvature, and lesser curvature (fig. 2–5). The greater curvature, as the name implies, is the larger of the two and contains a slight groove called the *sulcus intermedius*. The lesser curvature is located on the right side of the stomach and contains a well-defined notch, the *incisura angularis.*

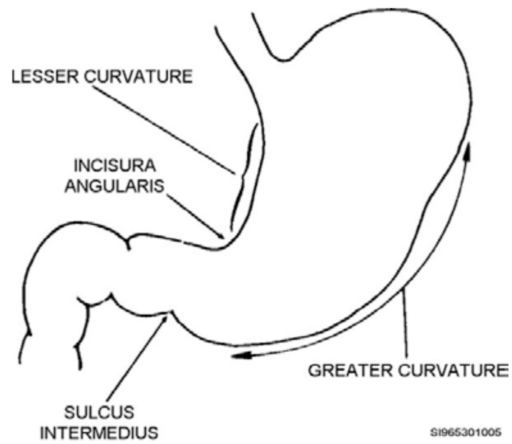

Figure 2–5. Curvatures of the stomach.

There are two openings in the stomach as shown in figure 2–6. The proximal opening at the junction of the esophagus is the *cardiac orifice*, which normally lies at the level of the eleventh thoracic vertebra about one inch to the left of the lateral sternal border. The *distal* opening, which communicates with the small intestine, is the *pyloric orifice*. It normally lies about one to two inches to the right of the midline at the level of the upper border of the first lumbar vertebra.

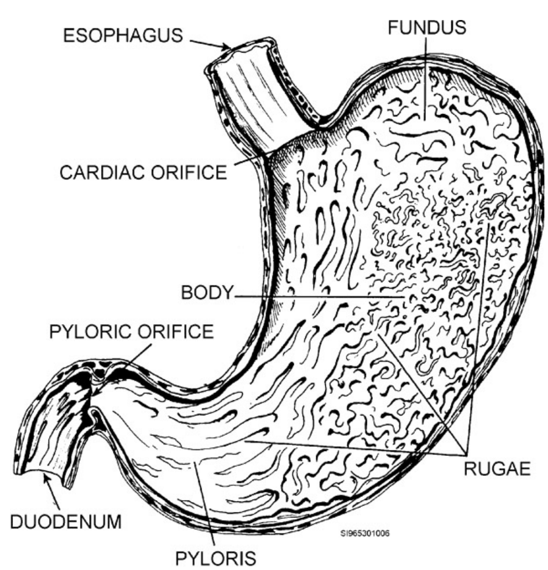

Figure 2–6. The stomach.

The stomach proper is divided into three main parts: the fundus, body, and pylorus. The fundus is the proximal, dome-shaped portion lying directly beneath the left hemidiaphragm. It extends inferiorly to a transverse plane passing through the cardiac orifice. The pylorus, or pyloric portion, is the distal portion of the stomach, which connects with the duodenum. The body is the portion of the stomach lying between the fundus and pylorus. Thick folds, called *rugae*, are located along the internal surface of the stomach. The rugae are most prominent when the stomach is empty and tend to flatten out when it is distended. The relationship of the stomach to surrounding abdominal structures can be seen in figure 2–7.

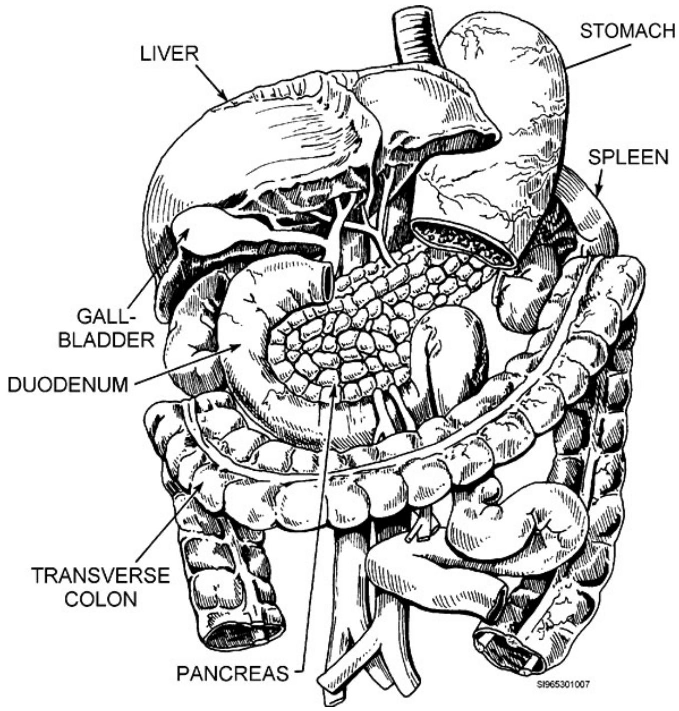

Figure 2–7. Location of the stomach in relation to other abdominal structures.

Variations in stomach location and shape

One of the problems technologists face when radiographing the stomach is including the entire stomach on the image receptor (IR). The problem lies in the varying locations of the stomach. We cannot teach you precisely where to center the IR and central ray (CR) for every patient. However, we will review the location and shape of the stomach relative to the four body habitus to provide the basic information needed to radiograph the stomach (fig. 2–8).

- Illustration A in figure 2–8 shows an individual with the *sthenic*, or average, build. The esophagus of this individual joins the stomach at the level of the xyphoid process, while the most inferior portion of the greater curvature is at the level of the iliac crest.
- The *hypersthenic* or obese individual is shown in illustration B. This person's stomach is almost *horizontally* situated and lies highest in the abdomen. Usually, the heavier the individual, the more horizontal the position of the stomach.
- The *hyposthenic* individual (illustration C) is more slender than the sthenic individual. This person's stomach is "J-" or "fishhook-" shaped and lies low in the abdomen. The most inferior portion of the greater curvature extends two to four inches below the level of the iliac crest.

- The *asthenic* individual is shown in illustration D. The “J-shaped” stomach is lower in the abdomen than in the hyposthenic individual. This stomach location is normally found in thin elderly patients who have lost their normal muscle tone.

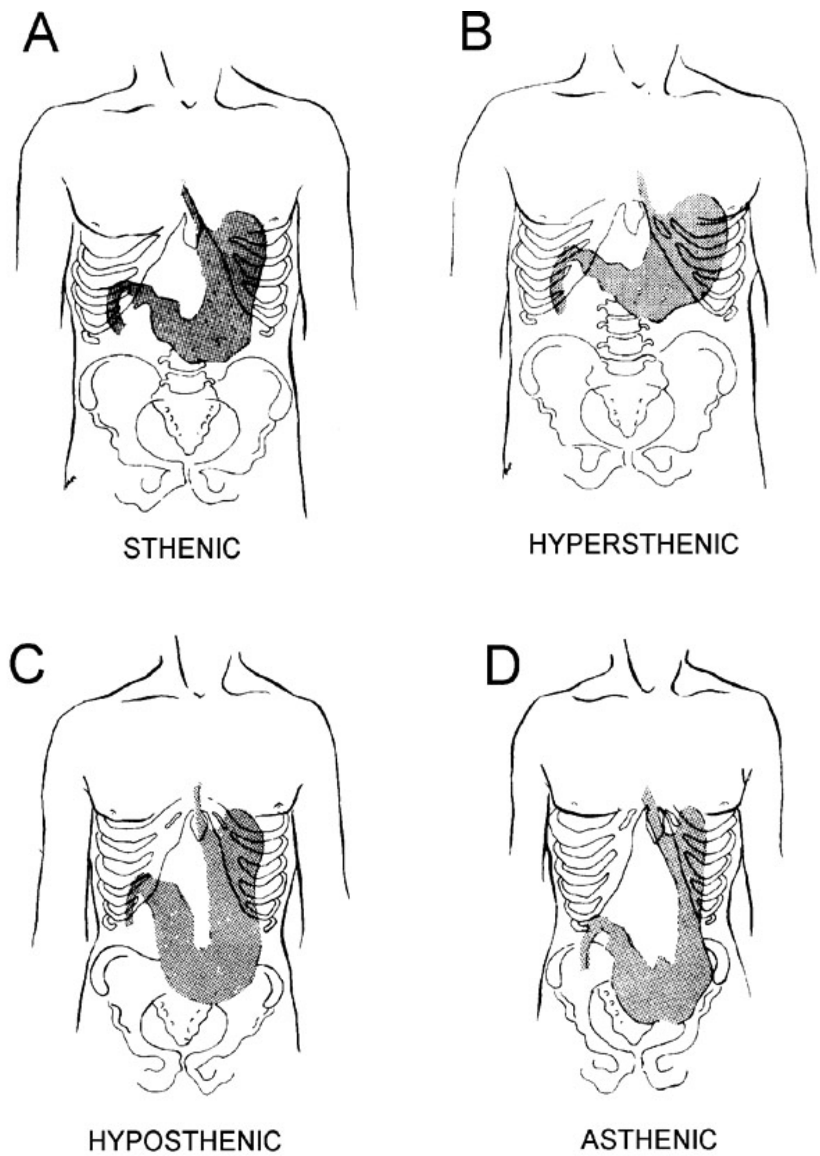

Figure 2–8. Variations in stomach location and shape.

Small bowel

At an adult length of approximately 22 feet, the small bowel connects the stomach to the large bowel and is divided into three portions: the duodenum, jejunum, and ileum.

Duodenum

The proximal portion of the small bowel, the duodenum, shown in figures 2–7 and 2–9, is about 8 to 10 inches (or 20 to 24 cm) long. It is the widest segment of the small bowel. The first part of the duodenum, the *duodenal bulb*, normally extends posterolaterally from the pylorus—thus oblique projections are required to view the bulb in profile. Occasionally, in obese patients, it lies in an anteroposterior direction, which requires a right lateral for profile demonstration.

From the bulb, the duodenum curves downward, descending over the head of the pancreas. It then curves medially and upward, behind the stomach. Finally, it turns sharply downward. Part of its course roughly resembles the letter C; thus, the proximal half of the duodenum is sometimes referred to as the C-loop.

Jejunum

The duodenum joins the *jejunum* over the left margin of the second lumbar vertebra. The jejunum, approximately 7 to 8 feet long, follows a random course.

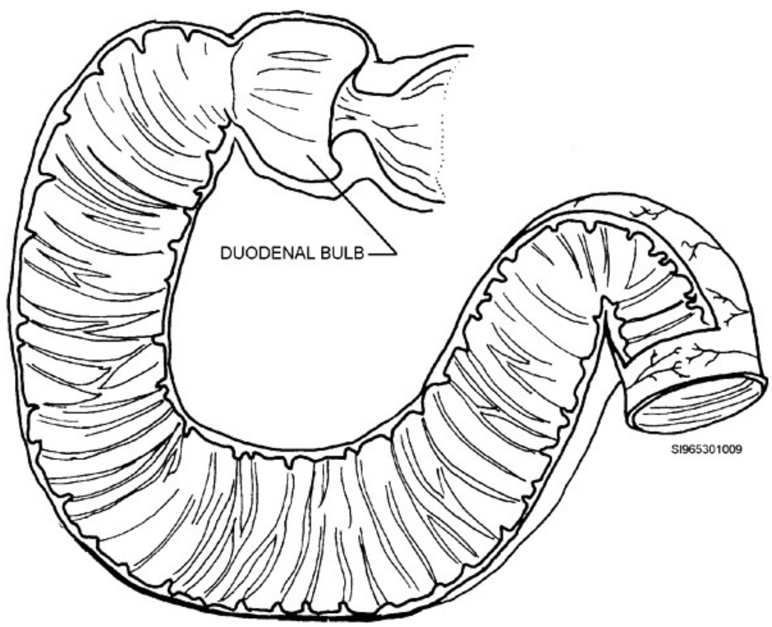

Figure 2–9. The duodenum.

Ileum

The third and *longest* portion of the small bowel, the *ileum*, is about 14 feet long and terminates at the *ileocecal valve*, which connects the ileum to the large bowel. The ileocecal valve, shown in figure 2–10, is especially significant radiographically; because, when visualized on a small bowel series, it generally marks the completion of the series.

Large bowel

The large bowel, or *colon*, is roughly horseshoe-shaped and extends from the ileocecal valve to the anus (fig. 2–10.). It is comprised of many small pouches, called *haustra*, that are caused by longitudinal bands that wrap around the bowel. The proximal portion of the large bowel is the *cecum*, which is located below the ileocecal valve. The cecum is about 2 ½ inches (or 6 cm) long, about 3 inches (or 7.6 cm) in diameter, and terminates in the appendix, or vermiform process.

Ascending colon

The *ascending colon* is that portion of the colon above the level of the ileocecal valve. It extends upward from the junction of the ileum and cecum, along the right side of the abdomen, and to the inferior surface of the liver. At this point, it turns anteriorly and medially to form the *right colic flexure* (previously known as the hepatic flexure)

Transverse colon

The *transverse colon* extends across the abdomen from the right colic (hepatic) flexure to the spleen. It passes over the descending segment of the duodenum, the pancreas, and the inferior margin of the stomach. At the level of the spleen it curves posteriorly and inferiorly to form the *left colic flexure* (previously known as the splenic flexure).

Descending colon

The *descending colon* extends downward from the left colic (splenic) flexure to the iliac fossa. From this point, it usually follows the inferomedial curvature of the ileum and joins with the *sigmoid colon.*

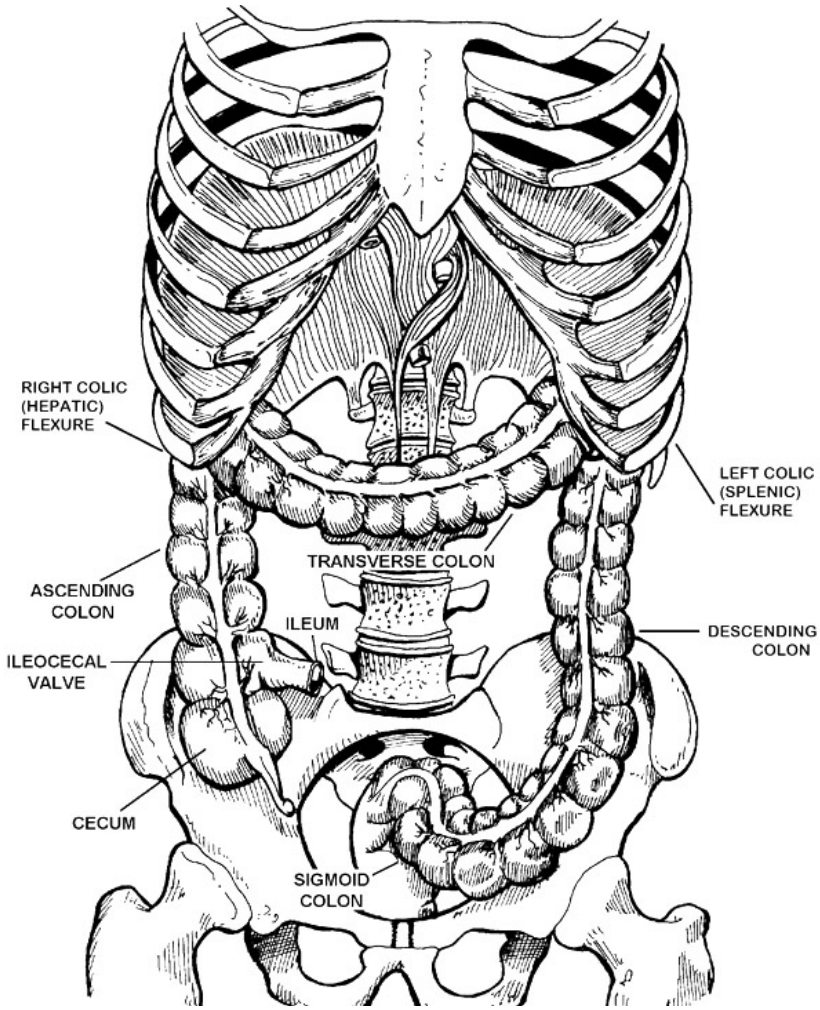

Figure 2–10. The large bowel.

Sigmoid colon

The term *sigmoid* means "shaped like the capitol Greek letter sigma" from which we get our letter S. The *sigmoid colon* is, of course, S-shaped. It dips into the pelvis, curving gently downward and toward the midline. Then it curves sharply upward and is slightly inclined toward the sacrum. At about the level of the third sacral segment, it curves posteriorly and joins with the *rectum*.

Rectum and anus

The rectum (fig. 2–11) extends downward, between the bladder and coccyx, and joins with the *anal canal*, which terminates in the *anus*—the distal orifice of the alimentary tract.

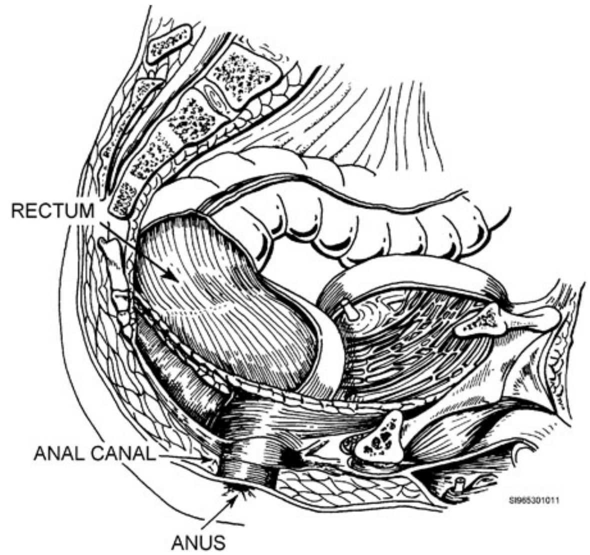

Figure 2–11. The rectum and anus.

809. Accessory organs of digestion principles

In the alimentary tract, several organs aid in digestion by producing and/or storing digestive juices. These are called the accessory organs of digestion; they include the salivary glands, liver, biliary system, and pancreas. Having already discussed the salivary glands, we proceed with the rest of the accessory organs of digestion, beginning with the liver.

Liver

An adult human liver weighs approximately 3.2 to 3.7 pounds. It is the largest gland (because it produces bile) in the body and the second largest organ of the body. It lies directly under the right hemidiaphragm and is divided into left and right lobes (fig. 2–12). On the medial side of the larger right lobe, two other minor lobes exist—the *caudate* (located on the right lobes posterior surface) and the *quadrate* (located on the inferior surface of the right lobe). The left lobe is small and wedge-shaped and is *separated* from the right lobe by the *falciform ligament*, which runs along the interlobar fissure.

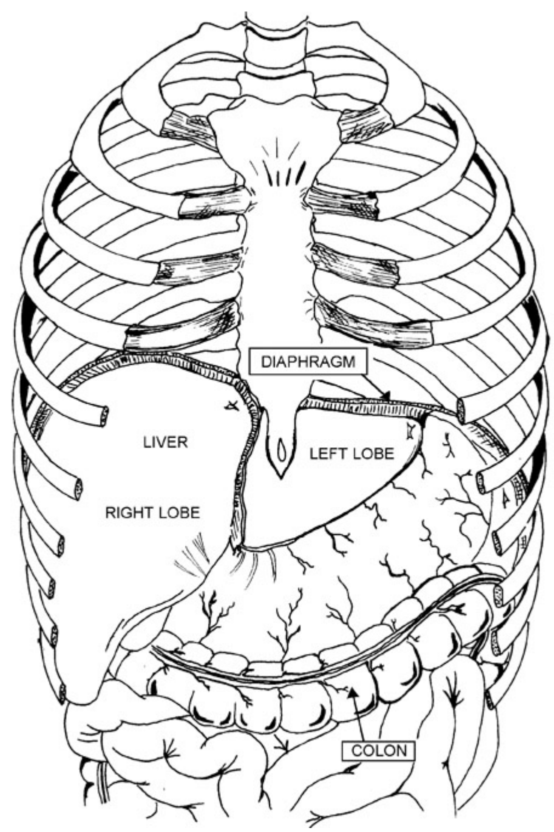

Figure 2–12. The liver.

Gallbladder and biliary system

The *gallbladder* (fig. 2–13) is on the inferior surface of the right and quadrate lobes of the liver. Its usual location is between the ninth rib and the iliac crest, but this varies greatly depending upon the patient's body habitus. The gallbladder has three main functions: store bile, concentrate bile, and contract when stimulated. Shaped like a pear, the gallbladder is a sac-like structure that stores bile for future use during the digestive process. When bile stays in the gallbladder for a longer period of time, it becomes more concentrated as a result of hydrolysis (removal of water). One of the problems associated with hydrolysis is if too much water is absorbed, the bile may become too concentrated and form stones (choleliths) in the gall bladder. When the gallbladder is stimulated, it contracts and releases some of the stored bile through the biliary ductal system.

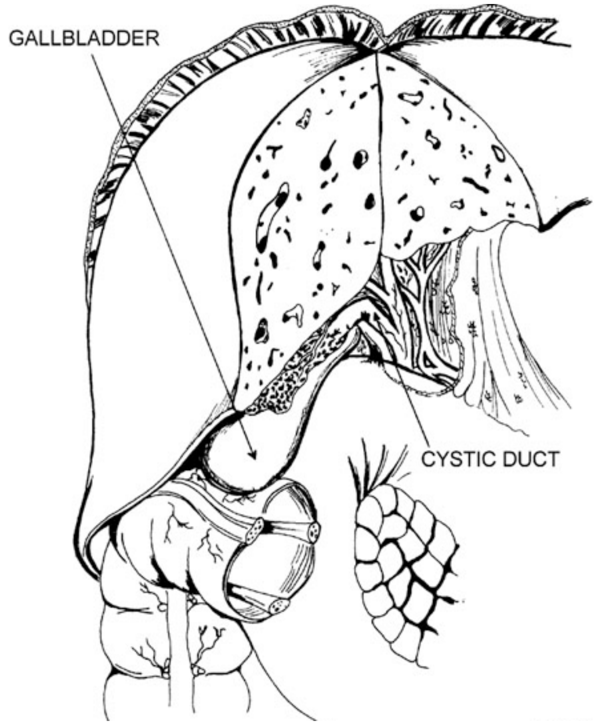

Figure 2–13. The gallbladder.

The biliary ductal system, illustrated in figure 2–14, is made up of the bile ducts found in the liver (called the *intrahepatic ducts*), *right* and *left hepatic ducts*, *common hepatic duct*, *cystic duct*, *common bile duct*, and *duodenal papilla*. The small intrahepatic ducts emanate from all lobules of the liver. They pass downward and inward following the blood vessels and empty into the larger right and left hepatic ducts. These larger ducts join to *form* the common hepatic duct. This duct descends to join the cystic duct from the gallbladder. These *combined* ducts then form the *common bile duct*. The common bile duct is about 3 inches (or 7.6 cm) in length. It descends on a slightly lateral course where it usually joins with the *pancreatic duct* to empty into the posterior wall of the duodenum through a common orifice at the *duodenal papilla*, a protrusion into the duodenal lumen. The pancreatic and the common bile ducts occasionally enter the duodenum separately. A sphincter muscle, the *sphincter of Oddi*, normally prevents reflux into the common bile and the pancreatic ducts.

Pancreas

The pancreas extends from the spleen across the abdomen to the “C-loop” of the duodenum (fig. 2–7). It is comprised of a tail, which lies against the spleen, a long, flat body, and an irregularly shaped head, which lies against the C-loop. The pancreatic duct extends from the tail through the midportion of the pancreas, through the head, and on to the duodenum. The *islets of Langerhans* are scattered throughout the pancreas and *produce insulin*. The pancreatic duct often *bifurcates* in the region of the head of the pancreas *and* gives rise to an accessory pancreatic duct, the *duct of Santorini*, which empties into the duodenum about 2.5 cm above the duodenal papilla.

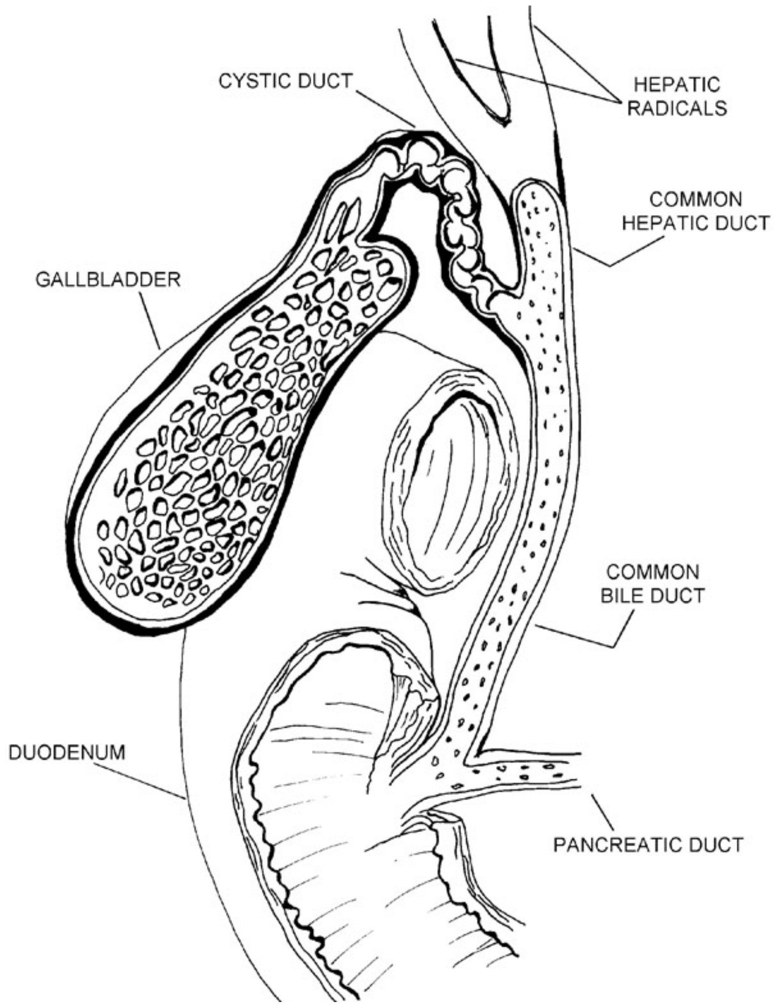

Figure 2–14. The biliary ductal system.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

807. The mouth, pharynx, and esophagus principles

1. Which bones comprise the hard palate?

2. What is the function of the soft palate during the swallowing process?

3. What two functions does saliva perform?

4. Match the salivary gland in column B with the appropriate description in column A. Each item in column B may be used more than once.

Column A	Column B
____1. Smallest salivary gland.	a. submandibular
____2. Empties via parotid duct.	b. parotid
____3. Located below and in front of each ear.	c. sublingual
____4. Empty into the mouth on either side of the frenulum of the tongue.	
____5. Empty via the ducts of Rivinus.	
____6. Located beneath the mucous membrane of the floor of the mouth.	
____7. Largest salivary gland.	

5. Which bony structures mark the superior and inferior borders of the pharynx?

6. Name the three parts of the pharynx.

7. Where does peristalsis begin?

8. Approximately, how long is the esophagus?

808. Stomach and intestines principles

1. On what curvature of the stomach is the sulcus intermedius located?

2. What notch is located on the lesser curvature of the stomach?

3. Name the two orifices of the stomach.

4. Name the three subdivisions of the stomach and indicate their relative location (proximal, middle, and distal).

5. Name the four body habitus.

6. In an individual of average build, at what level does the most inferior portion of the stomach lie?

7. The stomach lies highest in what body habitus?

8. Name the three portions of the small bowel and give their approximate lengths.

9. What is the C-loop?

10. Which structure connects the small intestine to the large intestine?

11. What are the small pouches of the large intestine called?

12. Name the nine divisions of the large bowel in order, from proximal to distal.

809. Accessory organs of digestion principles

1. Name the accessory organs of digestion.

2. Name the four lobes of the liver.

3. Which structure separates the right and left lobes of the liver?

4. Where is the normal location of the gallbladder?

5. Which two ducts combine to form the common bile duct?

6. Which muscle prevents reflux into the common bile and pancreatic ducts?

7. Which structures in the pancreas produce insulin?

8. What is the name of the accessory pancreatic duct that forms when the pancreatic duct bifurcates?

2–2. Contrast Studies of the Digestive System

This section covers various radiographic contrast studies of the digestive system to include sialography, esophagrams, upper GI, small bowel series, and barium enema (BE).

810. Contrast examinations of the salivary glands and proximal alimentary tract operating principles

Radiographic contrast examinations of the salivary glands are rarely performed anymore as CT and magnetic resonance imaging (MRI) are typically the modality of choice. For this reason, only a brief explanation of sialography is included along with our presentation of the proximal alimentary tract.

Sialography

The salivary ductal systems are demonstrated by injecting a contrast medium into the main duct of each gland opening into the mouth. The procedure is generally a simple one—your radiologist injects the contrast medium and you perform the necessary radiographs. Some radiologists prefer to fluoroscope the gland with spot images.

Special supplies

While the supplies used for a sialogram vary from one radiologist to the next, the following are frequently used:

- A small probe to locate and explore the main duct.
- A small gauge catheter or blunt needle.
- A syringe (2.5 or 5 cc capacity) with which to inject the contrast material.
- A local anesthetic, injectable or topical, to anesthetize the area about the main duct opening.
- A lemon cut in quarters.

The lemon can serve two purposes: (1) to stimulate the gland so that the duct opening can be easily located due to the discharge of saliva and (2) to evacuate the contrast material after the initial radiographs are obtained. A post-evacuation radiograph is usually made to check the degree of evacuation. If the contrast material is not completely evacuated before the patient leaves the department, the radiologist may ask the patient to continue stimulating the gland for one to three days using lemon slices, lemon juice, or chewing gum.

Sialography projections

The specific projections obtained for a sialogram vary with the gland being examined.

Either tangential projection, anterior-posterior (AP) or posterior-anterior (PA) is usually made if the parotid gland is being examined. The gland is located approximately midway between the anterior and posterior surfaces of the patient, so part-IR distance is the same for each projection. Adjust the head until the infraorbitomeatal line is perpendicular to the IR. Rotate the patient's face slightly toward the side being examined or until the parotid area is perpendicular to the IR. Direct the CR through the gland, perpendicular to the IR along the lateral edge of the mandibular ramus.

A true lateral projection may be requested in-order to visualize all the salivary glands. Extend the head slightly and adjust the skull into the true lateral position with the gland under examination nearest the IR. Direct the CR perpendicularly through the appropriate gland or one-inch superior to the mandibular angle. To visualize the parotid gland, rotate the patient's midsagittal plane 15 degrees toward the IR and center the CR one-inch superior to the mandibular angle.

Proximal alimentary tract

Contrast studies of the proximal alimentary tract (pharynx and esophagus) are often performed in conjunction with an upper GI series to evaluate swallowing difficulty. The radiologist will most times use the fluoroscopy machine to take spot images in rapid secession when imaging this area of anatomy. Our discussion is directed toward post-fluoro radiography and the projections that are usually made.

Pharynx

Radiographic examination of the pharynx involves AP and lateral radiographs that are made as the patient swallows a barium sulfate preparation. Radiographs of the oro- and laryngopharynx using barium sulfate are somewhat difficult to make because the bolus descends quickly through the area during deglutition (the act of swallowing). Because of this, many technologists tend to be late with their exposure. Also, the patient may not respond promptly to your instruction to swallow, which can cause you to make the exposure too early. One of the best ways to time the exposure to coincide with the barium-filled pharynx is to watch the patient's thyroid cartilage. During deglutition the thyroid cartilage moves up and forward and then relaxes back to its normal position when the process is completed. Make your exposure immediately when the cartilage reaches its most anterosuperior position. At that instant, the oropharynx and laryngopharynx are usually filled with barium sulfate. The posterior portion of the oral cavity is also well visualized at the peak of the swallowing process.

Esophagus

You make most radiographic examinations of the esophagus after the fluoroscopic phase of an upper GI series.

Some radiologists include a radiograph of the entire esophagus in the routine post-fluoro upper GI images. Usually, you make the projection with the patient recumbent in the right anterior oblique (RAO) position because this position presents a larger space between the heart and spine and, consequently, permits a more unobstructed view of the lower esophagus. The entire esophagus can usually be demonstrated filled with barium solution if the patient is allowed to drink the liquid barium sulfate through a straw continuously (drinking esophagram), beginning four or five seconds before the exposure. Of course, the exposure can be made after the patient swallows a single mouthful of liquid or paste barium, but demonstration of the entire esophagus filled with barium is difficult. A commercially prepared barium paste usually shows the outline of the entire esophagus due to the special coating characteristics of the medium, but the entire esophagus is not filled.

Cardiac series

You make radiographic projections of the esophagus to demonstrate enlargement of the heart with the patient erect, at a 72-inch source-to-image distance (SID), and after full inspiration to reduce magnification and distortion. The size of the heart is evaluated on the radiographs in addition to possible displacement of the esophagus as a result of heart enlargement. Also, the pulmonary structures are evaluated because pulmonary changes may occur with heart enlargement.

Four projections of the chest with a barium-coated esophagus are usually made for a cardiac series—PA, left anterior oblique (LAO), RAO, and left lateral. The left lateral is made as opposed to the right lateral to minimize the object-to-image distance and the resulting magnification. The degrees of rotation for the obliques vary slightly among radiologists; however, the RAO is *usually* 45 degrees, while the LAO is *normally* 55 to 65 degrees. The reason the degree of rotation is different for each oblique is because the heart is located somewhat to the left of the midline. Therefore, the LAO requires more rotation to project the heart clear of the spine.

You can obtain better results if you use a commercial barium sulfate paste with special coating properties for the cardiac series. Most radiologists can evaluate the esophagus if it is outlined by the paste as opposed to being filled with a liquid barium solution. The exact timing of the exposure is largely a matter of personal preference on the part of the technologist. It also depends on the thickness of the paste and cooperation of the patient. Some technologists ask the patient to swallow a mouthful of paste and immediately take a breath—the exposure is made either immediately after the breath, or after a delay of one to four seconds. The time lapse depends upon the thickness of the paste. Other technologists have the patient swallow one mouthful of paste, give the patient another mouthful to hold, and then repeat the above procedure. The first mouthful increases the possibility for good esophageal coating.

Two other factors should be considered while performing this examination. First, the exposure factors should be increased slightly over normal chest techniques to permit visualization of the lower esophagus. Second, displacement of the esophagus by the great vessels is usually evaluated, so it is important to outline the middle third of the esophagus as well as the distal third. Some radiologists do not care about the demonstration of the proximal third when a cardiac series is performed.

811. Upper gastrointestinal series operating principles

The standard upper GI series is an examination of the stomach and duodenum. It is made by a combination of fluoroscopy, spot images, and “overhead” radiographs. Our discussion will primarily focus on the post-fluoroscopy “overhead” radiographs.

Aiding gastric evacuation

Sometimes during the fluoroscopic phase of the examination, the contrast medium is slow to empty into the duodenum, preventing visualization of the duodenal bulb and the remainder of the duodenum. When this situation arises, have the patient lay in either the RAO or right lateral oblique (RLO) position. The effect of peristalsis is maximized in these positions due to the influence of gravity and stomach evacuation is accelerated.

Hypotonic duodenography

Hypotonic duodenography is an examination of the duodenum without interference from peristalsis. It enables the radiologist to evaluate the mucosa of the duodenum more effectively. The examination is often performed in conjunction with a standard upper GI series, or it may be ordered independently.

Following the administration of the contrast medium, the patient is given an injection of probanthine (Glucagon) or a similar drug that temporarily decreases the muscle tone of the duodenal walls and dilates the duodenum. The radiologist may or may not require follow-up images, but almost always records the duodenum using the fluoroscopy unit.

A potential side effect stemming from the injection of probanthine is loss of control of the voluntary muscles, including control of the respiratory muscles, which can result in *respiratory arrest*. If this condition occurs, artificial respiration must be administered until the effects of the drug have subsided. Consequently, your emergency tray containing resuscitation equipment should be readily available.

Overhead projections

The specific follow-up, or overhead, projections for an upper GI series vary among radiologists. However, five such projections are commonly performed. We discuss them from the aspect of the anatomy demonstrated. The duodenum is fairly well demonstrated in most of the projections (with the exception of the bulb), as will be noted.

1. The PA projection shows the general contour of the stomach and duodenal bulb. If taken erect, it also reveals the shape and relative position of the stomach.
2. The left posterior oblique (LPO) shows an air-contrast view of the body, pylorus, and duodenal bulb. The fundus is shown filled with barium sulfate.
3. The RAO, on all patients *except* the hypersthenic individual, provides the best demonstration of the pylorus and duodenal bulb. The degree of obliquity required presenting the pylorus and bulb in profile (which shows them best) depends upon the size, shape, and position of the stomach. Some radiologists request a standard 45 degrees oblique while others want two or more obliques with varying degrees of rotation.

4. The right lateral projection provides a profile view of the pylorus and duodenal bulb in a *hypersthenic* individual because those parts are usually aligned in an anteroposterior direction. This patient is sometimes referred to as having a *posterior bulb*.
5. The upright left lateral is the best projection to show the relationship between the stomach and retrogastric structures.

812. Contrast examinations of the small bowel operating principles

There are three methods by which contrast examination of the small bowel is performed. They are categorized according to the method of contrast medium administration, specifically: oral, intubation, and retrograde.

Oral method

The oral method is often done in conjunction with an upper GI series and is termed a small bowel series (or small bowel follow-through) The progress of the barium sulfate through the small intestine is simply followed by taking identical 14×17 inch collimated PA or AP abdominal radiographs at specific time intervals as determined by your radiologist. Use the supine (AP) position to allow the barium-filled stomach to slide superiorly and laterally to visualize the retrogastric portions of the duodenum and jejunum and prevent compress of the small bowel. If the greatest radiographic quality is desired, use the prone (PA) position to actually compress the abdominal structures.

A common protocol is to take a radiograph every 20 minutes for the first hour, every 30 minutes for the second hour, and every hour thereafter, if necessary. Always use a lead time-marker to show the amount of time that has passed from ingestion of the barium to when the image was created. Computerized annotation on digital images is not acceptable in a court-of-law. Some radiologists evaluate each image immediately so that they can examine the patient under fluoroscopy if a suspicious area is seen. Radiographs are taken until contrast medium is demonstrated passing through the ileocecal valve into the large bowel (colon). At that time, the radiologist usually examines the patient fluoroscopically taking spot images of specific small bowel structures when appropriate.

In addition to demonstrating anatomy of the small bowel, the oral method is also used to evaluate the motility (function) of the small bowel. The radiologist determines the motility of the stomach and small bowel in two ways by evaluating the amount of time for the stomach to empty and by evaluating the time required for the barium to reach the colon. For these reasons, always include the stomach and lead-time markers on each of your 14x17 collimated abdominal radiographs.

Occasionally, the radiologist may wish to speed the motility of the small intestine in patients whose transit time exceeds three to four hours. Methods used to *accelerate* peristalsis include giving the patient a glass of ice water, cold saline, or water soluble oral contrast. Some medications also stimulate peristalsis.

If a considerable amount of saline or water is given, the contrast medium tends to become diluted; consequently, some structural details are lost. However, this method does reduce the transit time considerably, allowing the barium to reach the colon quicker—thus reducing the overall time for the examination. Also, the radiologist can more readily follow the head of the column of barium fluoroscopically. Of course, normal stomach evacuation and transit time are not evaluated with this method.

Intubation method

If the contrast medium cannot be administered orally as in the previously described method, it may be given through a tube introduced into the small bowel. Intubation has a definite advantage over other types of small bowel examinations in that the contrast medium can be introduced directly into a specific segment of small bowel. This allows visualization of the segment under study without superimposition of other portions of the small bowel. The tube is generally introduced by the nasogastric route into the small bowel, but may also be introduced percutaneously (by gastrostomy).

Retrograde method

Most rarely performed is the retrograde (reflux) method of small bowel examination. The contrast medium is introduced during a large volume BE. The reflux of the contrast medium through the ileocecal valve enables the small bowel to be demonstrated. This method is usually utilized to detect organic filling defects.

813. Contrast examinations of the colon operating principles

Two types of radiographic examinations are performed on the large bowel: the single contrast BE and double-contrast BE. One of two methods, direct or two-stage, may perform the double-contrast or air-contrast study.

Preparation of the barium solution for barium enemas

Prepare the barium sulfate solution for a colon examination according to established departmental procedures. Most radiologists prefer the solution to be warm—85°F or slightly warmer. A few want the temperature to be considerably colder—around 40°F. If the cooler temperature is desired, you either have to mix the preparation in advance and refrigerate it, or mix the barium sulfate with refrigerated water. In either case, to ensure the correct temperature, use a thermometer rather than estimating the temperature. Also, keep in mind that if the solution is left standing for a long time, it will approach room temperature. For this reason, it is usually best to mix the solution immediately before each examination. However, if this is not possible, place the solution container in water of the appropriate temperature until you are ready to use it.

The thickness of the barium sulfate solution for a colon examination also varies. The ratio of barium sulfate to water ranges from one part barium to four to eight parts water by volume. The most important factor when preparing barium is *consistency from one batch to another*. This means you should have a reliable means of measuring both parts of the mixture so that the thickness can be repeated day after day. The usual procedure calls for adding a certain amount of water to a disposable BE bag and then agitating the bag until the barium sulfate is in solution.

NOTE: Make sure to shake the BE bag solution again just prior to the start of the exam procedure.

Most radiologists prefer using premixed, high-density barium sulfate for air-contrast BEs. Premixed liquid barium products are more consistently mixed by the manufacturer, more uniform than barium suspensions mixed in a radiology department, and better for air-contrast BEs because the premixed liquid is thicker and provides excellent coating of colon walls. A disadvantage of these preparations is their slightly increased cost over barium powder.

Whether a premixed liquid or a regular powdered barium sulfate is used is a radiologist preference however whichever is chosen and at whichever temperature, the solution must flow sufficiently to coat the walls of the colon. Sometimes the patient's colon may spasm during the administration of the barium and the procedure itself. If spasms occur, your radiologist may make the decision to mix a topical anesthetic (like lidocaine) to the contrast media or administer glucagon intravenously.

Barium enema bags

Most departments use disposable BE bags with special tips that include a retention balloon. The purpose of the retention balloon is to help patients hold the tip in place in the rectum and prevent contrast leakage out the anus throughout the procedure. Foam tape is also useful to secure the BE tip in the patient's rectum so to avoid accidental expelling of the BE tip. To insert the tip, the patient is placed into the Sim's position (recumbent on the left side, leaning forward slightly, and raising and bending the right knee to rest it on the table). Prime the contrast into the BE bag tube while repositioning the slide-clamp towards the tip end of the tube (approximately four inches from the tip). This reduces the amount of unnecessary air induced into the patient's colon. To insert the BE bag tip into the patient's rectum, first apply ample surgical lubricant to the enema tip to make inserting the tip through the anal sphincter easier. Instruct the patient to try and relax and take slow deep breaths.

Insert the tip slowly and gently, anteriorly for the first 1½ inches, and then superiorly (as if aiming for the umbilicus). The tip should extend into the rectum approximately three to four inches.

At this point, inflate the retention balloon if one is used. Some radiologists prefer to do inflate the retention balloon under fluoroscopic guidance to reduce the possibility of damage to the rectum. In any event, inflate the balloon slowly using the squeeze inflator provided with the enema kit. The inflators are designed to introduce the appropriate amount of air in a single squeeze. Once the balloon is inflated, engage the plastic clamp and engage a hemostat on the air tube to prevent it from deflating. Since the balloon is inflated just proximal to the anal sphincter, patients will feel the urge to defecate. It is important to explain this feeling to them and encourage them to not push the BE tip out of their rectum. Instruct them to continue taking slow deep breaths to help ease any discomfort.

Procedures

There are two types of large bowel procedures commonly performed: the single-contrast BE and the double-contrast BE.

Single-contrast barium enema

The single contrast BE is a relatively simple procedure in which an amount of barium is introduced into the colon sufficient to fill the entire colon. The radiologist takes spot images of the colon, rotating the patient to better visualize each segment. Next, the technologist performs the required overheads. When finished, as much of the barium solution as possible is drained back into the bag, the tip is removed, and the patient is placed on a bedpan or taken to a toilet. In most cases, a post-evacuation image is obtained to demonstrate the colon's ability to evacuate.

Double-contrast barium enema

Double-contrast BE studies employ a positive contrast medium (barium) and a negative contrast medium (air). When *evaluating* for polyps and diverticulitis, double-contrast studies are the exam of choice. Thick barium is used in conjunction with air for optimal imaging. Patients must be properly prepped for double-contrast studies because it is essential that the colon (large bowel) is clear of all fecal material.

Two-stage procedures

The two-stage method of air-contrast examinations is performed to demonstrate neoplasms and polyps that typically form on the inner walls of the large bowel. In the first stage, thick barium is introduced and allowed to fill the descending colon. Air is then used to push the barium across the transverse colon and into the ascending colon. Once the radiologist visualizes barium throughout all areas of the colon, the BE bag is placed at a level below the rectum and the plastic clamp is disengaged allowing any excess barium to drain out of the colon.

During the second-stage, more air (or gas) is introduced into the colon under fluoroscopic guidance to ensure the air column stays behind the barium. The large quantity of air introduced during this stage finishes moving the remaining barium throughout the colon and forces the barium to adhere to the walls (and mucosal lining) of the large bowel.

Single-stage procedure

A single-stage procedure is simply where the barium and air are introduced simultaneously into the colon to reduce the overall procedure time and radiation exposure to the patient. To reduce further the amount of contrast needed to coat the colon walls and time needed to move the contrast throughout the colon, the patient can be placed in the following positions: the Trendelenburg position, both lateral positions, and various oblique positions.

The major difference between the single and two-stage methods is that with the single-stage method, the barium solution is not evacuated before the air is introduced. Again, it is important that the patient’s colon be exceptionally clean to avoid fecal material obscuring small polyps or other unwanted pathology.

Fluoroscopic images

With both the procedures discussed above, your radiologist will take “spot” images of specific colon structures and of any area that looks suspicious for a pathologic finding. During fluoroscopy, it is common for the patient to be asked to roll or rotate to varying oblique positions to better demonstrate anatomy free of superimposition or to better distribute the air/barium mixture. Your role is to ensure the patient moves around on the table safely and achieves the desired position in a timely fashion. Use good communication skills to give clear, concise instructions to the patient. Lastly, don’t forget to assist the movement of the BE bag while the patient is moving to ensure the tip doesn’t accidently get prematurely expelled from the rectum.

Overhead projections

Most radiologists have a standard set of BE overhead images for you to perform prior to allowing the patient to evacuate the contrast media from their colon. These overhead images may be adjusted according to the fluoroscopic findings. Several projections are usually performed. As a rule, the IR (collimated to a 14 x 17 inch exposure field) should be centered to the iliac crest for all projections, except for those indicated below. Also, when a large patient is examined, it may be difficult or impossible to include the entire colon on a single image. When this is the case, take two exposures with the IR orientated crosswise instead of one lengthwise for the AP or PA projections. Oftentimes though, you can include the entire colon on the obliques even though it may not be possible on the PA or AP projections.

When performing air-contrast radiographs, you should rotate the patient 360 degrees before performing each radiograph to recoat the walls of the colon with barium solution. For example, if the patient is supine and you wish to perform a right lateral decubitus, rotate the patient 360 degrees to the supine position before turning the patient on the right side for the lateral decubitus projection.

PA, AP, and 45 degrees anterior or posterior oblique projections are usually included when radiographing the colon. On the PA and AP radiographs, the right and left colic flexures and the sigmoid colon are usually not well visualized because the loops are overlapped. The LPO or RAO usually provides an unobstructed view of the right colic (hepatic) flexure, while the RPO or LAO does the same for the left colic (splenic) flexure.

A lateral projection of the rectum is also frequently performed. For this projection, position the patient so the midcoronal plane of patient is centered to the IR. Whether a right or left lateral is performed is up to department policy or radiologist preference. Direct the CR perpendicularly through a point on the midcoronal plane at the level of the anterior-superior iliac spine (ASIS).

To demonstrate the sigmoid colon and rectum, utilize the LPO position (35 to 45 degrees angulation) and direct the CR perpendicular approximately two inches lateral of the ASIS at the level of the iliac crest. In addition to the LPO position, an AP axial projection is typically performed. Position the patient supine and direct the CR 30 to 40 degrees cephalic (caudal for the PA) to a point approximately two inches inferior to the level of the ASIS.

The *Chassard-Lapine method* demonstrates the coils of the sigmoid colon and rectum free of superimposition (fig. 2–15). The Chassard-Lapine method can be performed before or after the patient is allowed to expel the contrast medium. To perform, seat the patient on the side of the table and have him or her abduct the femurs so they will not interfere with the flexion of the patient’s body. Have the patient lean forward as far as possible and hold the ankles for support. Direct the CR perpendicularly through the midline of the lumbosacral region at the level of the greater trochanters to the center of the IR. The exposure for this procedure should be approximately the same as that required for a lateral projection of the rectum.

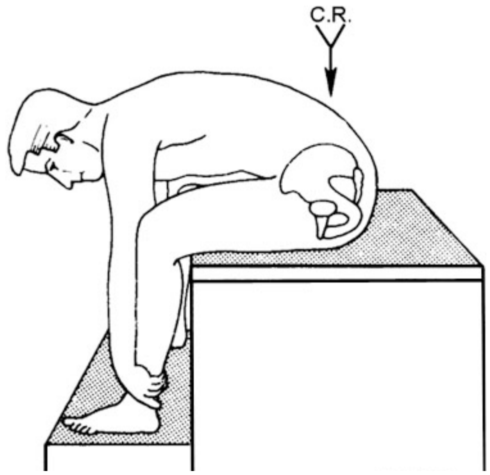

Figure 2–15. Chassard-Lapine projection.

To demonstrate air/fluid levels during a double-contrast BE, use a horizontal CR to perform decubitus images. On occasion, an upright AP or PA projection may be requested; if so, make sure to account for the effects of gravity and center the IR at a lower level. Lastly, keep in mind that even though the thickness of an abdomen is the same, you should reduce your exposure slightly when performing air-contrast projections because of the radiolucency of air.

814. Basics of the contrast examinations of the biliary system

Ultrasound (sonography), CT, MRI, and nuclear medicine have all improved the technique visualization of the gallbladder and biliary system. Sonography though, is by far the imaging venue of choice for gallbladder and biliary tract conditions.

Terminology

There are some specific terms used in reference to the biliary system. *Chole* refers to bile therefore a cholegraphy is a basic radiographic examination of the biliary system. *Cysto* refers to being a bag or sac therefore *a* cholecystography is an examination of the gallbladder. *Cholangio* refers to the bile ducts therefore cholangiography is the overall radiographic examination of the biliary duct system.

Procedures

In previous years, the gallbladder was radiographically imaged with the use of a specific oral contrast medium during an oral cholecystogram or OCG. With advancements in sonography and the fact that the specific type of oral contrast used for imaging the gallbladder is no longer produced, the OCG has been replaced by other direct injection procedures that show the biliary system. The percutaneous transhepatic cholangiography, the postoperative cholangiography, and the endoscopic retrograde cholangiopancreatography (ERCP) are typical exams performed during and after gallbladder surgery to visualize the biliary system.

Percutaneous transhepatic cholangiography

The percutaneous transhepatic cholangiography is a procedure performed preoperatively of the biliary system. When this exam is performed, it is typically to place a drainage catheter used to treat obstructive jaundice due to an obstruction. The procedure is performed by inserting a “skinny” needle through the patient’s right lateral intercostal space into the hilum of the liver. With the use of fluoroscopy, contrast media is used to visualize the biliary tree.

Postoperative cholangiography

The postoperative cholangiogram (also known as the T-tube cholangiogram) is performed to visualize the patency of the ductal system, the functionality of the hepatopancreatic ampulla sphincter, to locate any leftover stones, and identify further pathology. The reason this exam is also known as the T-tube cholangiogram is because the exam is completed by using the "T" shaped tube that is surgically placed in the common hepatic and common bile ducts for postoperative drainage. The radiographic exam is performed under fluoroscopy by *injecting a water-soluble* iodinated contrast medium directly into the ductal system by means of the T-tube left in place after the cholecystectomy (surgical removal of the gallbladder) procedure.

Endoscopic retrograde cholangiopancreatography

The ERCP is a procedure performed to look for pathology in the biliary system and the pancreas. To perform this exam, a physician uses a fiber optic endoscope to inject contrast media into the common bile duct. The endoscopic is inserted through the mouth, into the stomach, and eventually into the duodenum. Once there, the physician visually locates the hepatopancreatic ampulla (ampulla of Vater). A small tube is then passed through the endoscope and inserted into the ampulla. Once is place, the contrast is injected in the common bile duct by means of the tube.

NOTE: Patients must be closely monitored for adverse contrast media reactions during an ERCP. Always make sure emergency medical equipment and supplies are readily available.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

810. Contrast examinations of the salivary glands and proximal alimentary tract operating principles

1. What two-fold purpose does the lemon serve during sialography?

2. Which salivary gland is demonstrated with an AP or PA tangential projection?

3. Which position can be used to demonstrate all salivary glands?

4. When performing contrast examinations of the pharynx, how should you time the exposure to ensure there is contrast in the pharynx?

5. If you want to visualize the entire esophagus filled with barium solution, which technique should be used?

6. Why should esophagrams for heart evaluation be made with the patient upright, at a 72-inch SID, and on full inspiration?

7. What four projections are usually included in a cardiac series?

8. Why does the LAO require more rotation than the RAO?

9. Which type of barium preparation is best for a cardiac series?

811. Upper gastrointestinal series operating principles

1. Which two positions may be used to accelerate stomach evacuation during an upper GI?

2. What is hypotonic duodenography?

3. What potential side effect must we be alert for during hypotonic duodenography?

4. Which upper GI projection provides the best view of the duodenal bulb on all patients except the hypersthenic individual?

5. Which projection is best for showing the relationship between the stomach and retrogastric structures?

812. Contrast examinations of the small bowel operating principles

1. When exposing the time-lapsed abdominal radiographs, which view would be appropriate if you want to visualize the barium-filled stomach to slide superiorly and laterally?

2. Why should you always use lead-time markers on your small bowel abdominal radiographs?

3. Abdominal radiographs are taken until the contrast media passes through what anatomical structure of the bowel?

4. How does the radiologist evaluate the motility of the stomach and small bowel?

5. When contrast cannot be administered orally, what advantage is there to the intubation method?

6. Why is the retrograde method usually utilized?

813. Contrast examinations of the colon operating principles

1. What is the most important factor when preparing barium solutions?
2. Why do most radiologists prefer using premixed liquid barium for air-contrast BEs?
3. What is the purpose of the retention balloon on the tip of BE bag and tube?
4. Describe the Sim’s position.
5. How is the BE bag tip inserted into the patient’s rectum?
6. For a single contrast BE, why is a post-evacuation image obtained?
7. When polyps and diverticulitis are being evaluated for, which BE exam is the exam of choice?
8. What is the major difference between the direct and two-stage methods of the BE?
9. When the radiologist is taking the fluoroscopic images, why would the patient be asked to roll or rotate to varying oblique positions?
10. What parts of the colon are not well visualized on the AP and PA projections?
11. If you want to visualize an unobstructed view of the left colic flexure, which projection should you perform?
12. How should the CR be angled to demonstrate the sigmoid colon with the patient supine?

13. Which exam would you perform if your radiologist wants to visualize the coils of the sigmoid colon and rectum free of superimposition?

814. Basics of the contrast examinations of the biliary system

1. Which term refers to the overall radiographic examination of the biliary duct system?

2. What type of biliary tree exam uses a “skinny” needle that is inserted through the patient’s right intercostal space to access the hilum of the liver?

3. Why is the T-tube cholangiogram performed?

4. During an ERCP, which device does the physician use to inject contrast media into the common bile duct?

Answers to Self-Test Questions

807

1. The maxillae and palatine bones.
2. It elevates during the process of swallowing to separate the nasal cavity and nasopharynx from the oral cavity and oropharynx.
3. It moistens food and begins the process of digestion.
4. (1) c.
   (2) b.
   (3) b.
   (4) c and a.
   (5) c.
   (6) c.
   (7) b.
5. The inferior portion of the skull and the level of the sixth cervical vertebra.
6. The nasopharynx, oropharynx, and laryngopharynx.
7. In the esophagus.
8. It is approximately 10 inches (or 24 cm) long.

808

1. The greater curvature.
2. The incisura angularis.
3. The cardiac orifice and the pyloric orifice.
4. Proximal, the fundus; middle, the body; distal, the pylorus.
5. Sthenic, hypersthenic, hyposthenic, and asthenic.
6. The iliac crest.

7. Hypersthenic.
8. Duodenum–8 to 10 inches, jejunum-7 to 8 feet, ileum–14 feet.
9. The proximal half of the duodenum.
10. The ileocecal valve.
11. Haustra.
12. Cecum, ascending colon, right colic (hepatic) flexure, transverse colon, left colic (splenic) flexure, descending colon, sigmoid colon, rectum, and anus.

809

1. The salivary glands, liver, biliary system, and pancreas.
2. The right, left, caudate, and quadrate lobes.
3. The falciform ligament (or interlobar fissure).
4. The inferior surface of the right lobe of the liver, between the ninth rib and the iliac crest but this varies greatly depending upon the patient's body habitus.
5. The common hepatic and cystic ducts.
6. The sphincter of Oddi.
7. The islets of Langerhans.
8. The duct of Santorini.

810

1. It stimulates the gland so that the duct opening can be easily located and it evacuates the contrast material after the initial radiographs are obtained.
2. The parotid.
3. A true lateral.
4. Make your exposure immediately when the thyroid cartilage reaches its most anterosuperior position.
5. Have the patient drink the liquid barium sulfate through a straw continuously beginning four or five seconds before the exposure.
6. To reduce magnification and distortion.
7. PA, LAO, RAO, and left lateral.
8. Since the heart is located somewhat to the left of midline, the LAO requires more rotation to project the heart clear of the spine.
9. Barium sulfate paste.

811

1. Right anterior oblique or right lateral.
2. An examination of the duodenum without interference from peristalsis in which the patient is given an injection of pro-banthine (Glucagon) to temporarily decrease the muscle tone of the duodenal walls and dilates the duodenum.
3. Loss of control of the voluntary muscles including control of the respiratory muscles, which can result in respiratory arrest.
4. The RAO.
5. The upright left lateral.

812

1. AP.
2. To show the amount of time that has passed from ingestion of the barium to when the image was created.
3. The ileocecal valve.
4. By evaluating the amount of time for the stomach to empty and by evaluating the time required for the barium to reach the colon.
5. It allows visualization of the segment under study without superimposition of other portions of the small bowel.

6. To detect organic filling defects.

813

1. Consistency from one batch to another.
2. Premixed liquid barium products are more consistently mixed by the manufacturer, more uniform than barium suspensions mixed in a radiology department, and better for air-contrast BEs because the premixed liquid is thicker and provides excellent coating of colon walls. Is to help patients hold the tip in place in the rectum and prevent contrast leakage out the anus throughout the procedure.
3. Is to help patients hold the tip in place in the rectum and prevent contrast leakage out the anus throughout the procedure.
4. The patient is recumbent on the left side, leaning forward slightly with the right knee raised and bent to rest on the table.
5. To insert the BE bag tip into the patient’s rectum, first apply ample surgical lubricant to the enema tip to make inserting the tip through the anal sphincter easier. Instruct the patient to relax and take slow deep breaths. Insert the tip slowly and gently, anteriorly for the first 1½ inches, and then superiorly (as if aiming for the umbilicus). The tip should extend into the rectum approximately three to four inches.
6. To demonstrate the colon’s ability to evacuate.
7. Double-contrast BE.
8. With the single-stage method, the barium solution is not evacuated before the air is introduced.
9. To better demonstrate anatomy free of superimposition or to better distribute the air/barium mixture.
10. The right and left colic flexures and the sigmoid colon.
11. The RPO or LAO.
12. 30 to 40 degrees cephalic.
13. The Chassard-Lapine.

814

1. Cholangiography.
2. Percutaneous transhepatic cholangiography.
3. To visualize the patency of the ductal system, the functionality of the hepatopancreatic ampulla sphincter, to locate any leftover stones, and identify further pathology.
4. An endoscope.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

Do not return your answer sheet to AFCDA.

20. (807) Which structure separates the nasal cavity and nasopharynx from the oral cavity and oropharynx during the swallowing process?
    a. Epiglottis.
    b. Soft palate.
    c. Hard palate.
    d. Septal cartilage.

21. (807) Which salivary glands are located in the superior-posterior aspect of each cheek?
    a. Parotids.
    b. Sublingual.
    c. Subparotids.
    d. Submandibular.

22. (807) Which structure serves as a passageway for both food and air?
    a. Oropharynx.
    b. Nasopharynx.
    c. Proximal trachea.
    d. Proximal esophagus.

23. (807) In what portion of the digestive system does peristalsis begin?
    a. Pharynx.
    b. Stomach.
    c. Esophagus.
    d. Duodenum.

24. (808) Which structure is located on the *lesser* curvature of the stomach?
    a. Cardiac notch.
    b. Angle of Treitz.
    c. Incisura angularis.
    d. Sulcus intermedius.

25. (808) What is the *distal* opening of the stomach called?
    a. Antrum.
    b. Pyloric orifice.
    c. Cardiac orifice.
    d. Duodenal papilla.

26. (808) The thick folds located throughout the internal surface of the stomach are called
    a. gyri.
    b. villi.
    c. rugae.
    d. haustra.

27. (808) Which portion of the colon is *between* the cecum and the right colic flexure?
    a. Sigmoid.
    b. Ascending.
    c. Transverse.
    d. Descending.

28. (809) Which structure does the joining of the cystic duct and common hepatic duct form?
    a. Gallbladder.
    b. Pancreatic duct.
    c. Ampulla of Vater.
    d. Common bile duct.

29. (810) A lemon is used during a sialography study to
    a. reduce salivation and keep the duct openings closed for imaging.
    b. stimulate the gland so the duct openings can be located.
    c. improve the taste of the contrast agent.
    d. act as a local anesthetic.

30. (810) To demonstrate the entire esophagus on a drinking esophagram, you make the exposure
    a. as soon as the patient begins drinking.
    b. one to two seconds after the patient begins drinking.
    c. four to five seconds after the patient begins drinking.
    d. after the patient has finished an entire eight ounce cup of barium.

31. (810) Which obliques are *normally* included as part of a cardiac series?
    a. 45º RAO, 45º LAO.
    b. 45º RAO, 55º to 65ºLAO.
    c. 45º RPO, 45º LPO.
    d. 45º RPO, 55º to 65ºLPO.

32. (811) Which position should be used to *speed* stomach evacuation during an upper gastrointestinal (GI) series?
    a. Upright RAO.
    b. Upright LAO.
    c. Recumbent RAO.
    d. Recumbent LAO.

33. (811) Which condition may occur as a result of administering Probanthine for hypotonic duodenography?
    a. Hypotension.
    b. Hypertension.
    c. Respiratory arrest.
    d. Pulmonary edema.

34. (811) Which upper GI projection provides a profile view of the pylorus and duodenal bulb in a *hypersthenic* patient?
    a. PA.
    b. LAO.
    c. RAO.
    d. Right lateral.

35. (811) Which upper GI projection best shows the relationship between the stomach and retrogastric structures?
    a. RAO.
    b. RPO.
    c. Right lateral.
    d. Upright left lateral.

36. (812) When performing a small bowel series using the oral method, radiographs are taken until contrast medium is demonstrated in the
    a. ileum.
    b. colon.
    c. rectum.
    d. jejunum.

37. (812) What method of small bowel examination is used to evaluate *motility* of the small bowel?
    a. Oral.
    b. Intubation.
    c. Retrograde.
    d. Hypotonic duodenography.

38. (813) An advantage of using premixed liquid barium for air-contrast barium enemas is that it
    a. is water-soluble.
    b. is less expensive than powdered barium.
    c. provides better coating of the colon walls.
    d. has better photon absorption properties than powdered barium.

39. (813) Which barium enema projection provides an unobstructed view of the right colic flexure?
    a. PA.
    b. LPO.
    c. RPO.
    d. Left lateral decubitus.

40. (813) The Chassard-Lapine method is used to demonstrate the
    a. splenic flexure.
    b. hepatic flexure.
    c. cecum and appendix.
    d. sigmoid colon and rectum.

41. (814) If you are performing a cholecystography exam, what anatomy is being visualized?
    a. Pancreas.
    b. Bile ducts.
    c. Gallbladder.
    d. Biliary system.

42. (814) What type of contrast medium is used for T-tube cholangiograms?
    a. Oral cholecystopaques.
    b. Water-soluble injectable.
    c. Injectable cholecystopaques.
    d. Water soluble noninjectable.

Unit 3. Contrast Studies of the Genitourinary Tract

THE UROGENITAL SYSTEM consists of the urinary and reproductive organs. Malfunction of any component of this complex system may result in permanent damage or, in the case of the urinary organs, even death. Consequently, early and accurate diagnosis of such maladies is essential for surgical or medical correction. As a rule, such diagnosis involves radiological examination of the affected component. Because you are required to assist with these examinations, you must be familiar with the structure and function of the organs involved and versed in the procedural steps used for radiographically demonstrating them.

This unit begins with a look at the anatomy and physiology of the urinary system. After that, the intravenous urogram (IVU), retrograde urograms, cystogram, and cystourethrogram are explained. Finally, we cover anatomy and radiographic considerations of the female reproductive system.

3–1. Anatomy and Physiology of the Urinary System

The urinary system is vital to life because it provides a means for collecting waste products from the bloodstream, filtering and storing these products, and then excreting the waste. The major anatomical structures of the urinary system are the kidneys, ureters, bladder, and urethra.

815. Principles of the kidneys and ureters

The kidneys (two bean-shaped structures) are the principal organs of the urinary system. Each kidney is about 4 to 5 inches (10 to 12 cm) long, 2 to 3 inches (5 to 7 cm) wide, and 1 inch (2.5 to 3 cm) thick.

Location of kidneys

The kidneys are in the retroperitoneal space on each side of the vertebral column. The superior margins of the kidneys lie *approximately* at the level of the twelfth thoracic vertebrae. Their inferior margins are usually at the level of the third lumbar vertebra. The left kidney is situated approximately 1 cm higher than the right because of the location of the liver in the right upper quadrant just above the right kidney.

NOTE: This is the usual location of the kidneys when the patient is supine. When the patient is upright, these organs descend slightly.

Figure 3–1 illustrates the relationship between the urinary system, spine, pelvis, and rib cage.

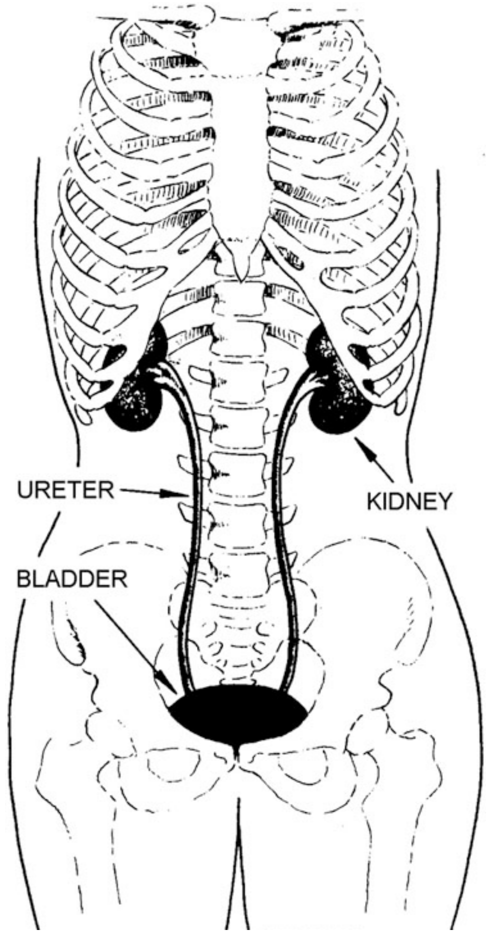

Figure 3–1. The urinary system in relation to surrounding structures.

Because the kidneys are retroperitoneal structures (lying behind the peritoneum), they are posterior to most other abdominal organs. The liver, for example, covers the greater portion of the anterior surface of the right kidney, and the descending portion of the duodenum covers a small segment of the medial aspect of this surface. The right colic (hepatic) flexure and a portion of the transverse colon cover the remaining inferior portion. The spleen covers most of the anterior surface of the left kidney while the posterior gastric wall covers a portion of the superior aspect of this surface. The posterior pancreatic surface overlies the medial midsection. The jejunum covers the inferomedial surface of this kidney, and the inferolateral tip is covered by the transverse colon.

Not all of the abdominal structures lie anterior to the kidneys. For instance, the adrenal glands are on the medial and superior aspects of the upper portions of both kidneys. Because of their location, they are sometimes referred to as suprarenal glands. These glands are part of the endocrine system and serve no urinary function.

The diaphragm covers the superior renal surfaces and a portion of the posterior surfaces. The twelfth rib pair usually overlies both kidneys. Occasionally, the eleventh rib pair also overlies the upper aspect of each kidney. The remainder of both organs is covered by muscular and fatty tissue. Laterally, the renal organs are cushioned by layers of fatty tissue, which lie between them and the lateral walls of the abdomen.

Kidney structure

The medial surfaces of the kidneys are concave. The *renal hilum* is an opening on the medial aspect of each kidney that allows for passage of the renal artery, vein, and pelvis. All other surfaces of the renal organs are completely covered by a layer of fatty tissue referred to as the *perirenal-fat pad*. This fatty tissue serves as a shock absorber and a temperature-control device for the kidneys. It also serves to separate the adrenal glands from the renal organs: a significant fact when a differential diagnosis of adrenal versus renal cortical tumor masses is sought. Figures 3–2 and 3–3 illustrate the structures of the kidney. Refer to these figures as the renal components are covered.

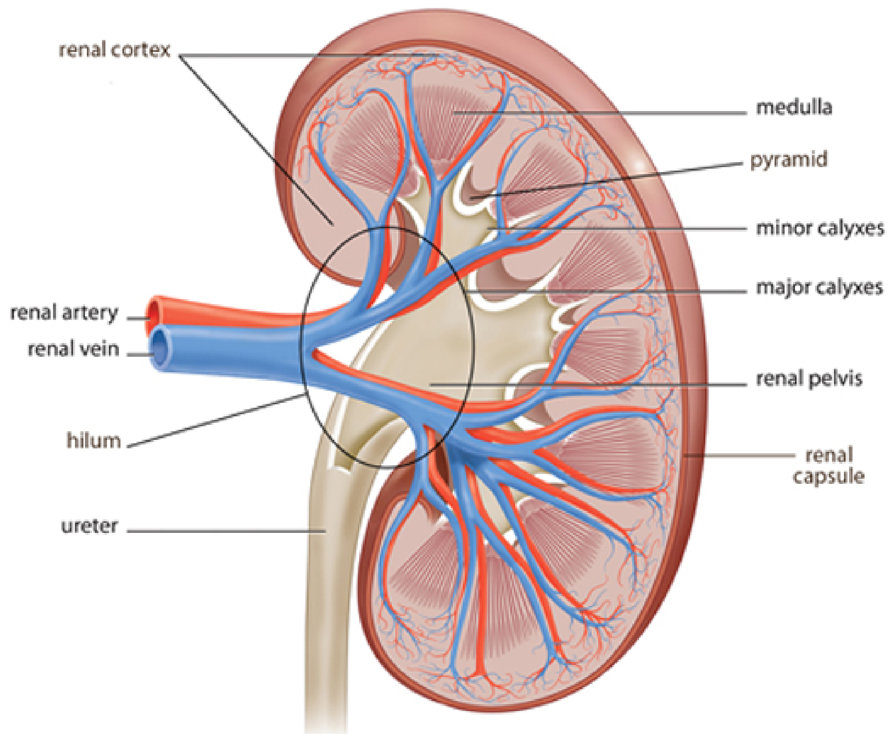

Figure 3–2. Coronal section of kidney.

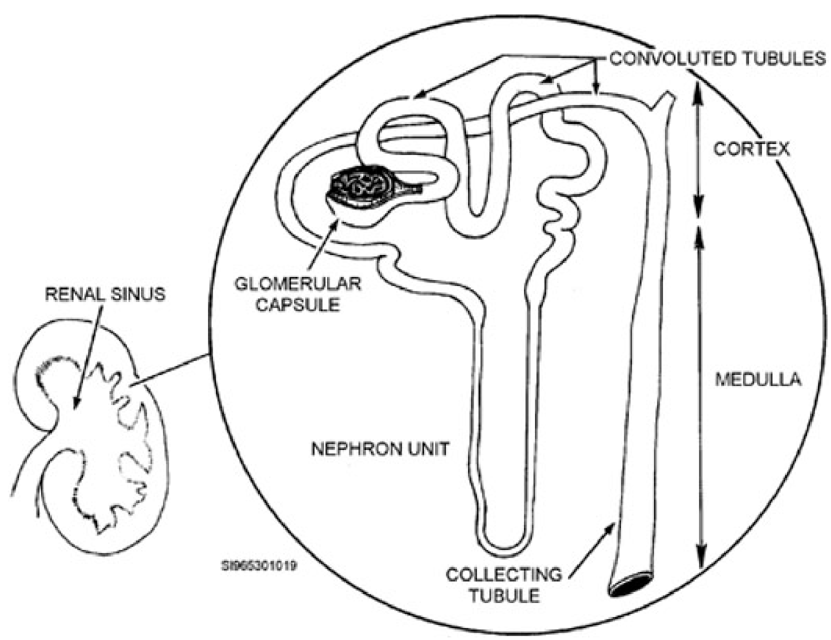

Figure 3–3. The nephron unit and collecting tubule.

The cortex or outer layer contains the glomeruli, glomerular capsules, and convoluted tubules that form the *nephron units* (the functional units of the kidney). There are about one million nephron units in each kidney. The *medullary* layer of renal tissue is inside the cortex and contains the collecting tubules, which begin the passageway for urine collection. The collecting tubules converge to form a series of conical masses, the *renal pyramids*, which number from 8 to 15.

The *renal sinus* is an expanded extension of the hilum. It forms the central cavity of the kidney and houses the minor calyces, major calyces, and the renal pelvis.

The *minor calyces* are a group of small, cup-shaped tubes numbering from 4 to 13. They are situated along the outer curvature of the sinus and are in close contact with the apices of the pyramids.

NOTE: The minor calyces actually surround one or more of the papillae extending through the surface of the apices.

The minor calyces extend into the central portion of the renal sinus for a short distance and then join to form the *major calyces*. These structures are two or three short, wide tubes which extend further into the renal sinus and then join to form the funnel-shaped *renal pelvis*. The pelvis leaves the kidney through the hilum, curves downward, and joins with the ureter. The minor calyces, major calyces, and renal pelvis are continuous with each other.

Kidney function

The primary purpose of the kidneys is to filter blood, removing the waste products that the blood takes from the individual cells of the body. As the renal artery(ies) enter(s) the kidney through the hilum, it begins to branch into smaller and smaller segments eventually forming arterioles. At this stage, the vessel is called the afferent arteriole, and it enters the glomerular capsule and further divides into capillaries. These capillaries inside the capsule are called the glomerulus. The glomerular capsule is able to absorb water and waste products from the glomerulus and transfer this fluid, called glomerular filtrate, to the convoluted tubule. The capillaries then reunite to form the efferent arteriole, which exits the capsule.

After the glomerular filtrate enters the convoluted tubule, much of the water and usable dissolved substances are reabsorbed by a surrounding capillary network, which is branched off the efferent arteriole. This changes the filtrate into urine, which is then passed to the collecting system. In this manner, the kidneys not only filter waste products from the blood stream, but also maintain electrolyte balance and fluid level within the body.

Ureters

The ureters are hollow, musculomembranous tubes that join with the renal pelvis and extend to the posteroinferior surface of the urinary bladder. There is normally one ureter for each kidney although a small segment of the population may have two ureters exiting a single kidney, which may or may not join together before reaching the bladder (a condition known as a duplicated collecting system). Normal ureters are 10 to 12 inches (25 to 30 cm) long, vary in diameter, and are divided into abdominal and pelvic portions.

Juncture of the distal renal pelves and the proximal ureters occurs in the region between and just anterior to the transverse processes of the first and second lumbar vertebrae. The *abdominal* portions pass downward, over the medial surfaces of the psoas major muscles, and behind the peritoneum, to the pelvic brim, and cross the wings of the sacrum just medial to the sacroiliac joints.

The pelvic portions of the ureters follow the general curvature of the pelvis. They curve forward and medially at about the level of the ischial spines, pass through the peritoneum, and join the urinary bladder in the region of the *trigone*. Figure 3–1 illustrates the ureters position in relationship to the kidneys, vertebral column, pelvis, and urinary bladder.

Each ureter is comprised of three layers, or coats: (1) an outer fibrous coat, (2) a middle muscular coat, and (3) an inner mucous coat. The fibrous layer is continuous with the renal membrane, which forms the floor of the renal sinus. The muscular middle coat is formed by three layers of muscle tissue similar to those found in the alimentary tract and is responsible for ureteral peristalsis. The mucosal inner coat extends from the renal papillae to the mucous membrane lining of the urinary bladder with which it is continuous.

816. Principles of the bladder and urethra

The remaining distal portion of the urinary tract is comprised of the urinary bladder and urethra. Radiographic studies of these structures may be done in conjunction with or separate from radiographic studies of the kidneys and ureters.

Urinary bladder

The “storage area” of the urinary system is the urinary bladder. This structure is a hollow musculomembranous sac located in the lower anterior portion of the true pelvis.

The precise location of the bladder will vary in accordance with the amount of fluid it contains. Generally, the inferior portion is behind the symphysis pubis, while the entire bladder is anterior to the rectum and underneath the peritoneum.

The urinary bladder wall is comprised of an external serous coat, three layers of muscle tissue, a submucous coat, and a mucous membrane lining. The outer layer of muscle tissue is comprised of longitudinal fibers, the middle layer of circular fibers, and the inner layer of still more longitudinal fibers. This muscular arrangement allows free expansion of the bladder as it fills with urine. As the bladder fills, the superior surface rises into the abdominal cavity rounding off the posterior and lateral borders. The bladder is completely full when it contains 500 ml of urine. Most people feel the urge to urinate around 250 ml. The mucosa consists of loose folds (similar to the rugal folds of the stomach), which allow this membrane to stretch as the muscular walls expand. The urinary bladder and its component structures are depicted in figure 3–4.

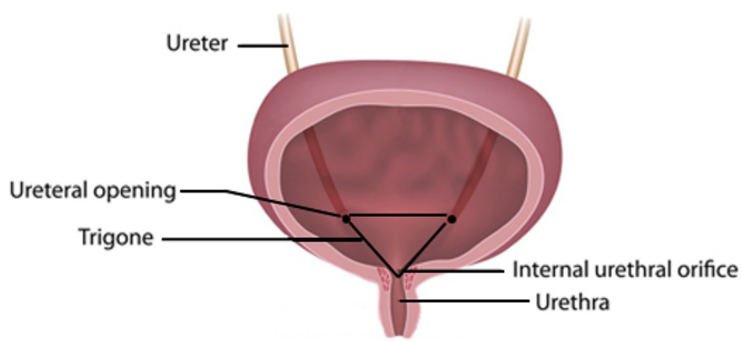

Figure 3–4. The urinary bladder.

The *trigone* is a triangular area in the posteroinferior bladder wall. The three corners of the trigone are formed by the two ureteral orifices superiorly and the urethral orifice inferiorly. Its structure is basically the same as that described for the remainder of the bladder, but the musculature is not as expansive as is that of other segments of the bladder wall, and the mucosal lining is always smooth. The distal ends of the ureters pierce the wall of the trigone in the upper outer regions, pass through the tissue on an inferomedial course for about two centimeters, and terminate in the *ureteral orifices*.

When the bladder is empty, these openings are about one inch apart, but when the sac is full, they can be around two inches apart. This illustrates the degree and direction of trigonal expansion. As the trigone stretches with the remainder of the bladder during filling, its musculature tightens on the distal ureteral ends, thus clamping them off and preventing urine reflux into the ureters. The trigone also houses the internal urethral orifice. This crescent-shaped aperture is located in the apex of the trigone, which forms the most inferior portion of the bladder. The circular muscle fibers of the floor of the bladder are concentrated around the internal urethral orifice, thus forming the *internal urinary* *sphincter*. This layer of concentrically arranged muscle fibers contracts to close the urethral orifice, and relaxes to open it.

Urethra

The urethra is a hollow, narrow tube which extends from the bladder to the external surface of the body. The male urethra is about 7 to 8 inches (18 to 20 cm) long and is comprised of *prostatic*, *membranous*, and *cavernous portions*. The prostatic urethra is the widest and most dilatable portion of the tube. It extends downward for about three centimeters and passes through the prostate gland. This gland lies directly below and close to the external surface of the bladder floor. The membranous portion of the urethra is the shortest and least dilatable segment of the tube. It extends anteroinferiorly from the under surface of the prostate to the bulb of the urethra—a distance of about 1.25 cm. The cavernous portion is the longest segment of the male urethra, usually about 15 cm in length, extends from its juncture with the membranous segment, through the penis to the external urethral orifice. It first passes upward to the front of the symphysis pubis and then downward through the penis.

The female urethra is much shorter and straighter than that of the male. It extends from the internal urethral orifice downward and forward for a distance of about 1 ½ inches (4 cm). As a rule, the female urethra is of uniform diameter and, because it is imbedded in the anterior vaginal wall, is relatively immovable.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

815. Kidneys and ureters principles

1. Describe the location of the kidneys.

2. Why is the left kidney situated slightly higher than the right?

3. What endocrine glands are located on the superior portions of each kidney?

4. What is the renal hilum?

5. In what layer of kidney tissue are the nephron units located?

6. Which structures form the nephron units?

7. Which structures converge to form the renal pyramids?

8. The minor calyces, major calyces, and renal pelvis are housed within which structure?

9. What is the name of the blood vessel that enters the glomerular capsule?

10. Where is glomerular filtrate converted into urine?

11. Name the two portions of a ureter.

12. Name the three tissue layers of a ureter.

816. Principles of the bladder and urethra

1. How is the bladder located in relation to the peritoneum?

2. The bladder is considered completely full when it contains how much urine?

3. What is the trigone?

4. Which three structures form the corners of the trigone?

5. Name the three portions of the male urethra.

6. What is the longest segment of the male urethra?

7. Approximately, how long is the female urethra?

3–2. Contrast Studies of the Urinary System

The quantity of radiographic urinary system studies have steadily decreased over the years due to the increased use of CT. CT studies demonstrate urinary system anatomy, function, and pathology quite well. Standard radiographic studies may be requested due to patient condition or possibly the unavailability of a CT unit if at a small AF clinic. A variety of radiographic studies is performed to demonstrate urinary anatomy and function. This section reviews the following radiographic contrast studies: intravenous urogram, retrograde urography, cystography, and cystourethrography.

817. Operating principles of intravenous urography

Intravenous urography, also called *excretory urography*, involves the intravenous injection and subsequent renal processing of a water-soluble injectable contrast medium, followed by abdominal radiography. This exam over the years has routinely been referred to as an intravenous pyelography (IVP) which is incorrect because the prefix *pyelo* refers strictly to the renal pelvis. An IVU demonstrates much more than the renal pelvis to include the major and minor calyces, both ureters, the urinary bladder, and it serves as a renal-function test. One of the keys to the success of this procedure deals with the proper preparation of the patient.

Patient preparation for an intravenous urogram

Like other contrast medium examinations, excretory urography calls for a certain amount of patient preparation. Although IVU preparatory instructions vary among radiologists, fecal material and gas (air) in the bowels will obscure visualization of the urinary tract structures.

Bowel preparation

For adults, common bowel preps include placing the patient on a low-residue diet for one to two days prior to the IVU. Since the intestines superimpose the urinary system on a radiograph, cleansing the bowel is a prerequisite to clear fecal material and gas out of the intestines. Accurate radiologic diagnosis of uropathy is difficult, if not impossible, when fecal material and gas is present.

Some radiologists ask that the patient take two ounces of castor oil the evening prior to the examination and a cleansing enema the next morning; others feel that castor oil is too harsh and that enemas introduce air into the colon, thus defeating their purpose. These radiologists instead prefer a mild, commercially prepared laxative, such as magnesium citrate or Dulcolax, in the evening and a suppository comprised of similar chemicals in the morning. However, if some gas is still present and the exam must be conducted, the problem of obscuring gas shadows can be resolved in a majority of patients by placing the patient in a prone position. The prone position shifts the gas laterally, away from the renal structures, by exerting pressure on the abdomen.

Regardless of the method used, bowel cleansing is an important prerequisite for an IVU. If it is not done or is incomplete, the exam may have to be canceled and rescheduled.

Fasting

Fasting serves to reduce the possibility of vomitus aspiration should a contrast reaction occur. If the stomach is empty at the time of reaction; the quantity of vomitus is dramatically reduced. Thus, the possibility of aspiration is greatly reduced. Consequently, the patient is usually asked to eat only a light supper the evening before the exam and nothing thereafter. Patients should be NPO (nothing by mouth) after midnight the evening before the examination. Clear fluids (water) are okay in order for the patient to stay hydrated and to take required medications that do not interfere with the IVU or the contrast media. Patients should not be dehydrated for an IVU.

Reasons for an intravenous urogram

As stated prior, an IVU demonstrates the anatomy of the urinary system as well as its function. The following are reasons an IVU may be requested to be performed.

- Renal cysts and tumors.
- Stones in the kidneys, ureters, or bladder.
- Upper urinary tract infections.
- Post traumatic investigation.
- Preoperative assessment of the kidneys and ureters.
- Renal hypertension (elevated blood pressure caused by renal artery disease).

Routine intravenous urogram procedures

Always follow your department protocols to prepare and perform an IVU. We now discuss basic procedures that should be common no matter where you are.

Pre-injection

The following are pre-injection procedures:

1. Review the radiology request form, have the patient fill out your locally approved IV contrast questionnaire, check/record applicable lab results, and acquire your scout image (flat KUB [kidneys, ureters, and bladder] of the abdomen).
2. Review all information acquired in step 1 with your radiologist.
3. Explain exam to the patient, perform venipuncture, and prepare IV contrast media for injection.

Post-injection

The following are post-injection procedures:

1. Inject the contrast media via the IV line. Make sure to record the exact time that you started the contrast injection. All timing aspects and further radiographs are based off of the injection start time.

   NOTE: Follow your department policies regarding all IV contrast injections. A radiologist or physician must be present or in close-proximity to be able to respond to any level of contrast media reaction.
2. Most IVU protocols calls for 100 ml (or less) of IV contrast media to be injected. The injection should take no more than 1 minute to complete.
3. Monitor the patient for any type of iodination contrast media reaction throughout the exam. Most reactions happen quickly (within 5 minutes) but delayed reactions are definitely possible.
4. Acquire images at the specified time elapsed intervals as per your radiologist request and department protocol.

Images to acquire

The common set of images acquired when performing an IVU are: an AP scout image, an AP nephrogram, a 5-minute AP supine KUB image, a 10 to 15-minute AP supine KUB image, 20-minute AP oblique images, and a post-void image (can be prone or supine).

NOTE: All images are taken with suspended expiration unless otherwise stated. As well, always make sure to include right or left reference markers and time markers on every image.

Scout image

Prior to injection of IV contrast media for an IVU, an AP scout (KUB) image is acquired. Have the patient void so the bladder is empty before you perform the scout film. This reduces dilution of the contrast material in the bladder during the exam. Also, because some IVUs can take an hour or more, having the patient void beforehand prevents him or her from having to use the rest room in the middle of the exam.

The scout film serves several purposes:

1. It allows the radiologist to determine whether the patient's bowel is adequately cleaned out. If the patient has considerable gas and fecal material in the bowel, the examination may not be diagnostic because the contrast medium in the urinary tract may be obscured.
2. It allows the radiologist to see a urinary tract stone or other abnormality that may be obscured by the contrast medium.
3. The scout film enables you to check radiographic technique and positioning and make necessary adjustments for subsequent radiographs.

Film centering is especially important during an IVU because you must include the anatomy from the upper margins of the kidneys to the superior portion of the symphysis pubis. This is not usually a problem with average-sized patients. Simply center an IR (open to 14×17-inches lengthwise) to the iliac crest. However, on a large patient you may not be able to include the necessary anatomy on a single radiograph. It may be necessary for you to center the 14×17-inch collimated IR three or four inches higher than normal and then make a second exposure collimated to using a 10×12-inches and centered two inches above the symphysis pubis to include the lower pelvis.

When performing the scout film and all other AP projections of the kidneys during an IVU, some radiologists prefer that you flex the patient's knees slightly to place the lower back in contact with the table as you would for an AP lumbar spine. In addition, the radiologist may want you to elevate the head and shoulders on one or two pillows. Doing so places the long axis of the kidneys near parallel with the plane of the IR and reduces their distortion on the radiograph.

Nephrogram image

The nephrogram image is simply a full view AP supine KUB taken immediately after completing the contrast media injection. For this image to be acquired at the correct time, make sure to set your exposure technique as well as have the X-ray tube and IR aligned and centered appropriately to the patient before beginning the contrast injection. With everything ready to go, once the injection is complete all you have to do is leave the X-ray exposure room, give the patient breathing instructions, and expose the image. This image is taken to *demonstrate* the contrast media in the *collection* system of the kidneys.

5-minute image

Take a full a full view AP supine KUB image at 5-minutes after you began the contrast injection. Make sure to include the entire urinary system.

10 to 15-minute image

Take a full a full view AP supine KUB image after 10 to 15 minutes has surpassed from the time you began the contrast injection. Make sure to include the entire urinary system.

20-minute posterior oblique images

Acquire bilateral AP oblique images at 20 minutes post-commencement of the contrast injection. The obliques are designed to show the kidneys at a different angle and to project the ureters free from superimposition with the spine. To perform these images, *ensure* the patient's midcoronal plane forms *approximately* a 30 degree angle with the plane of the IR. Make sure the arms will not be in the image and center the IR to the iliac crest.

Post-void image

The last routine image is acquired after the full lengths of the ureters are visualized on the previous radiographs. Once the radiologist is satisfied with the information obtained, the patient is allowed to use the restroom and void (empty his or her bladder). After voiding, acquire a bladder image collimated to a 10x12 inch crosswise field. The particular method of acquisition is up to your department protocol for an IVU. This image can be acquired AP, PA, or AP erect.

Post-void images of the bladder are used to evaluate enlargement of the prostate gland in males and to check urine retention in both sexes. The urine should always be *strained* if a urinary (kidney) stone is suspected and the straining device should be *inspected* for stones *prior* to disposal. A simple straining method is to provide the patient with a container covered with gauze.

Compression of the ureters

Some radiologists use ureteral compression to restrict the flow of contrast material into the bladder during an IVU to outline the renal pelvis and calyces better. This procedure is accomplished by using a compression device across the upper pelvis at the level of the anterosuperior iliac spines. This is the level where the ureters cross the sacrum. Compression placed above or below this level is *not* effective. Compression squeezes the ureters against a prominent portion of the sacrum, temporarily blocking the flow of urine. This creates a condition known as *urine stasis* and causes the collecting systems of the kidneys to swell with contrast and urine making them more easily seen on a radiograph. Compression is usually applied after completion of the injection and released at a specified time after one or more radiographs are made. A radiograph can also be made a few seconds after release of the compression to visualize the contrast-filled ureters.

Compression can be applied in a number of ways, although you usually use the compression band supplied with your radiographic unit. Some radiologists prefer to place a blood pressure cuff or similar inflatable device with a pressure gauge underneath the compression band. After the band is tightened until it is snug, the cuff is inflated a specified amount, usually from 90 to 110 mm of mercury. Using a device such as this is advantageous because the amount of pressure on the ureters can be measured and duplicated from one examination to the next. You can also place a foam rubber pad or other positioning aid under the compression band and tighten the band to compress the ureters.

If the patient cannot tolerate the compression because of recent surgery, abdominal mass, or discomfort, the purpose of the compression can be partially satisfied by using the Trendelenburg position (10 to 20 degrees). This position uses gravity to retard the flow of the contrast medium into the bladder. When performing radiographs with the patient so positioned, be sure to angle the tube caudally to the same degree the table is tilted to prevent distortion.

818. Operating principles of additional procedures used to evaluate the urinary system

If indicated beyond the routine IVU study, other exams can be performed to evaluate for specific urinary conditions.

Pediatric intravenous urogram

One of the problems associated with an IVU on pediatric patients under age nine is that preparation of the gastrointestinal tract is difficult or clinically contraindicated. As a result, gas and fecal shadows can overlie the kidneys and obscure the contrast medium. This problem is easily solved by giving the patient a carbonated beverage, which distends the stomach with gas. Distention of the stomach displaces the bowel downward so that it no longer overlies the kidneys. Also, the excellent contrast produced between the resulting gas in the stomach and the contrast medium-filled kidneys provides even better demonstration of the kidneys than if the patient was properly prepared in the standard way. Usually, two ounces of beverage is given to an infant and 12 ounces to an eight year old, with proportional amounts for ages in between.

Hypertensive intravenous urogram

The volume of blood reaching the kidneys is one of the mechanisms your body uses to regulate blood pressure. Therefore, if there is a narrowing (either congenital or acquired) to the renal artery significant enough to restrict blood flow to the kidney, your body will increase blood pressure to compensate. A hypertensive IVU is performed to determine if hypertension (high blood pressure) is being caused by *stenosis* (narrowing) of a renal artery. If stenosis is present in a renal artery; excretion of the contrast material by the kidney of the affected artery can be delayed when compared with the opposite kidney. To evaluate the difference between the appearance and concentration of contrast material in the kidneys, the medium is injected rapidly into the vascular system, after which radiographs are taken at 30 second or one minute intervals for about five minutes.

Following the prescribed number of images, a *urea washout study* may also be performed. The study is accomplished by infusing a mixture of saline and urea, a substance that promotes the secretion of urine. Radiographs are made at five or ten minute intervals to determine if the contrast material “washes out” of one kidney faster than the other does.

Retrograde studies of the urinary tract

All procedures covered to this point have been excretory studies. That is, the kidneys excrete the contrast into the urinary tract. Other radiographic examinations of the urinary tract are called retrograde studies. Retrograde means “moving backward” or “against the normal flow.” For retrograde studies, contrast medium is introduced through the urethra into the urinary tract. These studies demonstrate urinary tract structure, but are *not* a function test of the urinary system.

Retrograde urography

Retrograde urography is a nonfunctional exam is performed by using a catheter to introduce contrast media against the normal flow of fluid. This procedure is normally used to identify calculi or other obstructions in the urinary system as well as to evaluate the renal pelvis and calyces. A retrograde urogram is performed under sterile conditions in the radiology department, urology, or surgical suite. The patient is typically sedated and placed in the modified lithotomy position.

One of your responsibilities is preparing the contrast medium. Either injectable or noninjectable urographic media may be used. Generally, a noninjectable such as Retrografin or Cystokon is used because it contains an antibiotic to reduce the possibility of infection. Either contrast medium may be used as is; however, some physicians prefer to dilute the contrast material to a specific weight-by-volume concentration to reduce irritation to the renal structures. When instructed to dilute the contrast material, use either sterile water or saline and mix the contents under sterile conditions. As a footnote, information pertaining to any contrast material (how it is used, mixed, contraindications, etc.) is obtained from the accompanying literature. If the manufacturer’s literature unavailable, you use a *Physicians’ Desk Reference* (current edition) to obtain the same information.

From the technologist’s point of view, the procedure is a simple one. After the physician has placed the catheter at the desired location in the urinary tract using a cystoscope, he or she will inject the contrast medium and the technologist will perform one or more abdominal radiographs until the desired anatomy has been demonstrated.

Intravenous and retrograde urographies are not competitive studies; they are complimentary. Their relationship can be illustrated by the fact that a suspicious area seen on an IVU can be specifically studied in a retrograde urogram. The major advantage of a retrograde study is that optimum demonstration of the renal pelvis and calyces can be obtained by controlling the amount and concentration of the contrast material.

Retrograde cystography and cystourethrography

Cystograms are performed by retrograde introduction of an iodinated contrast medium into the bladder. When the exam includes voiding the contrast back out of the bladder through the urethra, the procedure is then called a cystourethrogram or voiding cystourethrogram (VCU).

General procedures

The exact procedures for performing a cystogram or cystourethrogram vary by radiologist and/or location. The typical cystogram is performed to evaluate for trauma, stones, tumors/masses, or inflammatory urinary bladder disease. The VCU study goes a step further evaluating the urethra and the patient’s ability to void (urinate). Before beginning the exam, have the patient void to ensure the bladder is as empty as possible. The radiologist or physician then places a catheter through the urethra and into the bladder. The contrast media is then induced to the bladder through the catheter by natural gravity means. Do not try to speed up the contrast administration or use pressure of any kind as this may cause the bladder to rupture. Depending upon the patient, the bladder may need 150 to 500 ml of contrast media to be considered completely full.

Most radiologists monitor the filling phase under fluoroscopy to ensure the bladder is sufficiently filled but not overfilled. Some radiologists perform all films during fluoroscopy with digital spot films, while others film only the urethra in this manner and include “overhead” radiographs for the bladder. In either case, voiding films of the urethra are usually performed under fluoroscopy. The voiding film allows evaluation of the urethra and permits the radiologist to check for urine reflux into the ureters during voiding. (In some instances, when a patient relaxes the internal urinary sphincter to void, the ureteral valves also relax, allowing urine to back-flow into the ureters. This condition can cause urinary tract infections.)

Projections

Usually, you are required to perform several projections of the bladder during a cystogram. In all cases, center the IR two inches above the superior border of the symphysis pubis. If centering for a voiding study, center the IR directly at the pubic symphysis.

Perform the *AP (supine) axial projection* with the CR angled 10 to 15 degrees caudal centered to the IR. Ensure the CR travels through the anatomy at a level two inches anterior to the symphysis pubis. If the neck of the bladder and proximal urethra are of primary interest, then 5º caudal angulation of the CR is typically all that is needed to project the pubic bones below those structures.

For the *PA (prone) axial projection*, angle the CR 10 to 15 degrees cephalic to a point one inch below the tip of the coccyx. The CR should exit the patient just above the symphysis pubis. This PA projection is the best for demonstrating the prostate because it minimizes object-to-image distance (OID). For VCU studies, the CR stays perpendicular to the IR and symphysis pubis.

To evaluate for reflux of the contrast medium into the distal ureters, perform the *posterior oblique projections.* Position the patient 40 to 60 degrees RPO and LPO. Center the IR approximately two inches above the anterior border of the symphysis pubis and two inches medial to the ASIS. The CR is perpendicular to the IR and is directed the same, two inches above and medial to the symphysis pubis and ASIS. If the neck of the bladder and proximal urethra are of primary interest, add 10 degrees caudal angulation to the CR.

Lateral projections of the bladder are taken to demonstrate the anterior and posterior bladder walls and the base of the bladder. Place the patient in the right or left lateral recumbent position as you would for a lateral lumbar spine image. Place the center of the IR two inches above the symphysis pubis and direct the CR perpendicular to the IR.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

817. Operating principles of intravenous urography

1. Though IVU preparatory instructions may vary, why is it necessary for the bowels to be clear of fecal material and gas?

2. Why should a patient fast prior to an IVU study?

3. Why is it important to record the exact time that you started the contrast injection?

4. What is the common set of images acquired when performing an IVU?

5. Why is the IVU scout film performed?

6. Which anatomical area must be included on the IVU scout film?

7. Why should you flex the patient’s knees and elevate their head and shoulders using pillows?

8. When is the nephrogram image taken?

9. Why 20-minute posterior oblique images necessary?

10. Under what circumstances is the patient’s urine strained?

11. What condition is created by applying ureteral compression during an IVU?

12. What is the purpose of creating the condition mentioned in question 5?

13. If the patient cannot tolerate compression, what alternate procedure may be used to achieve the desired effect?

818. Operating principles of additional procedures used to evaluate the urinary system

1. What is the purpose of a hypertensive IVU?

2. How often are images taken after rapid contrast media injection for a hypertensive IVU?

3. What kind of exam—structural or functional—is retrograde urography?

4. Why are voiding film performed during cystography.

5. If the neck of the bladder and proximal urethra are of primary interest, how should you angle the CR?

6. Which projection would you need to perform if the prostate is of primary concern? Why?

3–3. Anatomic and Radiographic Considerations of the Female Reproductive System

This last section on contrast studies of the urogenital system was a discussion of the female reproductive system. Now, we begin with a look at the anatomy of the female reproductive system and then we study hysterosalpingography.

819. Principles of the anatomy of the female reproductive system

Anatomy of the female reproductive system is divided into two categories, internal and external, which are connected by the vaginal canal. Our discussion is directed to the internal structures, including the vagina, uterus, fallopian tubes, and ovaries. Refer to figures 3–5 and 3–6 as we discuss them.

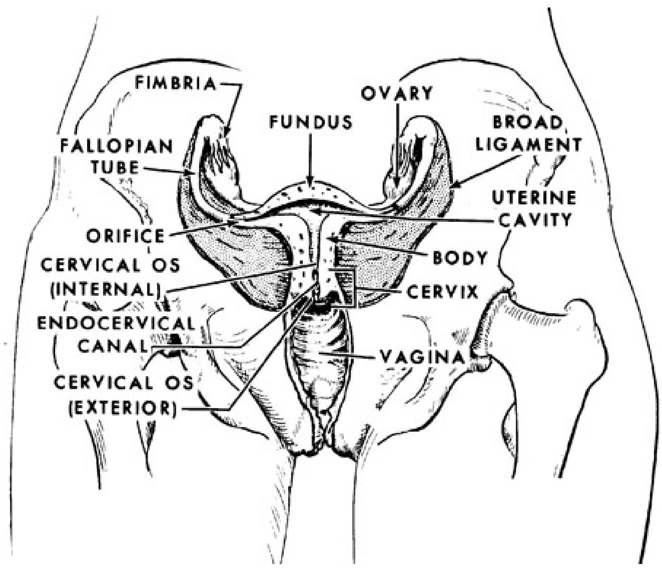

Figure 3–5. The female reproductive system (anterior view).

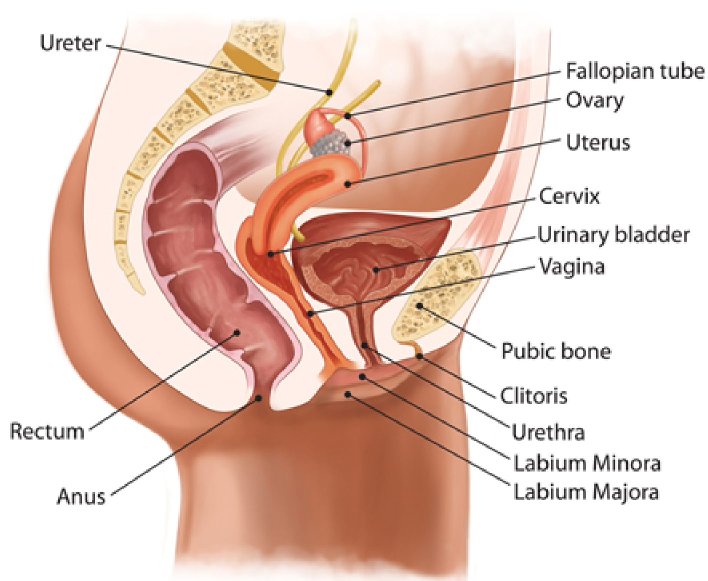

Figure 3–6. Sagittal section of the female reproductive system.

Vagina

The vagina is a musculomembranous tube that connects the external structures to the uterus. It extends superiorly and posteriorly to a point where it meets the inferior portion of the uterus. The vagina lies between the rectum and the urinary bladder.

Uterus

The pear-shaped uterus is a hollow, thick-walled structure situated in the pelvic cavity between the rectum and the urinary bladder. It consists of the *cervix* or neck, which is the narrow, inferior end; the *corpus* or body, which comprises the majority of the organ; and the *fundus*, which is the curved superior position. The uterus is usually tipped anteriorly, with its anterior surface close to the posterior and superior aspects of the bladder. The cervix joins with the vagina and has two openings, the external cervical os and the internal cervical os. The external os opens into the vagina. The internal os opens into the uterine cavity. Between these two openings runs the endocervical canal. There are two small orifices in the upper lateral aspects of the body. These are the uterine openings of the fallopian tubes. The fundus forms an oval roof and is situated above the level of the fallopian orifices.

The fallopian tubes

The fallopian tubes, also called the uterine tubes or oviducts, are hollow musculomembranous structures which extend laterally from the uterus to the ovaries. They are about 12 centimeters (cm) long and lie along the leading edge of the broad ligament that supports the uterus. Their lateral ends consist of several irregular finger-like projections called *fimbriae*, which surround, but do not encase, the ovaries. The purpose of the fallopian tubes is to conduct the mature egg which has been released by the ovary into the uterus.

The ovaries

The ovaries are the primary organs of the female reproductive system. These almond-shaped organs are located on either side of the uterus below the fallopian tubes. They are approximately four centimeters long, two centimeters wide, and eight millimeters thick. The ovaries are comprised of a central framework of vascular tissue that houses numerous ovarian follicles. These follicles serve as containers for the ova, or eggs, and appear in varying stages of maturity.

820. Operating principles of hysterosalpingography

A hysterosalpingogram (HSG) is a radiographic examination of the uterus and fallopian tubes. It is usually done to help determine why a patient is unable to become pregnant.

Radiographic considerations

While HSG is performed for other reasons, it is usually done to determine whether the fallopian tubes are patent (open or unobstructed). Patency of the tubes is evaluated as part of sterility “work-up.” If the tubes are patent, the positive contrast medium passes through them and “spills” into the peritoneal cavity. This can be seen on the radiographs.

Patient prep and the examination

An HSG is usually performed 10 days *after* the onset of menstruation. At this point, the endometrium is less congested, and it is still several days before ovulation, so the risk of pregnancy is minimal. Just prior to the study, give the patient time to empty her bladder, irrigate the vaginal canal, and perform perineal cleaning. By emptying the bladder, this reduces the possibility of a filled bladder impinging on the fallopian tubes or causing extraneous dense shadows that might interfere with visualization of the contrast medium.

Oily contrast media agents like Lipiodol and Ethiodol were normally the contrast of choice for injection during a HSG; however, in 1959, a water-soluble contrast medium named Sinographin was introduced and is still in use today. Sinographin provides the appropriate level of viscosity and quick absorption qualities with one main benefit to the patient; it virtually eliminated peritoneal irritation. The contrast media can be administered via a syringe or a device called a pressometer. During the HSG, patient discomfort and/or pain is considerable due to the intrauterine pressure maintained throughout the procedure. If fluoroscopy is not utilized, be quick as possible to assist the radiologist throughout the procedure and when obtaining the radiographs. Once the radiologist releases the pressure, the patient's pain and discomfort will subside.

NOTE: If a male tech is assisting the radiologist with the HSG, explain this in advance to the patient to ensure they are comfortable with a male tech assistant. Always use a chaperone when a male is the assisting technologist for a HSG.

Performing the radiographs

When fluoroscopy is used, generally the spot images are all that are taken/recorded. If radiographs are requested, use an IR collimated to 10×12-inches crosswise centered to a point two inches superior to the symphysis pubis. As a rule, only AP and AP oblique projections are performed during a HSG. Refer to your department's standard operating procedures for specific radiographs to be acquired if necessary.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

819. Principles of the anatomy of the female reproductive system

1. The vagina lies between which two structures?

2. Name the three portions of the uterus.

3. Name the two openings in the cervix.

4. What is another name for the fallopian tubes?

5. What are the fimbriae?

6. What are the primary organs of the female reproductive system?

820. Operating principles of hysterosalpingography

1. Why is an HSG usually performed?

2. How is patency of the fallopian tubes determined on an HSG radiograph?

3. When should an HSG be scheduled in relation to the patient's menstrual cycle?

4. Why is it important to perform the radiographs as quickly as possible during an HSG?

Answers to Self-Test Questions

815

1. They are situated in the retroperitoneal space on each side of the vertebral column. The superior margins of the kidneys lie approximately at the level of the 12th thoracic vertebrae. Their inferior margins are usually at the level of the 3rd lumbar vertebra.
2. Because the liver sits above the right kidney.
3. The adrenal (or suprarenal) glands.
4. An opening on the medial aspect of each kidney that allows for passage of the renal artery, vein, and pelvis.
5. The cortex.
6. The glomeruli, glomerular capsules, and convoluted tubules.
7. Collecting tubules.
8. The renal sinus.
9. The afferent arteriole.
10. In the convoluted tubule.
11. The abdominal and pelvic portions.
12. (1) an outer fibrous coat, (2) a middle muscular coat, and (3) an inner mucous coat.

816

1. Underneath the peritoneum.
2. 500 ml.
3. A triangular area in the posteroinferior bladder wall.
4. The two ureteral orifices superiorly and the urethral orifice inferiorly.
5. The prostatic, membranous, and caver nous portions.
6. The cavernous.
7. About 1 ½ inches (4 cm).

817

1. Because fecal material and gas (air) in the bowels will obscure visualization of the urinary tract structures.
2. To reduce the possibility of vomitus aspiration should a contrast reaction occur.
3. Because all timing aspects and further radiographs are based off of the injection start time
4. An AP scout image, an AP nephrogram, a 5-minute AP supine KUB image, a 10 to 15-minute AP supine KUB image, 20-minute AP oblique images, and a post-void image (can be prone or supine).
5. First, it allows the radiologist to determine whether the patient's bowel is adequately cleaned out. Second, it allows the radiologist to see a urinary tract stone or other abnormality that can be obscured by the contrast medium. Third, the scout film enables you to check your exposure and positioning and make necessary adjustments for subsequent radiographs.
6. From the upper margins of the kidneys to the superior portion of the symphysis pubis.

7. To place the long axis of the kidneys near parallel with the plane of the IR and reduce their distortion on the radiograph.
8. It is taken immediately after completing the contrast media injection.
9. They are designed to show the kidneys at a different angle and to project the ureters free from superimposition with the spine.
10. When a kidney stone is suspected.
11. Urine stasis.
12. It causes the collecting systems of the kidneys to swell with contrast and urine making them more easily seen on a radiograph.
13. Place the patient 10 to 20 degrees Trendelenburg position.

818

1. To determine if hypertension is being caused by stenosis (narrowing) of a renal artery.
2. Radiographs are taken at 30 second or one minute intervals for about five minutes.
3. Structural.
4. The voiding film allows evaluation of the urethra and permits the radiologist to check for urine reflux into the ureters during voiding.
5. 5 degrees caudal.
6. The PA prone axial projection. Because it minimizes OID.

819

1. The rectum and urinary bladder.
2. Cervix, corpus, and fundus.
3. The external cervical os and internal cervical os.
4. Uterine tubes or oviducts.
5. Several irregular finger-like projections which surround, but do not encase, the ovaries.
6. The ovaries.

820

1. To determine whether or not the fallopian tubes are patent.
2. Contrast medium spills into the peritoneal cavity.
3. 10 days after the onset of menstruation.
4. Because the patient is in considerable pain during the procedure.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

Do not return your answer sheet to AFCDA.

43. (815) At *approximately* what level do the superior margins of the kidneys lie?
    a. 12th thoracic vertebrae.
    b. 2nd lumbar vertebrae.
    c. Umbilicus.
    d. Xiphoid.

44. (816) The triangular area in the posteroinferior bladder wall is called the
    a. calyx.
    b. fundus.
    c. trigone.
    d. pyramid.

45. (816) From the bladder to the external urethral orifice, in what order are the three portions of the male urethra?
    a. Cavernous, prostatic, membranous.
    b. Prostatic, cavernous, membranous.
    c. Prostatic, membranous, cavernous.
    d. Membranous, prostatic, cavernous.

46. (817) Which aspect of the patient preparation for an intravenous urogram (IVU) *reduces* the possibility of vomitus aspiration should a contrast medium reaction occur?
    a. Fasting.
    b. Dehydration.
    c. Cleansing the bowel.
    d. Drinking a carbonated beverage.

47. (817) Which is *not a reason* for performing an intravenous urogram (IVU)?
    a. Upper urinary tract infection.
    b. Cysts or tumors.
    c. Diabetes.
    d. Calculi.

48. (817) The purpose of flexing the patient's knees slightly *and* raising the patient's head and shoulders with pillows for the intravenous pyelogram (IVP) scout film is to
    a. promote ureteral peristalsis.
    b. open the lumbar intervertebral disk spaces.
    c. place the kidneys more parallel with the image receptor.
    d. prevent the symphysis pubis from superimposing the neck of the bladder.

49. (817) Which image(s) allows visualization of the contrast media in the collecting system of the kidneys?
    a. Scout.
    b. Nephrogram.
    c. 5-minute KUB.
    d. Bilateral obliques.

50. (817) What type of *oblique* projections is normally performed for an intravenous urogram (IVU)?
    a. 15 degrees anterior.
    b. 30 degrees posterior.
    c. 45 degrees anterior.
    d. 45 degrees posterior.

51. (817) You provide the patient with a gauze-covered container when preparing for the post-void projection of an intravenous urogram (IVU) to
    a. check for kidney stones.
    b. check for urine retention.
    c. check for blood in the urine.
    d. measure the capacity of the bladder.

52. (817) When performing an intravenous urogram (IVU), what can you do in place of ureteral compression if the patient *cannot tolerate* the compression band?
    a. Substitute a blood pressure cuff.
    b. Place the patient in the prone position.
    c. Have the patient perform the Valsalva maneuver.
    d. Place the patient in the Trendelenburg position (10 to 20 degrees).

53. (818) Where should the image receptor (IR) be placed when radiographing the bladder during a cystogram?
    a. Centered to the level of the ASIS.
    b. Place the upper border at the level of the iliac crest.
    c. Place the lower border at the level of the symphysis pubis.
    d. Centered two inches above the level of the symphysis pubis.

54. (818) What projection *best* demonstrates the prostate gland during a cystogram?
    a. AP with 10 to 15 degrees caudal angulation.
    b. AP with 10 to 15 degrees cephalic angulation.
    c. PA with 10 to 15 degrees caudal angulation.
    d. PA with 10 to 15 degrees cephalic angulation.

55. (818) Which cystogram projection is used to demonstrate the anterior and posterior bladder walls?
    a. Lateral.
    b. Chassard-Lapine.
    c. 40 to 60 degrees posterior oblique.
    d. AP with 5 degrees caudal angulation.

56. (819) What is the name of the finger-like projections on the ends of the fallopian tubes that surround the ovaries?
    a. Cilia.
    b. Villi.
    c. Gyri.
    d. Fimbriae.

57. (820) A hysterosalpingogram is *usually* performed to determine
    a. ureteral reflux.
    b. prostate enlargement.
    c. patency of the fallopian tubes.
    d. stenosis of the subarachnoid space.

58. (820) At what point in the patient's menstrual cycle should a hysterosalpingogram (HSG) be scheduled to *minimize* the risk of pregnancy?
    a. Ten days after the onset of menstruation.
    b. Fifteen days after the onset of menstruation.
    c. Ten days after the completion of menstruation.
    d. Fifteen days after the completion of menstruation.

Please read the unit menu for unit 4 and continue ➔

Student Notes

Unit 4. The Central Nervous and Endocrine Systems

EACH OF OUR SENSES (sight, hearing, smell, taste, and touch), as well as our organic functions (respiration, circulation, digestion, etc.), are governed by a complex neural network that is called the nervous system. In the first section of this unit, we will discuss the structures of the central nervous system (CNS); specifically, the brain, spinal cord, meninges, and the ventricular system. In the second section of this unit, we will briefly talk about the nine glands of the endocrine system and how they, along with the CNS, coordinate and control the functions of the body.

4–1. Anatomy of the Central Nervous System

Anatomy of the central nervous system is divided into three parts. First, we discuss the brain and ventricular system, then the spinal cord, and finally the meninges.

821. Principles of the anatomy of the brain and ventricular system

The brain is the largest and most complex part of the CNS. It is encased by the cranial bones and is divided into lobes for anatomical purposes. Figure 4–1 and 4–2 shows the four main anatomical divisions of the brain, which consists of the cerebrum, diencephalon, cerebellum, and brain stem.

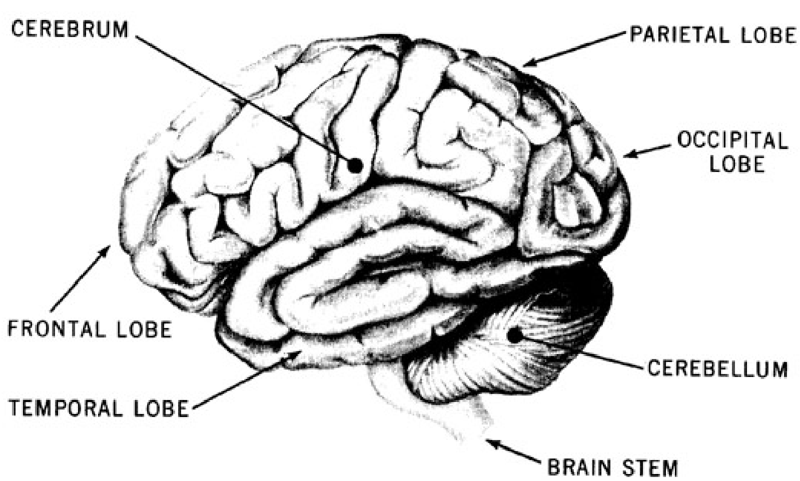

Figure 4–1. Lateral view of the brain.

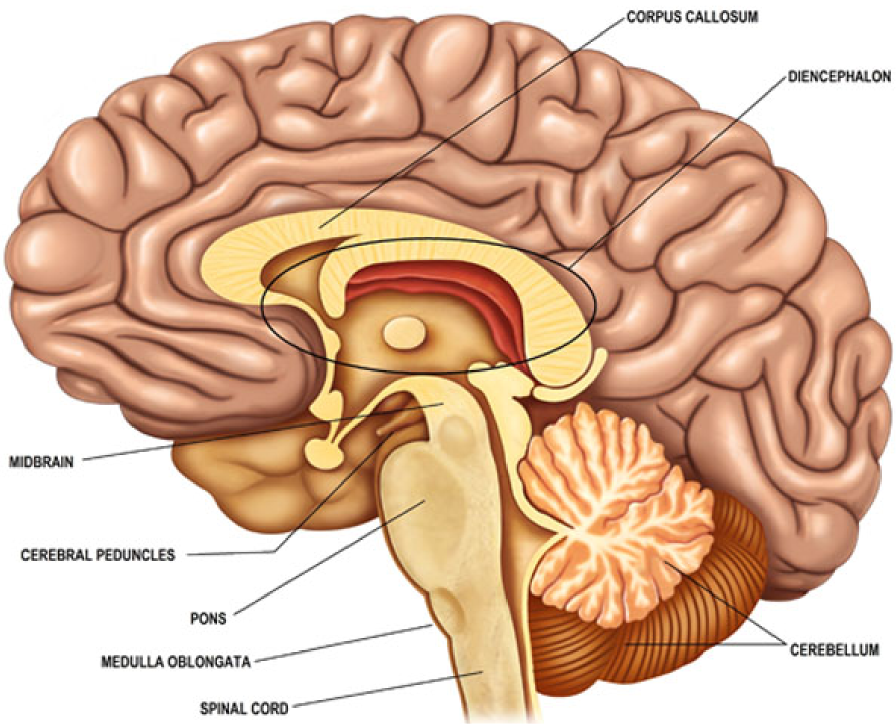

Figure 4–2. Midsagittal view of the brain.

Cerebrum

The cerebrum is the largest component of the brain and is also called the forebrain. Referring to figure 4–3, you can see it is divided into equal right and left hemispheres by a deep cleft called the *longitudinal sulcus* (or interhemispheric fissure). The hemispheres are connected by a transverse band of nerve fibers called *commissures*. The most prominent commissure is the *corpus callosum* which is between the cerebral hemispheres. Notice that the surfaces of these hemispheres are comprised of folded ridges (convolutions) called *gyri*. Shallow furrows called sulci separate the gyri from each other. Three of the sulci in each hemisphere are deeper than the others and serve to segment the cerebrum. These segments are referred to as *lobes*. As illustrated in figure 4–4, the four of the lobes of the brain are named for the cranial bones that cover them.

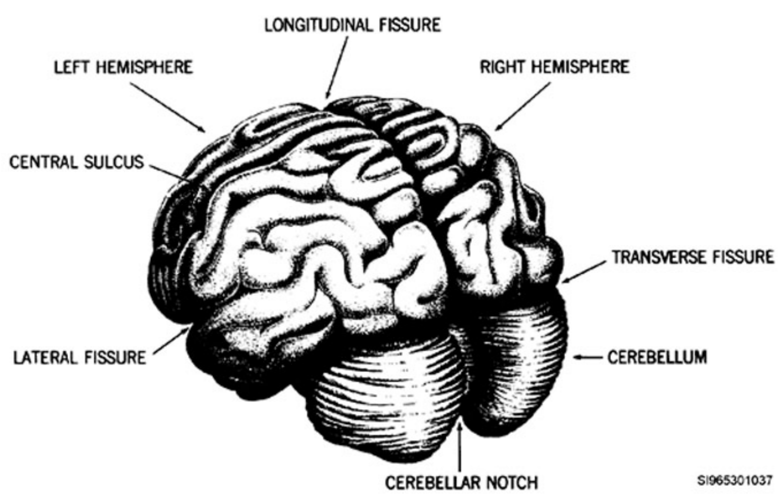

Figure 4–3. Division lines of the brain.

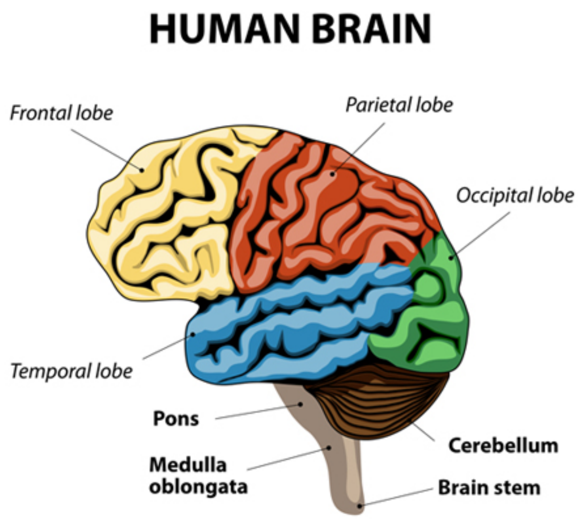

Figure 4–4. Lobes of the brain.

The following table shows which lobe or region of the brain affects a particular function:

Lobe	Region	Function
Parietal		Sense of touch, spatial relationship awareness, and academic tasks (i.e. reading).
Occipital		Vision.
Frontal		Emotional control, self-awareness, motivation, judgment, problem solving, and talking.
Temporal		Memory, hearing, understanding language, and information processing.
	Cerebellum	Balance, coordination, and motor activities.
	Brainstem	Breathing, heart rate, arousal, consciousness, sleep and wake cycles.

The convoluted outer surface of the hemispheres is comprised of brain tissue known as gray matter because of its color. This gray matter spreads over an inner mass of specialized fibrous tissue called white matter (also named because of its color).

Diencephalon

The diencephalon, or interbrain, is the portion of the brain that extends from the brain stem to the cerebrum. The diencephalon region consists of the thalamus, hypothalamus, epithalamus, and subthalamus. These structures are responsible for cognition, awareness, control of the autonomic nervous system, regulation of emotional and behavioral patterns, regulation of eating and drinking, and body temperature control.

Cerebellum

The cerebellum is the second largest component of the brain. It is beneath the posterior aspect of the cerebrum. The cerebellum is comprised of a central stalk, called the *vermis*, and two hemispheres. The cerebellum is separated from the cerebrum by a deep cleft called the *transverse fissure*. Its hemispheres are also separated from each other by a shallower vertical cleft called the *cerebellar notch*.

Brain stem

The midbrain, pons, and medulla oblongata are referred to *collectively* as the brain stem. These structures are united and situated anterior to the cerebellum, beneath the cerebrum (refer back to figure 4–1). The medulla oblongata is actually continuous with the spinal cord, but for our purposes, we consider them as separate entities.

The midbrain is a short, constricted segment connecting the pons and cerebellum with the cerebrum. The *cerebral peduncles* of the midbrain carry impulses between the cerebrum and spinal cord.

The *pons* is a large bulbous mass of fiber tracts situated below the midbrain, anterior to the cerebellum, and superior to the medulla oblongata. It is comprised primarily of white matter, although it does house the nuclei of four cranial nerves in its central portion.

The *medulla oblongata,* often referred to as the bulb, is actually an enlarged area of the spinal cord. It is below the pons and just above the foramen magnum. The anterior surface of the medulla oblongata is comprised of two bundles of fibers called the *pyramids*. The posterior aspects of the medulla houses two major nuclei that receive the fibers from the white columns of the spinal cord.

Ventricular system

The midportion of the cerebrum houses four irregularly shaped, interconnected cavities called ventricles (fig. 4–5). The ventricles are lined with delicate tissues called the *choroid plexuses* that secrete the lymphlike cerebrospinal fluid (CSF) that fills the ventricles and the subarachnoid space. Each hemisphere of the cerebrum contains an irregularly shaped lateral ventricle. Each lateral ventricle is comprised of a central portion, or body, and three appendages referred to as the *anterior, posterior,* and *inferior horns*. The majority of the body and the anterior and posterior horns are situated directly below the corpus callosum. The anterior horn extends into the frontal lobe and the posterior horn into the occipital lobe. Each lateral ventricle *communicates* with the third ventricle by a channel called the *foramen of Monro.*

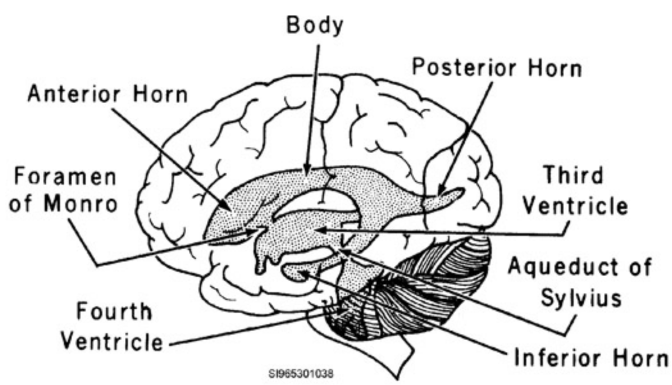

Figure 4–5. Ventricular system of the brain.

The third ventricle is situated along the midline, directly below the medial aspects of the lateral ventricles. It is housed between the masses of the thalamus, and its anterior-inferior portion extends downward through the hypothalamus. The third ventricle consists of a central portion and irregularly shaped projections extending posteriorly and anteroinferiorly. The posterior portion is above the pineal body and, thus, is referred to as the *suprapineal recess*. The third ventricle communicates with the fourth ventricle through the *aqueduct of Sylvius*.

The rhomboid (diamond-shaped) fourth ventricle is a midline structure situated in the space between the cerebellum and the brain stem. Its posterior aspect is formed by the concavity between cerebellar hemispheres. The fourth ventricle is continuous with the central canal of the spinal cord. Other than the aqueduct of Sylvius, there are three openings into the fourth ventricle—the *foramen of Magendie* and two *foramina of Luschka*. The ventricle communicates with the cisterna magna through the foramen of Magendie and with the subarachnoid cisterns through the two foramina of Luschka.

822. Principles of the anatomy of the spinal cord

The spinal cord is the longest and most inferiorly situated portion of the CNS. Essentially, it provides a means of communication between the brain and the nerve fibers connecting to the various parts of the body.

External structure

As you can see in figure 4–6, the spinal cord is an extension of the brain stem. It joins the medulla oblongata in the region of the first cervical vertebra and then descends through the spinal canal to about the level of the first or second lumbar vertebra. The cord is approximately 18 to 20 inches (42 to 45 cm) long, one centimeter in diameter, and is roughly cylindrical. It terminates at about the level of the L1-L2 interspace in a sharply constricted cone called the *conus medullaris*. The *filum terminale*, a slender filament, extends from the apex of the conus to the first coccygeal segment where it is attached to the osseous tissue of the vertebral column.

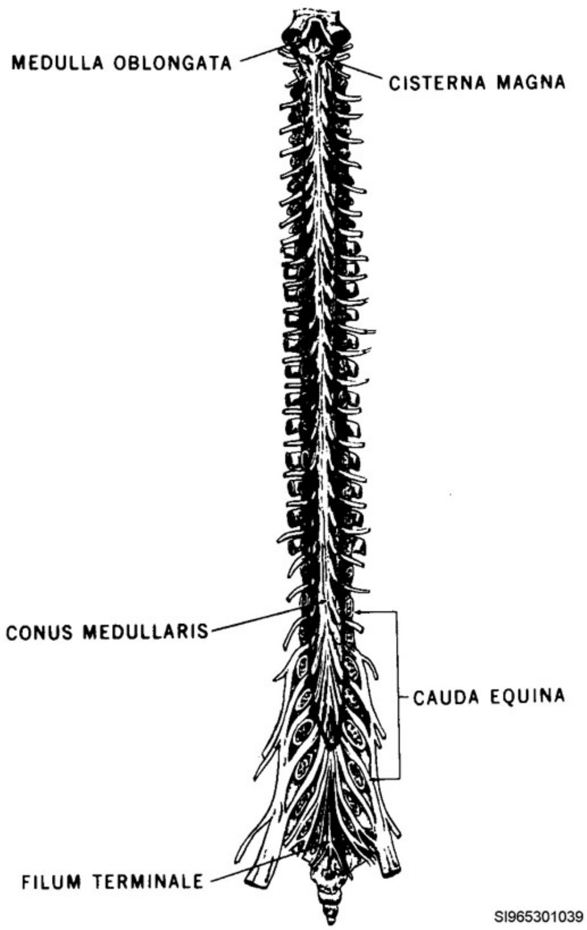

Figure 4–6. The spinal cord.

A relatively deep fissure scores the anterior or ventral surface of the cord. This centrally situated depression is called the *ventral median fissure*. The posterior, or dorsal surface, is scored by a similar but much shallower depression called the *dorsal medial sulcus*. These major depressions divide the cord into lateral halves. Two shallow furrows referred to as the dorsal lateral sulcus and ventral lateral sulcus, respectively further mark each half. Figure 4–7 illustrates the location of these grooves.

The dorsal nerve roots pass through the dorsal lateral sulci and provide the posterior connection between the spinal nerve and the central portion of the cord. The ventral nerve roots pass through the ventral lateral sulci and serve to connect the anterior portion of the central part of the cord with the spinal nerve. Figure 4–8 illustrates the appearance of the nerve roots emanating from their respective sulci and joining to form the spinal nerves.

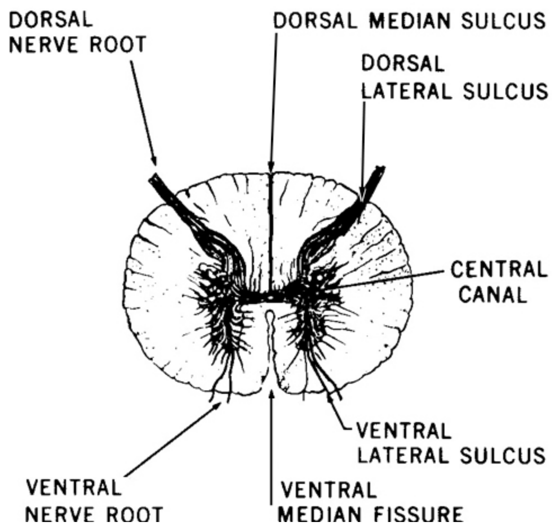

Figure 4–7. Transverse section through the spinal cord.

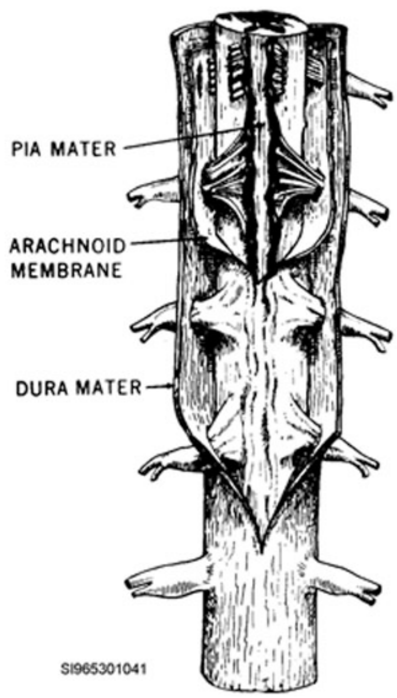

Figure 4–8. Nerve roots emanating from their sulci.

The spinal cord gives off 31 pairs of spinal nerves. Referring back to figure 4–6, you can see the cervical and thoracic nerves exit transversely from the cord, and those on the lumbar region descend almost vertically from the conus medullaris. Thus, the lumbar and sacral nerves descend individually from the conus to their respective points. This region is referred to as the *cauda equina*, which means "horses tail" because the nerves in this region resemble the coarse hair in the tail of a horse. The cauda equina is a group of vertically situated lumbar and sacral nerves that extend from about the second lumbar vertebra to the second sacral segment. The spinal cord and cauda equina are completely invested by three layers of membranous tissue that we discuss in the next lesson.

Internal structure

The inner portion of the spinal cord is comprised of a roughly “H”-shaped central column of gray matter and surrounding fiber tracts of white matter (fig. 4–7). Both types of tissue are continuous with that of the medulla oblongata. The cross-section through the cord shows the structural relationship between the core and its surrounding tissue.

823. Principles of the meninges

The brain and spinal cord are completely covered by three layers of protective membranous tissue that are referred to collectively as the meninges. They are comprised of the pia mater, arachnoid membrane, and dura mater.

Pia mater

The *pia mater* (literally translated “tender mother”) is the innermost portion of the meninges. It is a highly vascular membrane and is adjoined to the underlying brain and spinal cord. The intracranial portion of the pia mater covers the gyri and dips down into the sulci of the cerebrum and cerebellum. It extends into the transverse cerebral fissure, forms the tela choroidea of the third ventricle, and part of the choroid plexuses of the lateral and fourth ventricles. It also covers the outer surfaces of the corpus callosum, hypothalamus, mamillary bodies, pons, and medulla oblongata.

The spinal portion of the pia mater is somewhat thicker than the intracranial portion. It completely encircles the cord and is closely adjoined to it. The tissues of the pia completely fill the median fissure and form a sturdy band along its ventral margins. The pia extends into the filum terminale and blends with the dura mater (outer meningeal membrane) in the region of the second sacral segment, where it joins the peritoneum.

Arachnoid membrane

The term *arachnoid* means spiderlike. Its use in connection with the meninges refers to the similarity between a spider’s web and the delicate structure of the middle meningeal membrane. Referring back to figure 4–8, you will notice the arachnoid membrane is situated between the pia mater and the dura mater; it loosely envelopes both the brain and spinal cord. The arachnoid, unlike the pia, does not dip down into the sulci of the cerebrum and cerebellum. The arachnoid membrane is not closely adherent to the pia mater but is separated from it by the *subarachnoid* space. CSF produced by the ventricular system is circulated throughout this space. CSF surrounds the structures of the brain to provide cushion and protection. The subarachnoid space is not uniform in depth, but forms many widened pockets called *cisterns*. The three principal cisterns are located in the vicinity of the cerebral peduncles, the junction of the pons and the medulla oblongata, and the inferior surface of the cerebellum and the brain stem. The spinal portion of the arachnoid membrane loosely invests the cord and terminates in the distal reaches of the cauda equina.

Dura mater

The *dura mater* (literally “hard mother”) is the outermost meningeal membrane. Comprised of strong, fibrous tissue, the dura completely covers the outer surfaces of the brain and spinal cord. Its intracranial portion is comprised of two layers. The outer periosteal layer is in direct contact with the inner surfaces of the cranial bones. The smooth inner meningeal layer overlies the arachnoid membrane. Both layers of the dura are joined except in the places where the venous dural sinuses pass between them. The meningeal layer of the dura is separated from the arachnoid membrane by the shallow subdural space. This space is similar to that found between the visceral and parietal layers of the pleura. It contains a small amount of fluid to prevent adhesion and friction.

The subarachnoid space

As previously described, the subarachnoid space is continuous around the brain and spinal cord and is divided into intracranial and spinal portions. It is not uniform in depth. The deep spaces in the intracranial portion are referred to as cisterns and surround the base and stem of the brain. The largest of these is the *cisterna magna*. It actually forms a funnel around the base of the cerebellum and the medulla oblongata.

824. Myelography procedures

Traditionally, radiographic procedures of the central nervous system were quite invasive. In many instances, the patient was actually taken to surgery, where burr holes were drilled in the cranium and needles were inserted through the brain into the ventricular system so that contrast could be administered. Fortunately, technological advancements have made these types of procedures obsolete. Today, brain and spinal cord imaging is accomplished primarily through noninvasive imaging techniques such as computed tomography (CT) and magnetic resonance imaging (MRI). However, there are still instances in which myelography affords the best diagnostic information. A myelogram consists of the radiologist introducing the contrast medium into the subarachnoid space followed by spinal imaging with fluoroscopy, CT, or overhead images. Your role consists of assisting the radiologist as needed and making some post-fluoroscopy radiographs.

Spinal puncture

A myelogram is a radiographic study of the spinal cord, specifically the subarachnoid space. (fig. 4–9) To access the subarachnoid space for an intrathecal injection of iodinated contrast medium, a procedure called a spinal puncture is performed. A spinal puncture is a procedure where a needle is inserted through a vertebral interspace and into the subarachnoid space for the purposes injecting a contrast medium or withdrawing CSF. Myelography is performed to evaluate for disk disease, spinal cord compression, trauma induced spinal cord swelling, locate bone fragments, and tumors or masses.

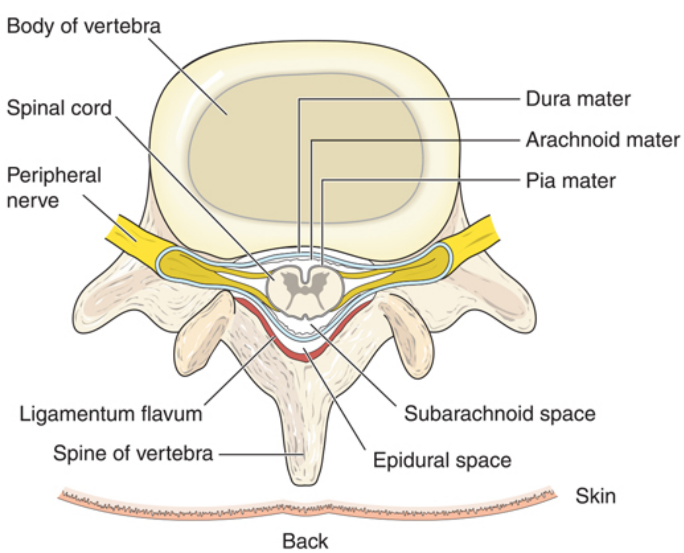

Figure 4–9. Subarachnoid space illustration.

Positioning the patient for lumbar puncture

The contrast medium is usually injected into the subarachnoid space by means of a lumbar puncture. An alternative injection site, less frequently used, is the cisterna magna, which we will discuss later. *Position* the patient for a lumbar puncture on the X-ray table in the prone *or* lateral recumbent position. Attach the headboard and footrest to the table because the table is tilted in both directions throughout the examination to allow the contrast material to gravitate to specific areas of interest. Also, set the fluoro tower lock at an appropriate level to prevent the fluoro tower from being lowered onto the needle while it is in the patient's back.

If the procedure is to be accomplished with the patient prone, place a rolled pillow under the patient's lower abdomen to straighten the normal lordotic curvature of the lumbar spine. This widens the space between the spinous processes, making the puncture easier. If the injection is to be made in the lateral recumbent position, place a sponge or pillow under the patient's lower thoracic and upper lumbar spine to make the spine parallel with the table. Then have the patient flex his or her spine by drawing the knees up toward the chin and drawing the head and shoulders forward (the fetal position). These actions aid the radiologist in locating the injection site for the lumbar puncture.

Positioning the patient for the cisternal puncture

On rare occasions, the contrast medium is injected into the cisterna magna, the widest portion of the subarachnoid space, located in the upper cervical region between the base of the cerebellum and the medulla oblongata. Called a *cisternal or cervical puncture*, the procedure is somewhat dangerous and only used when the subarachnoid space is obstructed, preventing flow of the lumbar-injected medium to the upper spine.

For the cisternal puncture, place the patient in the lateral recumbent position. Elevate the patient's head to place the cervical spine parallel with the table. Initially, until the injection is completed and the needle withdrawn, the patient's head is flexed forward and the head end of the table is elevated. Immediately after injection, the head is hyperextended and usually held in place by another physician or technologist to prevent the contrast medium from entering into the ventricular system of the brain. Contrast material in the ventricles can lead to severe complications, and, in rare instances, they can be fatal. However, two of the more common reasons for hyperextending the patient's head are: (1) to reduce the chance of a severe headache from the contrast medium and (2) to make removal of the contrast medium easier.

Injection of the contrast medium

After the preliminary procedures are completed, the radiologist removes an amount of CSF equal to the amount of contrast medium he or she intends to introduce and injects the contrast medium into the subarachnoid space. Most all non-water-soluble (oily/viscous) contrast media agents for myelography have been replaced with *nonionic* water-soluble injectable media such as Omnipaque. The major advantage of using water-soluble media is that they do not need to be removed after the procedure because they are quickly absorbed by the body. Therefore, the injection needle can be immediately withdrawn from the subarachnoid space after the medium is introduced.

NOTE: Standard ionic water-soluble injectable media are not designed for intrathecal use. Severe complications can result if they are injected into the subarachnoid space.

Fluoroscopy

After the contrast agent has been administered and the needle has been withdrawn, the radiologist begins the fluoroscopic portion of the exam. The contrast is made to flow to the area of interest in a controlled manner by using gravity when tilting the table in either direction. Because the contrast medium is heavier than CSF, it flows to the most dependent portion of the subarachnoid space easily. Once the contrast media is in the desired area of interest, the radiologist performs a series of spot images looking for impingement on the spinal cord caused by a herniated disk, bone fragment, or mass.

If the upper thoracic or cervical spinal canals are examined using fluoroscopy, an additional technologist may be needed to maintain the patient's head in an elevated and hyperextended position to prevent the contrast media from entering the ventricles of the brain.

Following the injection, conventional radiography will continue to provide good diagnostic contrast for at least 30 minutes. At about one-hour post-injection, the contrast medium will be too diluted to provide diagnostic information on conventional images, but should still be sufficiently concentrated to be useful in CT imaging for several more hours.

Post-fluoro projections

After the radiologist finishes the fluoroscopic portion of the exam, he or she will most likely require certain overhead radiographs. The patient's head must not be permitted to drop below the level of the spine. If the contrast medium is in the thoracic or cervical spines, hyperextension of the head must be maintained.

The specific projections performed depend upon the radiologist's fluoroscopic findings. However, standard projections include AP, AP oblique, and standard or cross-table lateral radiographs. Any other particular variations are dependent upon the radiologist's preference; therefore, you should always follow the standard operating procedures of your department when performing this procedure.

Alternative imaging

CT is often utilized to image the spinal column post intrathecal injection of a water-soluble contrast media agent. Though protocols will vary depending upon radiologist preference and the specific scanning capabilities of the CT unit, most post-myelography images are acquired at 1.5mm to 3 mm. It is also standard for the CT gantry to be angled parallel to the intervertebral disks.

MRI is a noninvasive radiology study that enables extraordinary anatomic detail of the brain, spinal cord, intervertebral disks, and CSF in the subarachnoid space. There is one major advantage when using MRI to image the spinal column, no intrathecal injection of contrast media is needed. In many areas of the country, MRI is the gold standard used to evaluate the brain and spinal cord however not all patients can get a MRI. Patients with pacemakers, aneurysm clips, neuro-stimulators, or other metallic objects inside the body may or may not be safe for imaging with MRI due to the type of material/make of the implant and the strength of the magnetic field used to create diagnostic images. If an MRI cannot image the patient, then CT and/or myelography can be used to evaluate the patient's condition.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

821. Principles of the anatomy of the brain and ventricular system

1. What are the four main anatomical divisions of the brain?

2. What is the name of the deep cleft that divides the brain into equal right and left hemispheres?

3. What is the corpus callosum?

4. Which four structures make up the diencephalon region?

5. Which structure separates the cerebellum from the cerebrum?

6. Which three structures comprise the brain stem?

7. Which structures within the ventricles produce cerebrospinal fluid?

8. Which ventricles are composed of anterior, posterior, and inferior horns?

9. Which structure connects the third ventricle with the fourth ventricle?

10. Which structure connects the fourth ventricle with the cisterna magna?

822. Principles of the anatomy of the spinal cord

1. Which bony landmark is the approximate level of the conus medullaris?

2. What is the slender filament that extends from the conus medullaris to the first coccygeal segment?

3. What is the name of the depression on the anterior surface of the spinal cord?

4. How many pairs of spinal nerves are given off by the spinal cord?

5. What is the cauda equina?

823. Principles of the meninges

1. Name the three layers of the meninges.

2. Which layer of the meninges is adjoined to the underlying brain and spinal cord?

3. CSF circulates through which meningeal space?

4. What is the name for a widened pocket in the subarachnoid space?

5. What is the name of the outer most meningeal membrane? What does this term literally mean?

824. Myelography procedures

1. What two basic body positions are used for a lumbar puncture?

2. What is the purpose for setting the fluoro tower lock during a lumbar puncture?

3. Why should you place a rolled pillow under the patient's abdomen for a prone lumbar puncture?

4. When is the cisternal puncture used in place of the lumbar puncture?

5. Why is the patient's head hyperextended immediately after the cisternal injection is completed?

6. How much CSF is typically removed during a myelogram?

7. What is the main advantage of water-soluble myelography contrast agents?

8. When fluoroscopy is used, what does the radiologist do once the contrast is in the desired area of interest?

9. Why would a second technologist be needed during the fluoroscopy portion of myelography for the upper thoracic or cervical canals?

10. What is one major advantage in using MRI to image the spinal column?

11. If MRI cannot image the patient, what can be used to evaluate the patient's condition?

4–2. The Endocrine System

The nervous and endocrine systems work together to direct actions from all body systems. The endocrine system encompasses nine glands of the body and all the hormones produced by those glands. The glands of the endocrine system are commonly called ductless glands because they secrete their hormones directly into the blood stream. Not to be confused, exocrine glands use ducts to secrete their products onto the body surface or into a body cavity. The hormones secreted internally by the endocrine glands control many of our life processes.

825. Basics of the function of hormones

Hormones produced by the endocrine glands are transported by the circulatory system (blood) to all parts of the body to affecting any cell with a receptor for that particular hormone. The same hormone may affect one cell one way and another cell in a different part of the body a different way. This phenomenon causes many diverse and powerful bodily responses.

Hormones

The word hormone comes from the Greek word *hormon* which means “that which sets in motion.” A hormone is a substance that is transported from a gland by the bloodstream to other tissues in the body to cause a physiological activity (response). Once a hormone is released into the bloodstream, the hormone circulates the body until it finds a cell with a specific receptor that is designed to attract that particular hormone. The hormone can then cause an activity like growth or it can cause the cells of another gland to release other hormones for further activity. Hormones that cause the release of other hormones are called *tropic hormones*. Tropic hormones create a mechanism of control for hormone production in glands far away from the primary hormone-producing gland. The pituitary gland produces a variety of tropic hormones to cause activities in other glands.

Chemical classifications of hormones

There are two chemical classifications of hormones: lipid-soluble and water-soluble.

Lipid-soluble hormones

Lipid-soluble hormones such as testosterone, estrogens, glucocorticoids, and mineralocorticoids are considered steroid hormones. Because they are soluble in lipids, these hormones are *able* to pass directly through the phospholipid bilayer of the plasma membrane and bind directly to receptors inside the cell nucleus. Lipid-soluble hormones are directly able to control the function of a cell from these receptors to affect the cell’s growth and function.

Water-soluble hormones

Water-soluble hormones include the peptide and amino-acid hormones such as insulin, epinephrine, human growth hormone, and oxytocin. As their classification indicates, these hormones are soluble in water. Water-soluble hormones are *unable* to penetrate the phospholipid bilayer of the plasma membrane; therefore, they are dependent upon receptor molecules on the surface of cells. When a water-soluble hormone binds to a receptor molecule on the surface of a cell, it triggers a subsequent reaction inside of the cell.

826. Basics of the glands of the endocrine system

In this lesson, we discuss the location and functions of the following endocrine glands: the pineal, pituitary, thyroid, parathyroid, thymus, adrenal, pancreas, and gonads. Refer to figure 4–10 as each is explained.

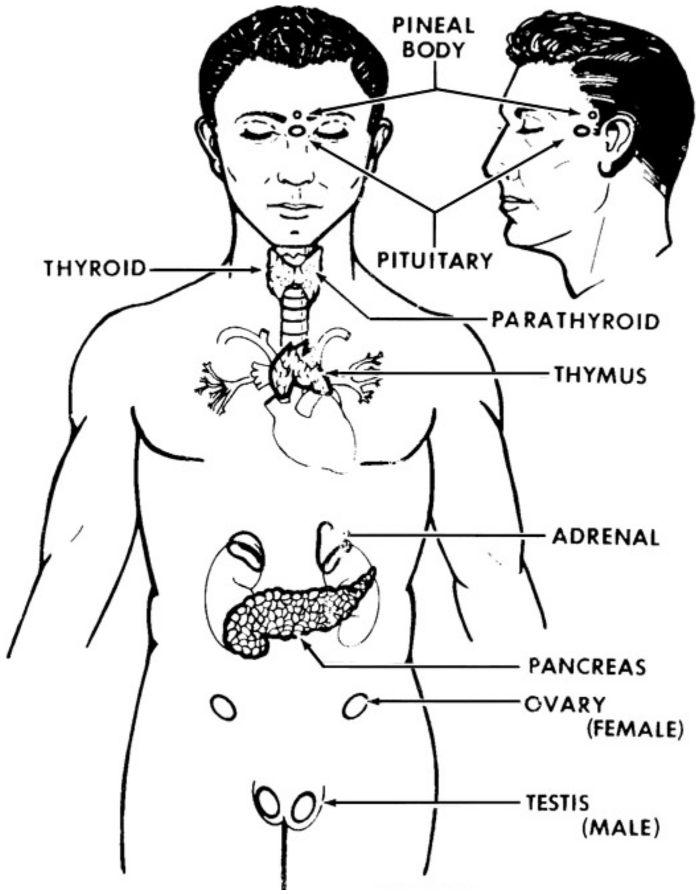

Figure 4–10. Endocrine glands throughout the body.

Pineal

The pineal body is a pinecone shaped gland located in-between the Thalamus and the Cerebellum (fig. 4–11). The pineal gland appears to be the primary site for melatonin production in the body. The effects of melatonin and the functions of the pineal gland are thought to affect the body's biological settings (clock). Higher melatonin levels are present during darkness which tends to promote sleepiness. During daylight, melatonin quantities are low and promote an individual being awake.

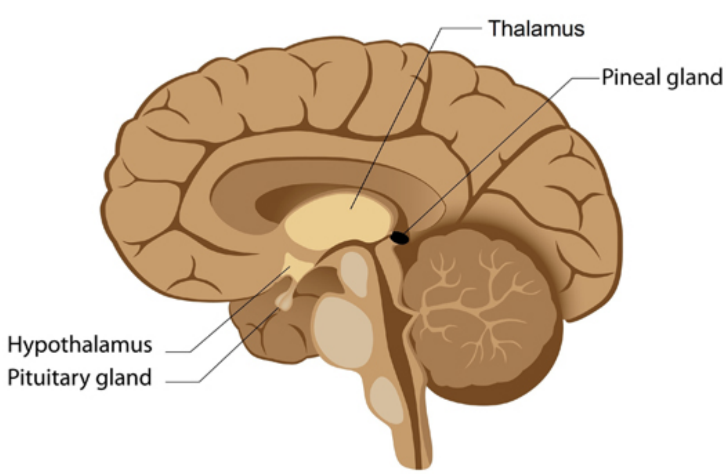

Figure 4–11. Pineal, pituitary, and hypothalamus gland locations.

Pituitary

The pituitary gland, used to be called the master gland because of how it regulates the secretions of various other glands. It is now known that the pituitary gland is controlled by the hypothalamus. Therefore, the hypothalamus is now considered the master gland of the body. The pituitary gland is located in the sella turcica, is pea-shaped, and is comprised of an anterior and a posterior lobe. The anterior lobe dominates the functions of the pituitary by secreting hormones that affect many body processes. The following are examples of some of these hormones and their actions:

- Somatotropin—Influences growth of body tissues.
- Thyrotropin—Influences the thyroid gland, causing it to secrete its hormone.
- Gonadotropin—Stimulates the gonads.
- Adrenotropin—Stimulates the adrenal glands.

Thyroid gland

The thyroid gland is located in the anterior portion of the neck just below the level of the thyroid cartilage. It contains two lobes, the left and right, which are connected by a median strip of tissue called the *isthmus*. The upper portions of each lobe follow the general contour of the lateral portions of the thyroid cartilage, which gives the thyroid a “butterfly” appearance. The hormone thyroxin is secreted by the thyroid gland. Thyroxin controls growth and development of the body and regulates body metabolism.

Parathyroid glands

There are four parathyroid glands, two on each lobe of the thyroid. Even though they are located on the thyroid gland itself, their composition and function are completely independent of the thyroid. They appear as small oval discs averaging about 6 mm in length and 3.5 mm in width. The parathyroids secrete parahormone, which regulates the calcium content in the blood and the general calcific metabolic state in the body.

Thymus

The thymus is located in the anterior portion of the upper mediastinum, overlying the trachea and the major blood vessels arising from the heart. The thymus is larger in small children and undergoes a gradual reduction in size with age. The thymus is important in the development of the immune system of a newborn. As such, it is adjunct to the lymphatic system. The thymus matures and releases a specific type of lymphocyte called *T cells* into the blood stream to fight infections.

Adrenal

The two adrenal glands located on the medial and superior aspects of the upper portions of each kidney consist of an outer section—the cortex, and an inner section—the medulla. The cortex produces several different corticosteroids that regulate salt, water, carbohydrate, protein, and fat metabolism. The medulla secretes adrenaline (epinephrine) and norepinephrine, which enable us to quickly mobilize our body resources in times of emergency or stress.

Pancreas

The pancreas is considered both an exocrine and endocrine gland. Its exocrine function is the production of pancreatic juices for the chemical digestion of fats, carbohydrates, and proteins, which it empties into the duodenum. Its *endocrine* function is the secretion of insulin in the tiny island-like cells called the *islets of Langerhans*. Insulin regulates the sugar metabolism of the body.

Gonads

The gonads are the primary sex organs and are responsible for reproduction, among other things. The female gonads are the ovaries and the male gonads are the testes.

Ovaries

The ovaries produce several estrogens, which are hormones affecting development of the secondary sex characteristics. The estrogens also affect the reproductive functions of the female. One estrogen—progesterone—primarily functions to prepare the uterus for implantation of a fertilized ovum.

Testes

The testes produce hormones called androgens that affect development of the secondary sex characteristics and maintenance of the reproductive functions. Two such hormones are androsterone and testosterone.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

825. Basics of the function of hormones

1. What is a hormone?

2. What is the name of a hormone that causes the release of other hormones?

3. Which type of hormone binds directly to receptors inside the cell nucleus?

4. What happens when a water-soluble hormone binds to a receptor molecule on the surface of a cell?

826. Basics of the glands of the endocrine system

1. Match the endocrine gland in column B with the appropriate description or phrase in column A. Each item in column B will be used once or more than once.

Column A	*Column B*
____1. Produce testosterone.	a. Thyroid.
____2. Secretes insulin.	b. Parathyroid.
____3. Master gland.	c. Thymus.
____4. Secretes adrenalin.	d. Adrenal.
____5. Regulates metabolism.	e. Pituitary.
____6. Larger in small children.	f. Pineal.
____7. Is pea-shaped and has an anterior and posterior lobe.	g. Pancreas.
____8. Functions as both endocrine and exocrine gland.	h. Ovaries.
____9. Produce progesterone.	i. Testes.
____10. Regulates calcium content in the blood.	j. Hypothalamus.
____11. Helps to fight infections.	
____12. Secretes melatonin.	

Answers to Self-Test Questions

821

1. Cerebrum, diencephalon, cerebellum, and brain stem.
2. Longitudinal sulcus.
3. A transverse band of nerve fibers that connects the hemispheres of the cerebrum.
4. It consists of the thalamus, hypothalamus, epithalamus, and subthalamus.
5. The transverse fissure.
6. The midbrain, pons, and medulla oblongata.
7. The choroid plexuses.
8. The lateral ventricles.
9. The aqueduct of Sylvius.
10. The foramen of Magendie.

822

1. The L1-L2 interspace.
2. The filum terminale.
3. The ventral median fissure.
4. 31.
5. A group of vertically situated lumbar and sacral nerves that extend from about the second lumbar vertebra to the second sacral segment.

823

1. The pia mater, arachnoid membrane, and dura mater.
2. The pia mater.
3. The subarachnoid space.
4. A cistern.
5. The dura mater. Hard mother.

824

1. Prone or lateral recumbent.
2. To prevent the fluoro tower from being lowered onto the needle.
3. To straighten the normal lordotic curvature of the lumbar spine and widen the space between the spinous processes.
4. When the subarachnoid space is obstructed, preventing flow of the lumbar-injected medium to the upper spine.
5. To prevent the contrast medium from entering into the ventricular system of the brain.
6. The radiologist removes an amount of CSF equal to the amount of contrast medium he or she intends to introduce and injects the contrast medium into the subarachnoid space.
7. Water-soluble myelography contrast agents do not need to be removed after the procedure because they are quickly absorbed by the body.
8. The radiologist performs a series of spot images looking for impingement on the spinal cord caused by a herniated disk, bone fragment, or mass.
9. An additional technologist may be needed to maintain the patient’s head in an elevated and hyperextended position to prevent the contrast media from entering the ventricles of the brain.
10. No intrathecal injection of contrast media is needed.
11. CT and/or myelography.

825

1. It is a substance that is transported from a gland by the bloodstream to other tissues in the body to cause a physiological activity (response).
2. Tropic.
3. Lipid-soluble.
4. It triggers a subsequent reaction inside of the cell.

826

1. (1) i.

   (2) g.

   (3) j.

   (4) d.

   (5) a.

   (6) c.

   (7) e.

   (8) g.

   (9) h.

   (10) b.

   (11) c.

   (12) f.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

Do not return your answer sheet to AFCDA.

59. (821) Which structure divides the cerebrum into right and left hemispheres?
    a. Major sulcus.
    b. Transverse fissure.
    c. Longitudinal sulcus.
    d. Tentorium cerebelli.

60. (821) Which three structures comprise the brain stem?
    a. Medulla oblongata, pons, and vermis.
    b. Midbrain, cerebrum, and spinal canal.
    c. Midbrain, pons, and medulla oblongata.
    d. Cerebellum, cerebrum, and occipital lobe.

61. (821) Which structure secretes cerebrospinal fluid?
    a. Thalamus.
    b. Choroid plexuses.
    c. Corpus callosum.
    d. Tentorium cerebelli.

62. (821) Which structure connects each lateral ventricle with the third ventricle?
    a. Foreman of Monro.
    b. Aqueduct of Sylvius.
    c. Foramen of Luschka.
    d. Foramen of Magendie.

63. (822) How many pairs of spinal nerves are there?
    a. 5.
    b. 7.
    c. 12.
    d. 31.

64. (822) The region of spinal and sacral nerves that extends from the second lumbar vertebra to the second sacral segment is known as the
    a. cauda equina.
    b. filum terminale.
    c. conus medullaris.
    d. medulla oblongata.

65. (823) The innermost layer of the meninges is called the
    a. pia mater.
    b. dura mater.
    c. subarachnoid space.
    d. arachnoid membrane.

66. (823) What are the widened pockets of the subarachnoid space called?
   a. Sulci.
   b. Cisterns.
   c. Caverns.
   d. Dural sinuses.

67. (824) Which patient positions may be used for performing a lumbar puncture?
   a. Supine and prone.
   b. Prone and lateral recumbent.
   c. Supine and lateral recumbent.
   d. Lateral recumbent and semi-erect.

68. (824) In which circumstance would a cisternal puncture be used for a myelogram?
   a. When the cervical spine is of interest.
   b. To introduce contrast into the ventricles.
   c. When the subarachnoid space is obstructed.
   d. When the patient cannot lay on his/her stomach.

69. (824) What is the primary advantage of the newer, water-soluble myelographic contrast agents?
   a. They are less likely to enter the ventricles.
   b. They provide better radiographic contrast.
   c. Incidence of contrast reaction is greatly reduced.
   d. They do not need to be removed after the procedure.

70. (824) The purpose of hyperextending the patient's head during a myelogramis to
   a. help diagnose a herniated disk in the cervical spine.
   b. prevent the contrast media from entering the ventricles.
   c. see if it produces an increase in cerebrospinal fluid pressure.
   d. prevent blood from rushing to the patient's head when the table is tilted.

71. (825) Water-soluble hormones are
   a. unable to penetrate the plasma membrane.
   b. able to penetrate the plasma membrane.
   c. able to directly affect the cells growth and function.
   d. considered steroid hormones.

72. (826) Which gland is comprised of an anterior and posterior lobe and secretes hormones that affect various other glands?
   a. Pineal.
   b. Adrenal.
   c. Pituitary.
   d. Parathyroid.

73. (826) This gland is considered the master gland of the body.
   a. Hypothalamus.
   b. Pituitary.
   c. Adrenal.
   d. Pineal.

74. (826) Which endocrine gland regulates metabolism and consists of two lobes connected by an isthmus that gives it a butterfly appearance?
   a. Pineal.
   b. Thyroid.
   c. Thymus.
   d. Parathyroid.

75. (826) The *islets of Langerhans* are located in which endocrine gland?
   a. Pancreas.
   b. Thymus.
   c. Ovaries.
   d. Testes.

Please read the unit menu for unit 5 and continue ➔

Student Notes

Unit 5. The Cardiovascular and Muscular Systems

THIS UNIT CONCLUDES OUR STUDY of anatomy and physiology. It includes two sections covering the cardiovascular and muscular systems. Blood and lymph are circulated throughout the body by the circulatory system. Occlusion, perforation, or disease of these organs and tissues can produce serious and often permanent damage. Not only are the components of the cardiovascular system affected but so are the organs or structures dependent upon them for blood supply. Prompt medical or surgical intervention is often required to correct a malfunction. The first section discusses the anatomy and physiology of the cardiovascular and lymphatic system. In the second section, the discussion outlines muscle structure, function, and basic anatomy.

5–1. Anatomy and Physiology of the Circulatory System

The circulatory system includes the lymphatic and cardiovascular systems. The primary purpose of the circulatory system is to carry oxygen and nutrients to the cells of the body and to remove carbon dioxide and waste from them. Secondary functions of the circulatory system include fighting infection and promoting healing of damaged tissues.

827. Lymph and blood circulation principles

Lymph is a yellowish fluid produced in various tissue spaces throughout the body. Lymph is similar in composition to blood plasma and is carried through the lymphatic system to the thorax where it reenters the blood stream at the junction of the internal jugular and subclavian veins.

Lymphatic system

The lymphatic system is composed of lymphatic vessels, glands, and nodes (fig. 5–1). It promotes the return of body fluids toward the heart; as such, it is an adjunct to the cardiovascular system. Lymph comprises the bulk of intercellular fluid. It functions as a transfer medium between blood and individual cells, supplying the cell with nutrients and oxygen, and fighting off bacteria. It contains lymphocytes, proteins, and waste by-products. Lymphocytes are a type of white blood cell that carries off waste and initiates formation of scar tissue. The proteins are a source of energy for the cells. The waste materials are a result of cellular metabolism.

Lymph vessels, nodes, and ducts

Lymph vessels comprise a network of tubes that begin in the intercellular spaces. Here tiny lymph capillaries collect lymph and transport it to lymph nodes located throughout the body. Lymph nodes or glands are small oval or bean-shaped bodies that vary from a pinhead to a lima bean in size. The lymph nodes filter out the waste by-products and fight bacteria. They are distributed along the course of the lymph vessels in close contact with veins, sometimes singly, but usually in groups or clusters. There are superficial and deep nodes. Lymph nodes are especially numerous in the neck (cervical), armpit (axillary), groin (inguinal), thorax, and abdomen. Small lymph vessels enter these nodes, and a larger trunk leaves the nodes. Eventually, vessels from the nodes carry lymph to a large duct in the thorax where the lymph is returned to the bloodstream into the left subclavian vein. Valves located in the vessels prevent back-flow.

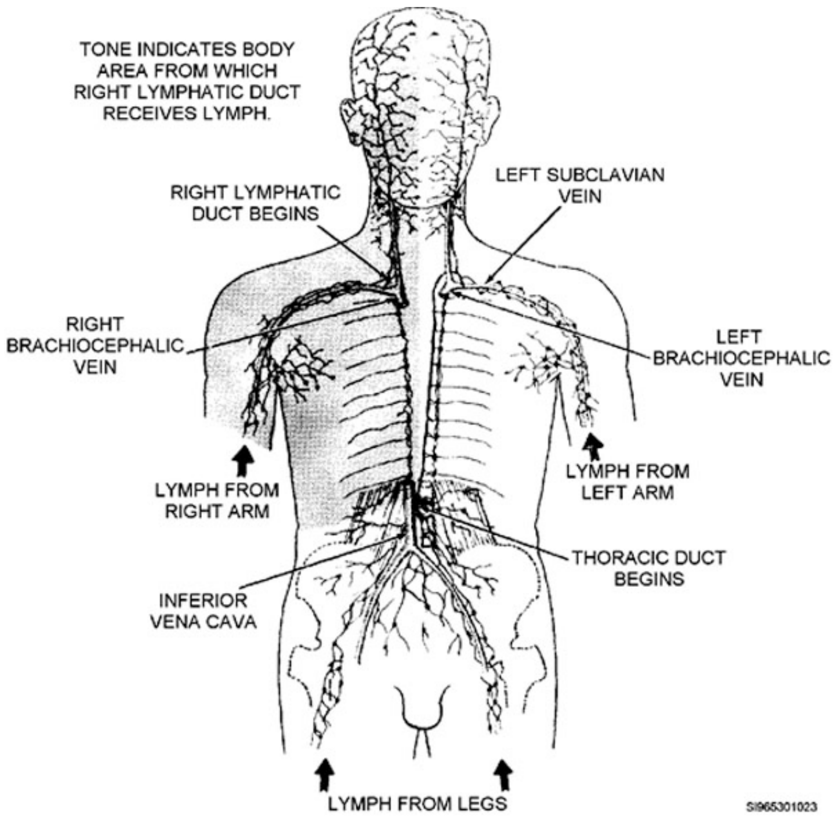

Figure 5–1. The lymphatic system.

Spleen

The spleen is the *largest* collection of lymphoid tissue in the body. It is a large, gland-like, ductless organ directly beneath the diaphragm, behind and to the left of the stomach. Two of its functions are to produce lymphocytes for fighting infection and to store red blood cells.

Blood and blood vessels

Blood is a transport medium for the body. It is comprised primarily of erythrocytes (red blood cells), leukocytes (white blood cells), platelets, and plasma. The functions of blood are to carry nutrients and oxygen to tissues of the body, remove waste products from tissues, protect the body against infection, and maintain proper temperature and fluid content in the body.

Blood is circulated throughout the body by a pump, the heart, and a series of blood vessels which are categorized according to size and function. Blood vessels that carry blood away from the heart are grouped under the general category of arteries. Blood vessels that carry blood back to the heart are called veins. Within each of these major groupings are further subdivisions generally relating to the size of the vessels.

The largest artery in the body is the aorta, which carries blood directly from the heart. Many smaller arteries branch off the aorta to distribute blood to all parts of the body. Each arterial branch becomes progressively smaller, eventually reaching the arteriole size. From arterioles, the blood passes through a network of microscopic, thin-walled channels called capillaries. Capillaries are only large enough to allow blood cells to pass through single file. It is at the *capillaries* that the *exchange* of nutrients and oxygen for carbon dioxide *and* waste products takes place with the cells of the body. From here the blood is collected into venules and then returned to the heart through veins of progressively larger size which eventually converge into two main vessels in the body, the superior and inferior vena cavae. The vena cavae channel blood directly into the heart.

Arteries are thick-walled and do not collapse when empty. The artery wall is actually composed of three layers of tissue. The middle layer is muscular and its purpose is to allow the arteries to expand and contract to maintain blood pressure. Veins are thin-walled and collapse when empty. The contraction of muscles adjacent to veins aids in the forward propulsion of blood toward the heart. Valves are spaced frequently along the inner walls of large veins to prevent the backflow of blood. At the center of the whole system is a pump, the heart.

Heart

The heart is the major organ of the circulatory system (fig. 5–2). It is hollow, muscular, somewhat cone-shaped, and slightly larger than the closed fist. The heart lies obliquely in the lower two-thirds of the thoracic cavity, with the apex directed downward and the bulk of its mass to the left of the median sagittal plane.

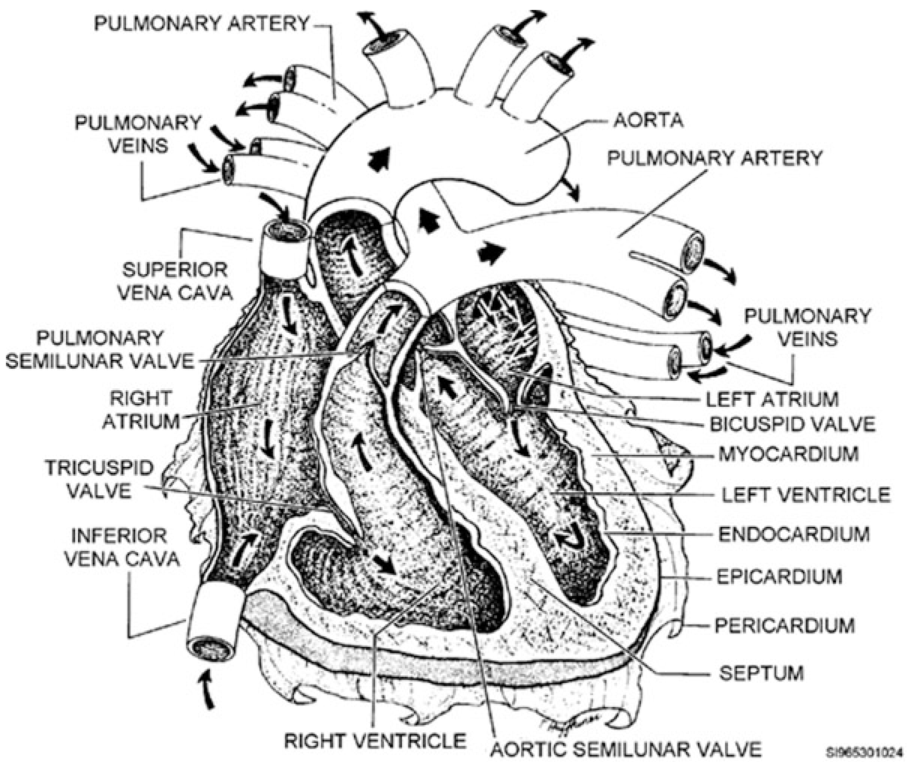

Figure 5–2. The heart.

Structure

Located in the mediastinum, the heart is *enclosed* in a dual-layered, loose-fitting sac called the *pericardium*. Between the outer fibrous layer and the inner serous layer is a serous liquid, *pericardial fluid*, which lubricates the smooth outer surface of the heart. The inner layer of the pericardium is considered the outer layer of the heart and may also be referred to as the epicardium. The myocardium is the middle, muscular layer which allows the heart to contract, and the endocardium is the smooth inner lining of the heart.

The superior portion, or base, of the heart consists of two receiving chambers, the atria. The main body extends into the apex and consists of two larger chambers, the ventricles, which are separated by a wall of tissue called the *interventricular septum*. A series of one-way valves guards the openings into each of the chambers of the heart and prevents blood from flowing in the wrong direction during systole (contraction of the heart). The tricuspid valve lies between the right atrium and ventricle; the mitral (or bicuspid) valve between the left atrium and ventricle; and the semilunar valves (pulmonic and aortic) guard the outlets of the ventricles.

Blood circulation

Deoxygenated blood from the body tissues enters the *right atrium* through the superior and inferior venae cavae (fig. 5–2). It then passes through the tricuspid valve into the right ventricle. Blood leaves this chamber through the pulmonary semilunar (pulmonic) valve and passes through the right and left pulmonary arteries to the lungs, where it receives a fresh supply of oxygen and releases carbon dioxide. The oxygenated blood returns to the heart through pulmonary veins, which open into the left atrium. From the *left atrium*, blood passes through the *bicuspid* (or mitral) *valve* into the *left ventricle*. This ventricle is the largest and strongest chamber of the heart, and from it the oxygenated blood passes through the aortic semilunar valve into the aorta from which it is distributed to the systemic circulation (all parts of the body except the lungs).

Heart action

Although variations in the individual heart rate depend on sex, age, and physical activity as well as other factors, the heart normally beats about 70 times per minute.

Each heartbeat or cardiac cycle consists of a phase of contraction called *systole*, followed by a phase of relaxation called *diastole.* Each wave starts at the atria and moves across the ventricles so that both atria contract simultaneously, forcing blood into the ventricles, followed immediately by both ventricles contracting simultaneously, forcing blood into the pulmonary and systemic circulation. When a chamber is in systole, blood is being forced out, and when it is in diastole, blood is entering. Each cardiac cycle takes approximately 0.8 seconds.

Blood pressure is a measure of how much force is exerted on the arterial walls by the blood. Blood pressure is normally divided into two phases: systolic and diastolic. The systolic pressure is the pressure during the heart’s contraction phase; the diastolic pressure is the pressure during the heart’s relaxation phase. The pressure difference between the two phases is the pulse pressure.

828. Aorta and other major vessels principles

Systemic circulation follows an orderly pattern in which blood from the heart courses through the major arteries to body tissues and returns to the heart through major veins and their tributaries.

Major arteries

The aorta is the primary arterial trunk line in the systemic circulation. It arises from the left ventricle, ascends superiorly, arches over the left lung, and descends through the thoracic and abdominal cavities along the spinal column to the level of the fourth lumbar vertebra. Here it bifurcates into the right and left *common iliac arteries*, which supply the lower extremities. Major arteries supplying other parts of the body branch out from the aorta at specific locations. For descriptive purposes, the aorta may be divided into four regions: the ascending aorta, arch of the aorta, descending thoracic aorta, and abdominal aorta.

The major arteries are shown in figure 5–3. Two arteries branch off the ascending aorta—the right and left coronary arteries. These arteries branch off almost immediately as the aorta leaves the left ventricle and supply the tissues of the heart itself. The aortic arch has *three main* branches, which go on to supply the head and upper extremities. *These are* the brachiocephalic, left common carotid, and left subclavian arteries. The descending thoracic aorta has no major branches, only giving off small arteries to supply thoracic viscera and musculature.

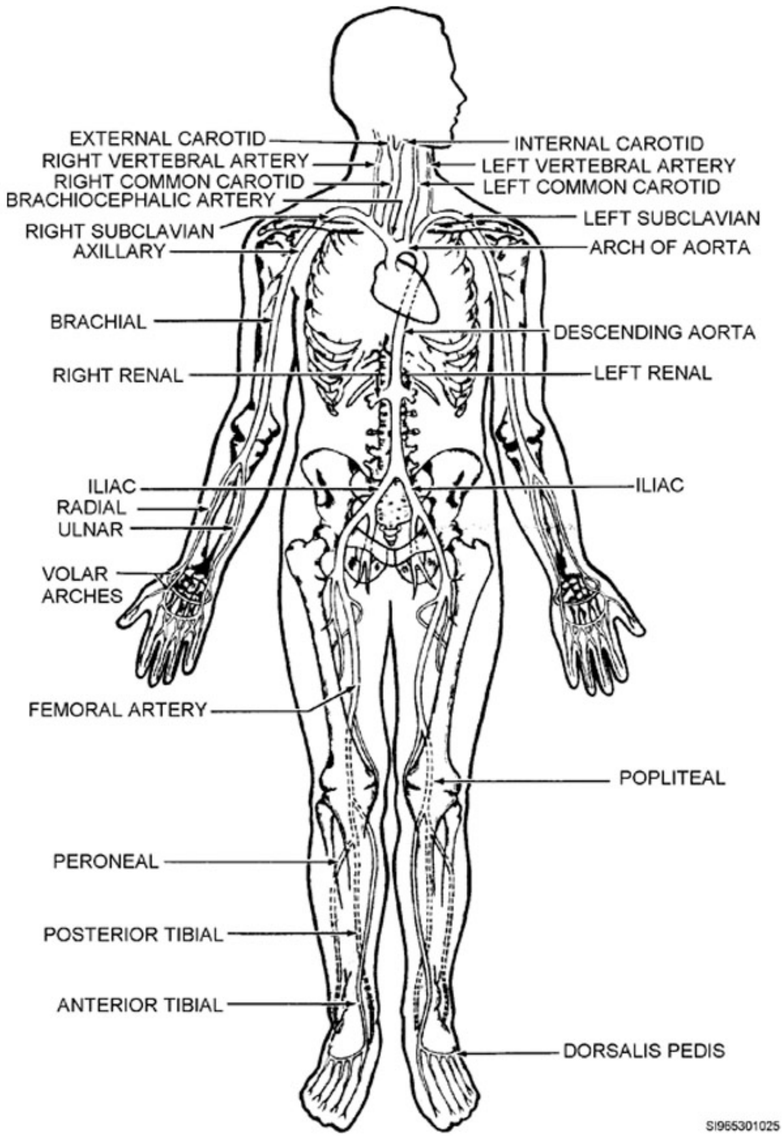

Figure 5–3. Major arteries.

As the aorta passes through the diaphragm, it becomes the abdominal aorta. The abdominal aorta has several main branches, the first of which is the *celiac* artery (or celiac trunk). The celiac trunk arises anteriorly from the aorta at the level of T12. The celiac trunk extends only a few centimeters before trifurcating into the hepatic, splenic, and left gastric arteries. Just below the celiac another major artery, the superior mesenteric, also branches off anteriorly to supply a large portion of the small bowel and the proximal colon. The next major branches of the abdominal aorta are the renal arteries, which originate at the level of the L1-L2 interspace to supply the kidneys with blood. Below the renal arteries, the inferior mesenteric artery branches off to supply blood to the distal two-thirds of the colon and the rectum.

The aorta bifurcates at the approximate level of L4 into the right and left common iliac arteries, which supply blood to the pelvis and both lower extremities. The major arteries of the upper and lower extremities can be seen in figure 5–3 and should be studied closely.

Major veins

In general, the major veins courses through the body in proximity to the arteries and, in many cases, have the same name. Blood from the heart tissue itself drains through the coronary sinus into the right atrium. The blood from the head and neck drains into the jugular veins; the blood from the upper extremities drains into the subclavian veins. On each side, these veins join to form the right and left innominate veins, which, in turn, unite into the *superior vena cava*, which opens into the right atrium. The superior vena cava also receives the azygos vein, which, with its tributaries, returns blood from the thorax to the superior vena cava. The azygos vein begins in the abdomen as an extension of one of the tributaries of the inferior vena cava, and it serves as a connection between the superior and inferior venae cavae in the return of blood to the heart.

The major veins are shown in figure 5–4. From the lower extremities and abdomen, two venous routes lead to the heart. In the direct route, blood from the lower extremities moves through the right and left common iliac veins, which join at the level of the fifth lumbar vertebra to form the inferior vena cava. This major vein courses through the abdominal cavity to the right of the aorta along the posterior abdominal wall. It receives the lumbar, genital, renal, adrenal, hepatic, and inferior phrenic veins as it ascends through the abdominal cavity, before it enters the right atrium of the heart.

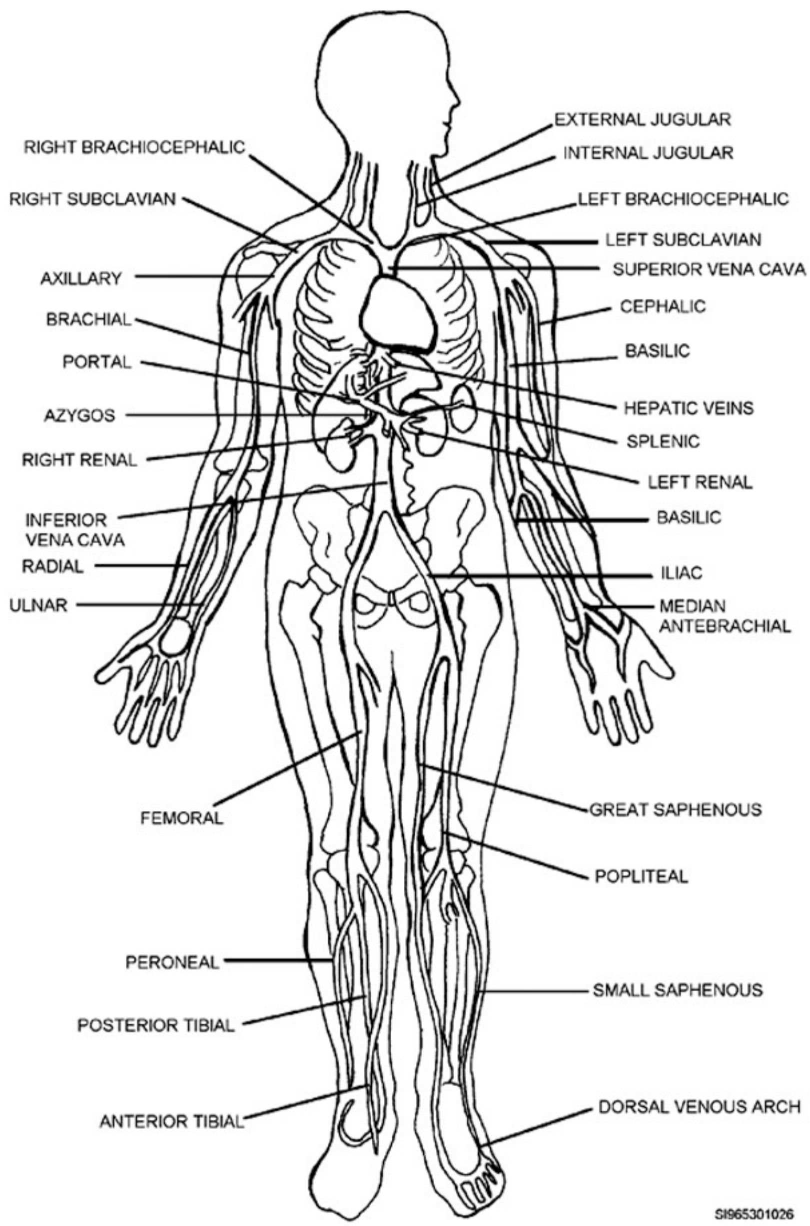

Figure 5–4. Major veins.

Blood from the spleen and the gastrointestinal tract is not returned directly to the heart by way of the inferior venae cavae. Instead, the veins draining the small intestine, stomach, lower esophagus, and spleen join to form the *portal vein*, which enters the liver. Blood from the tissues of the liver enters the hepatic vein, which then drains into the inferior venae cavae enroute to the right atrium.

829. Vessels of the head and neck principles

The arteries that carry blood to the cervical and cranial regions arise from the aortic arch, innominate, and subclavian arteries. As seen in figure 5–5, the ascending vessels include the left and right common carotids and the vertebral arteries. The left common carotid arises from the highest point of the aortic arch and ascends through the superior portion of the mediastinum into the neck. The right common carotid passes directly into the neck from its point of origin at the bifurcation of the innominate artery. Once in the cervical region, the appearance and configuration of the carotid arteries and their branches are essentially identical. The same is true of the vertebral arteries.

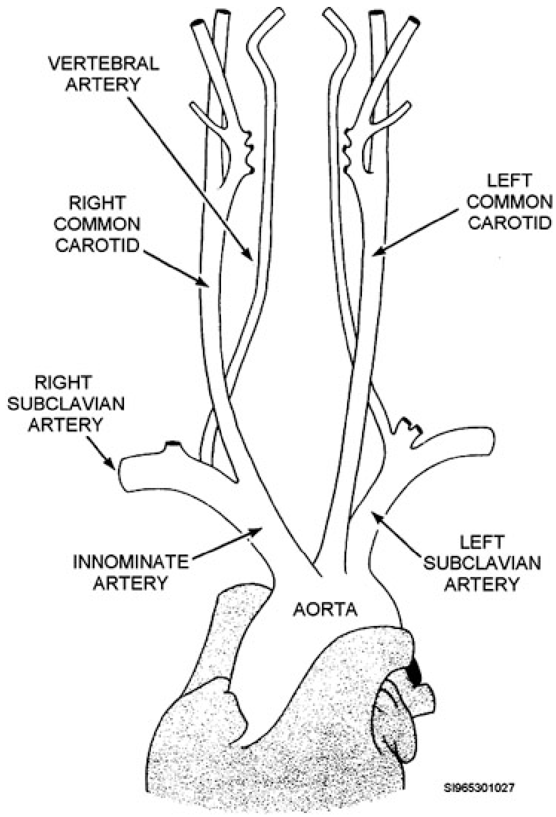

Figure 5–5. Branches of the aortic arch.

Carotid arteries

The cervical portion of the carotid artery ascends obliquely through the neck to a point approximately level with the superior aspect of the thyroid cartilage. Here it bifurcates, forming internal and external branches.

The external carotid artery curves laterally and then ascends along the side of the neck. It gives off numerous branches that supply the upper neck, face, and scalp.

The internal carotid artery supplies the brain. It ascends almost vertically from the carotid bifurcation to the floor of the skull. It then follows a tortuous path through the petrous portion of the temporal bone. The vessel then passes medially along the surface of the sphenoid bone and gives off the ophthalmic artery, which supplies the eye and the orbit. The *internal carotid* then curves upward and perforates the dura mater in the region of the sella turcica. It then bends upon itself and gives off the anterior cerebral, middle cerebral, posterior communicating, and choroidal arteries. These vessels supply the deep midportion of the cerebral hemisphere. Figure 5–6 illustrates the internal carotid system and shows the vessels as seen from the right side.

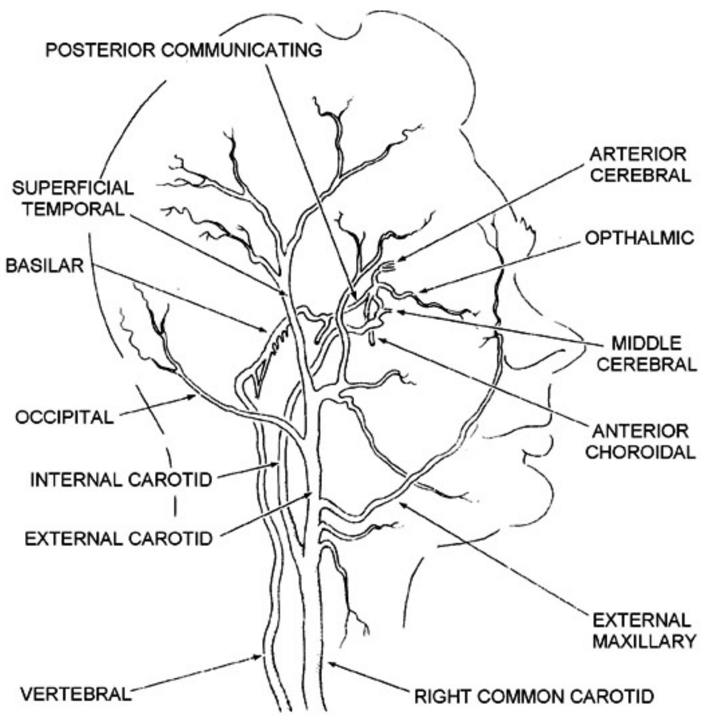

Figure 5–6. The arterial system of the head and neck.

Vertebral arteries

The vertebral artery arises from the subclavian and, as illustrated in figure 5–6, ascends through the foramina of the transverse processes of the cervical spine to the base of the skull. It then passes through the foramen magnum and joins with its counterpart on the opposite side to form the *basilar artery*. Before they join, however, each vertebral artery gives off one inferior cerebellar artery. These vessels pass through the foramen magnum and serve to nourish the lower portion of the hind brain.

The basilar artery, usually a midline structure, ascends on an anteriorly angled course to a point about one centimeter posterior to the dorsum sellae. Here it gives off several branches that supply the cerebellum and the posterior aspects of the cerebral hemispheres. The basilar artery terminates in the posterior cerebral arteries.

Circle of Willis

Both carotid and both vertebral arteries are joined at the base of the brain by the circle of Willis. Figure 5–7 illustrates the appearance and structural arrangement of this juncture. Notice that branches from the carotid system form the majority of the circle. The anterior cerebral arteries are joined by the anterior communicating arteries to form the anterior portion of the circle; while the internal carotid and the middle cerebral arteries form the majority of its lateral aspects. The posterior portion of the circle is formed by the posterior communicating and posterior cerebral arteries and is the terminal end of the basilar artery.

The circle of Willis is an important source of collateralized blood flow for the brain. The configuration of the vessels is such that if one of the four major vessels supplying the brain is occluded, blood can be diverted from the other vessels to supply the affected area of the brain, thereby preventing tissue damage.

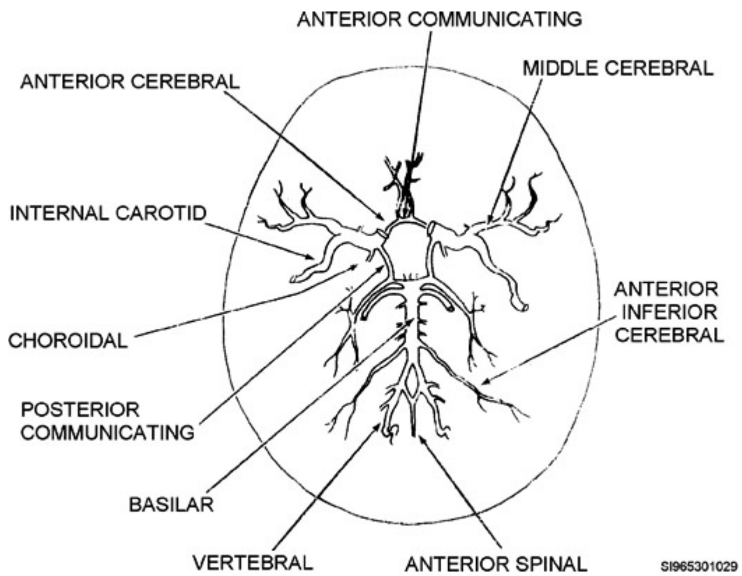

Figure 5–7. Circle of Willis.

Intracranial venous return

The vessels that comprise the venous network of the head and neck are divided into deep and superficial groups. The deep vessels of the head, those which drain blood from the brain, are comprised of the internal and external cerebral veins, the superior and inferior cerebellar veins, and the dural sinuses. Refer to figure 5–8 as we discuss these vessels.

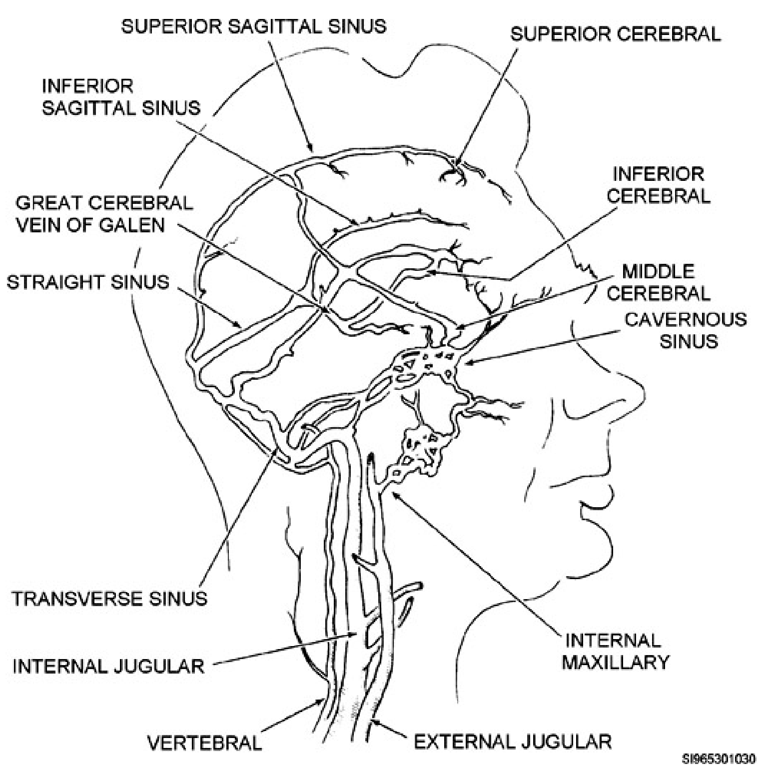

Figure 5–8. The dural sinuses of the head.

The internal cerebral veins empty the deep midportion of the cerebral hemispheres. The external cerebral veins empty the upper, middle, and basilar surfaces of the hemispheres. The cerebellar veins drain blood from the hindbrain. All of these vessels empty into the *dural sinuses*. The dural sinuses are large venous vessels that are actually expansions within the dura mater and completely surround the brain. The superior and inferior sagittal sinuses lie along the margins of the *falx cerebri* (a fibrous, curtain-like structure that separates the superior aspects of the cerebral hemispheres). They are joined by the straight sinuses. These sinuses join in the region of the internal occipital protuberance and form the confluence of the sinuses. The right and left transverse sinuses extend inferolaterally from this junction. They pass along the inner surface of the occiput and give rise to the inferior and superior petrosal and basilar sinuses. The latter gives rise to the sigmoid sinuses, which empty into the internal jugular veins. There are no valves in these thin-walled venous sinuses.

Superficial veins of the head

The superficial veins of the head, illustrated in figure 5–9, arise from the scalp and face. They describe a pattern similar to that of the external carotid arterial system and, for the most part, empty into the external jugular veins. As you can see, the occipital vein does not empty into either of the jugular vessels but passes down the posterior aspect of the neck to join with the deep cervical and vertebral vessels. The anterior facial vein empties into both of the large neck veins.

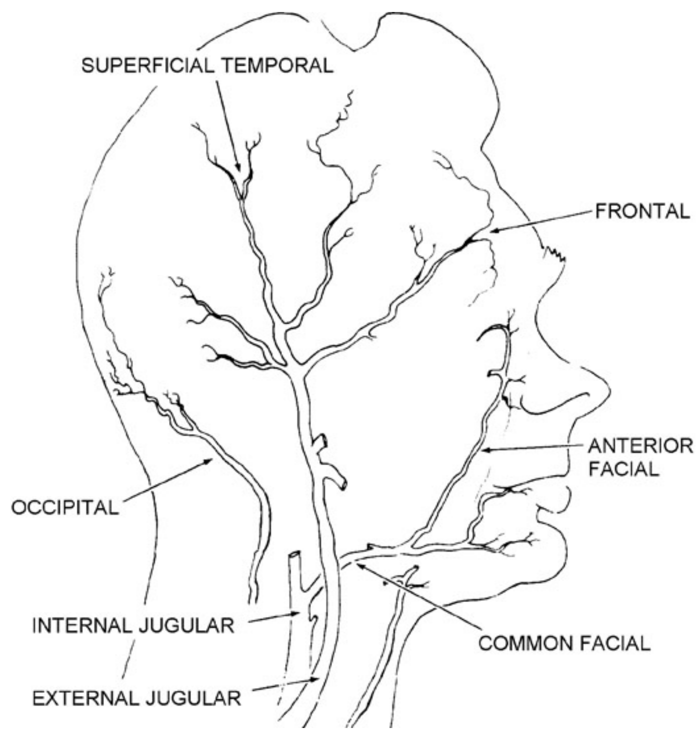

Figure 5–9. Veins of the head and neck.

The veins of the neck consist of the internal jugular veins (which are the largest), external jugular veins, the vertebral veins, and deep cervical vessels. As illustrated in figure 5–8, the vertebral vein originates at the base of the skull and passes downward through the foramina in the transverse processes of the cervical spine. Thus, it follows a course closely approximating that of the vertebral artery. This vein empties into the subclavian vein.

The external jugular veins, as shown in figure 5–9, commence near the angles of the mandible. They descend along the lateral aspects of the neck to about the level of the clavicles where they empty into the subclavian veins. The external jugulars receive tributaries from the smaller anterior and posterior external jugular veins, from the superior veins of the base of the neck and scapula, and from the large communicating branch from the internal jugulars.

The internal jugular veins arise from the sigmoid sinuses, pass through the jugular foramina in the floor of the skull, and descend (almost vertically) to join with the subclavian veins. These large vessels receive branches from the common facial, lingual, pharyngeal, and the superior and middle thyroid veins. Although their primary function is to drain blood from the brain, they also receive and carry off blood from the face and the structures of the neck.

The subclavian vein extends medially from the first rib to the sternal end of the clavicle. It lies anterior and inferior to the subclavian artery and receives several tributaries, including the external jugular vein. The subclavian joins with the internal jugular to form the innominate (or brachiocephalic) vein.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

827. Lymph and blood circulation principles

1. What is lymph and its function?

2. What is the function of lymph nodes?

3. What is the largest collection of lymphoid tissue in the body and where is it located?

4. List five functions of blood.

5. What is an artery? A vein?

6. Where are nutrients and oxygen exchanged for carbon dioxide and waste products?

7. Name the two main venous vessels in the body.

8. What is the purpose of the muscular layer of arteries?

9. In large veins, valves are spaced frequently along the inner walls for what purpose?

10. What is the name of the dual-layered sac that surrounds the heart?

11. What is located in between the outer fibrous layer and the inner serous layer of the pericardium? What is its purpose?

12. Name the three layers of heart tissue.

13. Name the four heart valves and describe their locations.

14. Describe the order of blood flow through the heart.

15. What are the two phases of the cardiac cycle?

16. Approximately, how long is each cardiac cycle?

17. What is the difference between the two phases (systolic and diastolic) called?

828. The aorta and other major vessels principles

1. Name the four major branches of the aorta.

2. Which two arteries branch off of the ascending aorta?

3. Name the three main branches of the aortic arch.

4. Which three arteries branch off the celiac?

5. At which level do the renal arteries branch off the aorta?

6. What artery supplies blood to the distal two-thirds of the colon and the rectum?

7. The aorta bifurcates at approximately what level?

8. What two veins unite to form the superior vena cava?

9. What vein is formed by the junction of the right and left iliac veins?

10. How is blood from the spleen and gastrointestinal tract returned to the heart?

829. Vessels of the head and neck principles

1. Which artery supplies blood to the upper neck, face, and scalp?

2. The anterior cerebral, middle cerebral, posterior communicating, and choroidal arteries are branches of which artery?

3. Which artery passes through the transverse processes of the cervical spine?

4. Which artery is formed by the junction of both vertebral arteries?

5. What joins the carotid and vertebral arterial systems at the base of the brain?

6. What is the function of the circle of Willis?

7. What is the name for the large venous vessels formed by expansions within the dura mater?

8. What are the largest veins in the neck?

9. Which two veins join to form the innominate vein?

5–2. The Muscular System

Most physiological activities of the body can be related to movement produced by the muscles. We exercise conscious control over some muscles to produce voluntary movements, such as the act of walking. Other movements, such as the heartbeat, are precipitated by conditions not under our voluntary control. Our study of the muscular system includes a look at the three types of muscular tissue, some skeletal muscle characteristics, and finally a study of some specific skeletal muscles.

830. The structure and function of muscle tissue principles

All muscles found in the human body can be classified into one of three types: smooth, cardiac, or skeletal.

Smooth

Smooth muscle is composed of spindle-shaped fibers that do not appear to have striations or stripes, as the other muscle types do when examined microscopically. Smooth muscles are sometimes called *visceral muscles* because they are located primarily in the walls of various abdominal organs, such as the stomach and the intestines. These muscles are stimulated by impulses from the autonomic nervous system, which controls the involuntary functions of the body. The walls of blood vessels also contain smooth muscle fibers that account for the dilatation and constriction of the vessels. Because smooth muscles are stimulated by automatic impulses, they are sometimes called *involuntary muscles.*

Cardiac

Cardiac muscle tissue, as the name implies, is only found in the walls of the heart. Microscopically, heart muscles appear similar to the skeletal muscles in that they are striated. Their actions—contraction and relaxation—are responsible for the pumping action of the heart that circulates blood throughout the body. Naturally, cardiac muscle fibers are involuntarily controlled.

Skeletal

Most of the muscles in the body are classified as *skeletal*. In fact, they alone constitute about 40 percent of the body weight. Skeletal muscles are so designated because they are attached to bones. They are also sometimes referred to as voluntary muscles because we exercise conscious control over them. As stated in the introduction to this section, the act of walking results from voluntary control over our muscles. In this case, we regulate the movements of our legs by consciously and voluntarily influencing the actions of certain leg muscles. Skeletal muscles are also sometimes called *striated muscles* due to their microscopic appearance. When magnified, a skeletal muscle fiber appears to be composed of alternate light and dark parallel stripes.

Although each skeletal muscle performs a uniquely specific task, each has certain common characteristic relating to form and function.

Basic parts of a skeletal muscle

Skeletal muscles are composed of three basic parts—a body, origin, and insertion (fig. 5–10). The body, or belly, is the large middle portion of the muscle responsible for performing the majority of the work of contraction. The skeletal muscles origin is the proximal point of attachment, located on the more fixed anatomical structure. As the muscle performs work (contracts), the *origin* remains relatively *immobile*. Conversely, the skeletal muscle's insertion is the distal point of attachment, located on the more movable structure.

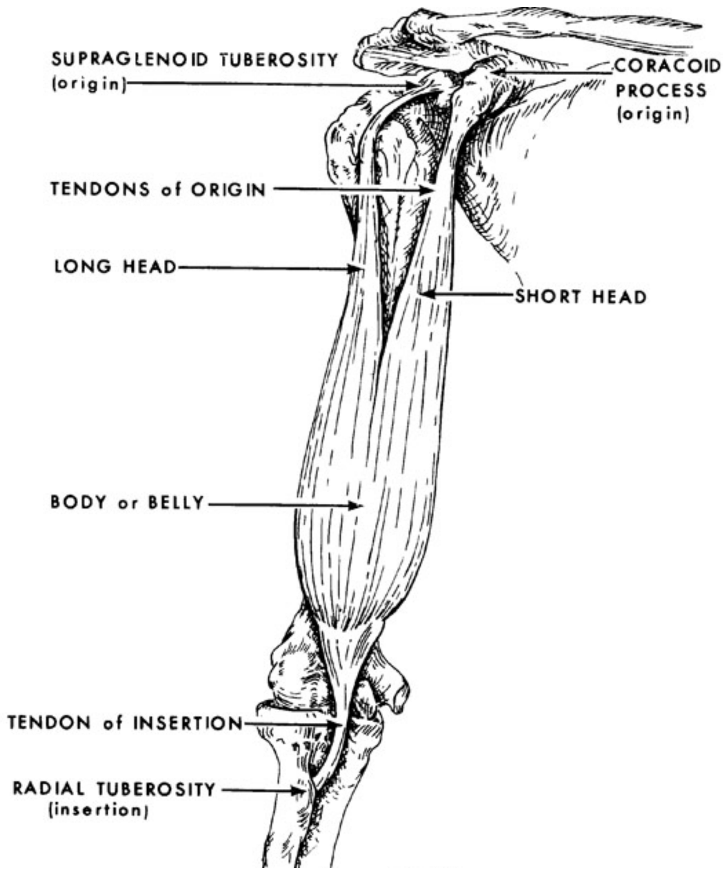

Figure 5–10. Basic parts of a skeletal muscle (biceps brachii).

The biceps brachii, illustrated in figure 5–10, among other functions, flexes the elbow. The distal portion of that muscle is attached to the forearm which is more movable during elbow flexion than the proximal attachment point—the scapula. Therefore, in this instance, the scapula is the origin, and the proximal forearm is the insertion. Notice that the biceps brachii has two points of origin, because the proximal portion is split into two divisions. When this is the case, each division is sometimes referred to as a head. Also, notice that the muscle tissue itself terminates in a tendon that connects the muscle to the points of origin and insertion.

In actuality, the origin and insertion of a skeletal muscle are functionally interchangeable. For example, if you chin yourself on a horizontal bar, the act includes flexion of the elbows, but your forearms are relatively stationary while the remainder of your body moves. This situation would reverse the origin and insertion of the biceps brachii. For general descriptive purposes, however, the origin is the proximal portion and the insertion is the distal portion.

Skeletal muscle actions

The human body has more than 400 skeletal muscles; they function in groups to provide various movements. Groups arranged to oppose each other are called *antagonistic* muscle groups. An example of antagonistic action is the flexion and extension of the elbow. As the biceps brachii contracts, the triceps brachii relaxes and the elbow flexes; conversely, as the triceps brachii contracts, the biceps brachii relaxes and the elbow extends. During elbow flexion, the triceps brachii is the antagonist of the biceps brachii. These combined actions of antagonistic muscles provide smooth, coordinated movements and help to regulate and stop the movements.

In most instances, more than one muscle crosses and regulates the movement of a particular joint. However, certain muscles are primarily responsible for movement and are called *prime movers.* A single muscle or group of muscles may be primarily responsible for the movement. In case of flexion of the elbow, the biceps brachii, brachialis, and brachioradialis all contribute to the movement. The biceps brachii and brachialis are primarily responsible for the movement, while the brachioradialis is considered an *agonist.* An agonistic muscle is one that aids a prime mover, whereas an antagonistic muscle is one that opposes a prime mover.

In addition to prime movers, agonists, and antagonists are *synergistic muscles*. These muscles stabilize joints so that the prime mover and the agonist function efficiently. Referring once again to elbow flexion, as the appropriate muscles act to flex the joint, certain muscles about the shoulder must contract to stabilize the arm so that flexion occurs in the desired direction or plane. Such stabilizing muscles are said to be synergistic.

831. Basic muscular anatomy principles

We conclude our discussion of the muscular system with a look at some of the specific skeletal muscles. We examine seven such muscles in terms of their origin, insertion, and action.

Serratus anterior

The serratus anterior is a thin muscle situated between the ribs and the scapula. It originates on the lateral aspects of the first eight ribs and inserts into the vertebral border of the scapula. Its major function is to rotate the scapula.

Trapezius

The trapezius is the large posterior muscle of the neck and shoulder. Anatomically, it is divided into the upper, middle, and lower portions. The origins of the trapezius extend from the external occipital protuberance, down the nuchal ligament, and along the spinous processes of the thoracic vertebrae. The insertions include the lateral one-third of the clavicle, the vertebral border of the scapula, and the base of the scapular spine. Actions of the trapezius include rotation and adduction of the scapula.

Deltoid

The deltoid is the large fan-shaped muscle on the *apex* of the shoulder. It originates from the lateral portion of the clavicle, the acromion process of the scapula, and the spine of the scapula. The deltoid muscle inserts into the deltoid tuberosity, located approximately in the middle of the shaft of the humerus. Actions of the deltoid are flexion, extension, and abduction of the arm.

Pectoralis major

The pectoralis major (commonly called the breast muscle) originates from the medial portion of the clavicle and the first six costal cartilages. It inserts into the edge of the bicipital groove of the humerus and contributes to adduction, medial rotation, and extension of the arm.

Psoas major

The psoas major muscle, often seen on abdominal radiographs, *originates* from the transverse processes and bodies of the lumbar vertebrae and *inserts* into the lesser trochanter of the femur. It flexes the thigh and the lumbar vertebral column and bends the column laterally.

Quadriceps femoris

The quadriceps femoris is the largest and most powerful group of muscles in the body. Located on the anterior thigh, the muscle group originates from the anterior-superior iliac spine and from the lateral surface, the lower medial surface, and the upper two-thirds of the anterolateral surfaces of the femur. They insert into the tibial tuberosity. The actions of the quadriceps femoris include elevating the femur and extending the leg.

Gastrocnemius

The gastrocnemius, or calf muscle, is located on the posterior portion of the lower leg and originates from the posterior portion of each femoral condyle. It inserts into the posterior surface of the calcaneus by way of the Achilles tendon. Actions include plantar flexion of the foot, extension of the knee joint, and flexion of the knee joint.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

830. The structure and function of muscle tissue principles

1. Match the type of muscle tissue in column B with the appropriate description in column A. Each item in column B may be used more than once.

Column A	Column B
____1. Found only in the heart.	a. Smooth.
____2. Found in the walls of the intestines and blood vessels.	b. Cardiac.
____3. Also called involuntary muscles.	c. Skeletal.
____4. Also called voluntary muscle.	
____5. Comprises approximately 40 percent of body weight.	
____6. Responsible for circulating blood to the body.	
____7. Attach to bones.	

2. Name the three basic parts of a skeletal muscle.

3. Where is a skeletal muscle’s origin?

4. Where is a skeletal muscle’s insertion part?

5. What are antagonistic muscle groups?

6. What are prime movers?

7. Which muscles are the prime movers for elbow flexion?

8. What is an agonistic muscle?

9. What is a synergistic muscle?

831. Basic muscular anatomy principles

1. Match the skeletal muscle in column B with the appropriate description in column A. Each item in column B may be used once or more than once.

Column A	Column B
____1. Inserts into the calcaneus by way of the Achilles tendon.	a. Serratus anterior.
____2. Its actions include flexion, extension, and abduction of the arm.	b. Trapezius.
____3. It originates on the lateral aspects of the first eight ribs and inserts into the vertebral border of the scapula.	c. Deltoid.
____4. Commonly called the breast muscle.	d. Pectoralis major.
____5. Its actions include elevating the femur and extending the leg.	e. Psoas major.
____6. Its actions include rotation and adduction of the scapula.	f. Quadriceps femoris.
____7. Originates from the transverse processes and bodies of the lumbar vertebrae and inserts into the lesser trochanter of the femur.	g. Gastrocnemius.
____8. The large fan-shaped muscle on the apex of the shoulder.	
____9. The largest and most powerful group of muscles in the body.	
____10. Also called the calf muscle.	

Answers to Self-Test Questions

827

1. Lymph comprises the bulk of intercellular fluid. It functions as a transfer medium between blood and individual cells, supplying the cell with nutrients and oxygen, and fighting off bacteria.
2. They filter out the waste by-products and fight bacteria.
3. The spleen; it is located beneath the diaphragm, behind and to the left of the stomach.
4. To carry nutrients and oxygen to tissues of the body, remove waste products from tissues, protect the body against infection, and maintain proper temperature and fluid content in the body.
5. An artery is any vessel that carries blood away from the heart. A vein is any vessel that carries blood to the heart.
6. In the capillaries.
7. The superior and inferior vena cavae.
8. It allows the arteries to expand and contract to maintain blood pressure.
9. To prevent the backflow of blood.
10. The pericardium.
11. Pericardial fluid. To lubricate the outer surface of the heart.
12. The epicardium, myocardium, and endocardium.
13. The tricuspid valve lies between the right atrium and ventricle; the mitral (or bicuspid) valve between the left atrium and ventricle; and the semilunar valves (pulmonic and aortic) guard the outlets of the ventricles.
14. Blood enters the heart through the right atrium. It then passes through the tricuspid valve into the right ventricle. From there it passes through the pulmonic valve to the lungs. It returns from the lungs and enters the left atrium. From there it passes through the mitral valve into the left ventricle. The left ventricle pumps blood through the aortic valve to the body (systemic circulation).
15. Systole and diastole.

16. 0.8 seconds.
17. Pulse pressure.

828

1. The ascending aorta, arch of the aorta, descending thoracic aorta, and abdominal aorta.
2. The right and left coronary arteries.
3. The brachiocephalic, left common carotid, and left subclavian.
4. The hepatic, splenic, and left gastric arteries.
5. L1-L2.
6. The inferior mesenteric.
7. L4.
8. The right and left innominate veins.
9. The inferior vena cava.
10. It enters the portal vein, which transports it to the liver. Blood from the tissues of the liver enters the hepatic vein, which then drains into the inferior venae cavae enroute to the right atrium.

829

1. The external carotid artery.
2. The internal carotid.
3. The vertebral artery.
4. The basilar artery.
5. The circle of Willis.
6. It is an important source of collateralized blood flow for the brain.
7. The dural sinuses.
8. The internal jugular veins.
9. The subclavian and internal jugular.

830

1. (1) b.
   (2) a.
   (3) a.
   (4) c.
   (5) c.
   (6) b.
   (7) c.
2. Body, origin, and insertion.
3. The proximal point of attachment, located on the more fixed anatomical structure.
4. The distal point of attachment, located on the more movable structure.
5. Groups arranged to oppose each other.
6. Muscles that are primarily responsible for movement.
7. The biceps brachii and brachialis.
8. One that aids a prime mover.
9. One that stabilizes a joint so that the prime mover and the agonist function efficiently.

831

1. (1) g.
   (2) c.

(3) a.

(4) d.

(5) f.

(6) b.

(7) e.

(8) c.

(9) f.

(10) g.

Do the unit review exercises before going to the next unit.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter.

Do not return your answer sheet to AFCDA.

76. (827) What is the *largest* collection of lymphoid tissue in the body?
    a. Liver.
    b. Spleen.
    c. Thyroid.
    d. Pancreas.

77. (827) Which valve lies *between* the left atrium and left ventricle?
    a. Aortic.
    b. Bicuspid.
    c. Tricuspid.
    d. Pulmonary.

78. (828) At the level of the *fourth lumbar vertebra*, the aorta *bifurcates* into the right and left
    a. renal arteries.
    b. femoral arteries.
    c. common iliac arteries.
    d. common carotid arteries.

79. (828) What are the three main branches of the aortic arch?
    a. Brachiocephalic, right subclavian, and left subclavian.
    b. Brachiocephalic, left common carotid, and left subclavian.
    c. Right subclavian, left subclavian, and left common carotid.
    d. Brachiocephalic, right common carotid, and left common carotid.

80. (828) What is the first main artery to branch off the abdominal aorta?
    a. Superior mesenteric.
    b. Hepatic.
    c. Celiac.
    d. Renal.

81. (828) The right and left innominate veins unite to form the
    a. pulmonary vein.
    b. inferior vena cava.
    c. superior vena cava.
    d. superior mesenteric vein.

82. (828) Blood from the spleen and the gastrointestinal tract is carried to the liver through the
    a. portal vein.
    b. hepatic vein.
    c. hepatic artery.
    d. inferior vena cava.

83. (829) Which artery gives off the anterior and middle cerebral branches?
    a. Basilar.
    b. Vertebral.
    c. Internal carotid.
    d. External carotid.

84. (829) Which two vessels unite to form the basilar artery?
    a. Vertebrals.
    b. Internal carotids.
    c. External carotids.
    d. Middle cerebrals.

85. (829) Blood is drained from the brain through the
    a. dural sinuses.
    b. cerebral sinuses.
    c. arachnoid sinuses.
    d. sinuses of Valsalva.

86. (830) Which type of muscle is found in the walls of blood vessels?
    a. Cardiac.
    b. Smooth.
    c. Skeletal.
    d. Voluntary.

87. (830) Which of the *major* parts of a skeletal muscle remains relatively immobile as the muscle contracts?
    a. Body.
    b. Origin.
    c. Tendon.
    d. Insertion.

88. (830) Muscle groups that are arranged to *oppose* each other are called
    a. agonistic.
    b. synergistic.
    c. antagonistic.
    d. prime movers.

89. (831) Which skeletal muscle covers the *apex* of the shoulder?
    a. Deltoid.
    b. Trapezius.
    c. Biceps Brachii.
    d. Serratus anterior.

90. (831) Which muscle, commonly seen on abdominal radiographs, originates from the transverse processes and bodies of the lumbar vertebrae and inserts into the lesser trochanter of the femur?
    a. Psoas major.
    b. Serratus anterior.
    c. Rectus abdominis.
    d. Quadriceps femoris.

Please read the unit menu for unit 6 and continue ➔

Unit 6. Scanography and Arthrography

SCANOGRAPHY AND ARTHROGRAPHY are not procedures you might normally associate together in a discussion of radiography. In fact, they have very little in common. However, they do both involve radiography of joints, but for different purposes. Scanography involves radiographing joints to determine the exact length of long bones, whereas arthrography is a contrast study of the soft tissue structure of joints. Nevertheless, we have grouped them together in this last unit and we begin with scanography.

6–1. Scanography

Scanography is also known as *orthoroentgenography*, (which comes from the Greek word *orthos* meaning "straight" or "at right angles to;" roentgenography is just another way to say radiograph) or simply, long bone measurement. No matter the term used, scanography is a radiographic method used to determine the exact length of long bones.

832. Basics of scanography

Scanography is performed either unilaterally or bilaterally for the upper or lower extremities. However, the most common method requested is the bilateral lower extremity scanogram.

Purpose

You perform scanography to radiograph the long bones of the upper or lower limbs absent of magnification to acquire accurate comparison long bone measurements. Scanography is *most* often performed on children to evaluate discordant (unequal) growth of the extremities. There are many possible causes for this condition, and sometimes it must be treated surgically to prevent it from adversely affecting the growth and development of the vertebral column. Once a discrepancy is noted, scanographic examinations are normally requested annually unless surgical intervention is performed; in which case more frequent follow-up is warranted.

Scanography is an accurate way of determining and monitoring limb length discrepancies. If a limb discrepancy is too great, a procedure called *epiphysiodesis* can be performed in some cases to stunt the growth of a limb by fusing the epiphysis of a long bone temporarily or permanently.

Principle

One of the problems inherent in attempting to measure structures radiographically is part magnification (size distortion) caused by the divergent X-ray beam. You should recall from volume two that x-rays diverge from a point source, which means as a structure is projected onto a film, it appears larger than it actually is. In performing scanography, you will attempt to eliminate magnification completely by using only the central portion of the X-ray beam, where divergence is minimal.

For example, when you perform a conventional radiograph of a long bone, the X-ray beam passes through the ends of the bone and continues to diverge so that it hits the film in an area not directly underneath the bone. This makes the projected image appear larger than the actual bone (fig. 6–1, A).

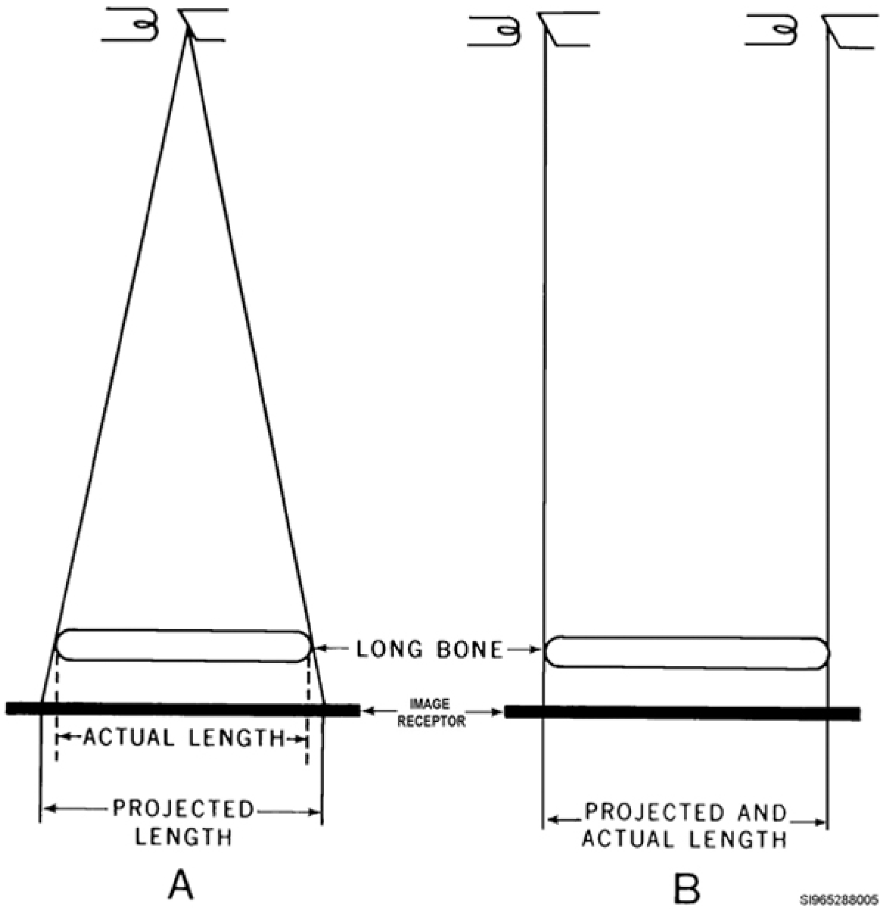

Figure 6–1. Principle of scanography.

In general survey radiographs, a certain amount of magnification is acceptable. However, when you perform a scanogram, unless you eliminate the magnification, accurate bone measurement is not possible. To overcome this magnification problem make two exposures with the CR directed perpendicular to each end of the bone, as shown in figure 6–1, B. In this manner, the length of the projected image is the same as the actual bone length.

833. Basics for performing scanogram procedures

Nearly all scanograms require the use of a special radiopaque measuring device such as the Bell-Thompson ruler. The Bell-Thompson ruler uses metal to serve as the ruler markers and numbers. You may radiograph both extremities simultaneously, or you may expose each one independently. The method used depends on the preferences of the radiologist and/or the orthopedist.

General considerations

The use of gonadal shielding and close collimation is critical when performing scanograms. Always use lead shielding to protect the gonadal region during a scanography exam. This is very important since most of the patients getting a scanogram normally are kids. In addition, collimation improves image quality but make sure not to clip any of the needed anatomy or the ruler.

Previously when using conventional film to image the lower limb, three exposures were made on a single 14 × 17 inch film/cassette. Expose the film in thirds; mask the middle and lower third exposing the hip joints on the top third, mask the top and lower thirds exposing the knee in the middle third, and finally mask the top and middle thirds of the cassette exposing the ankle joints on the lower third. Presently with digital IRs, pre-processing aspects of digital systems prohibit exposing the same imaging plate with masked views and require individual exposures to be shot on separate IRs. No matter the method of acquisition, the ruler and the patient must remain in the same place for all exposures of a particular long bone; only the tube and IR are moved between exposures. *If any movement of the patient or ruler occurs between the exposures, the whole procedure must be re-accomplished* thus increasing the patient's radiation exposure dose.

Scanographic procedure

Use tape to secure the ruler to the centerline of the table so it does not move. Position the patient supine on the radiographic table. Place the ruler directly next to the affected limb or long bone if you are radiographing each limb independently. If radiographing both legs simultaneously, place the ruler centered in-between the limbs. Ensure the ruler markings extend above the hip and below the ankle.

Always center the CR (perpendicular to the IR) directly over each joint of the limb being measured. Follow your department standard operating procedures for making the exposures; however, with digital IRs it is necessary to expose each joint on its own IR.

If there is a significant difference between the lengths of the legs, the joints will not be at the same level. It will not be possible to direct the CR to the center of both the knee joints or ankle joints simultaneously. When this occurs, direct the CR to a level midway between the joints of interest. Figure 6–2 is an illustration of how the processed radiograph should look.

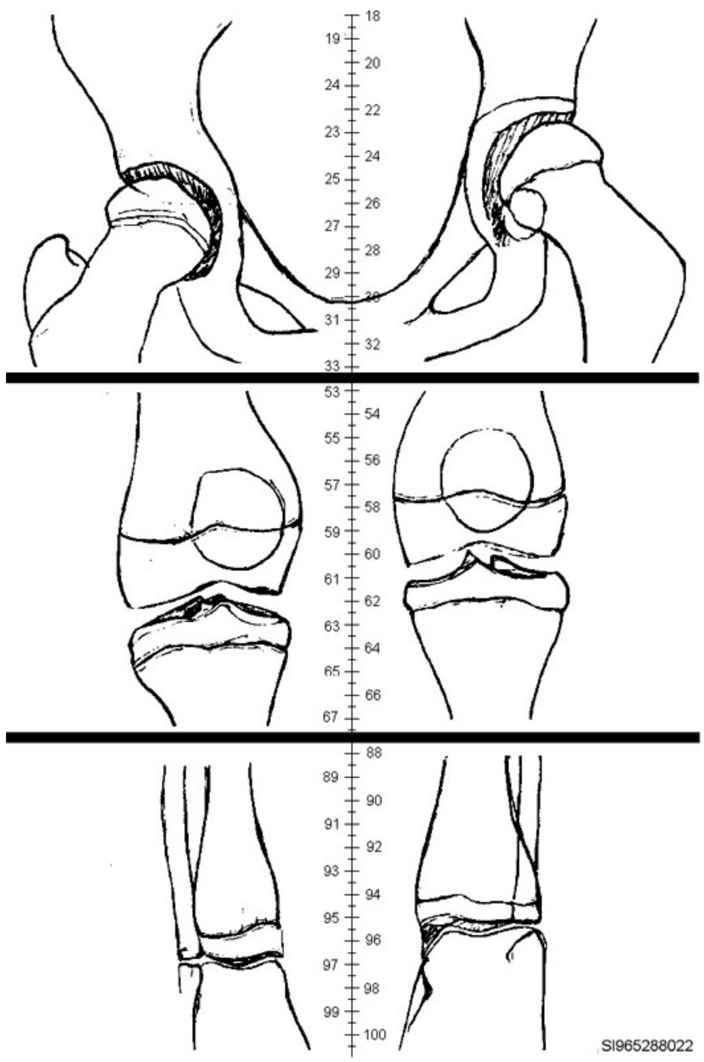

Figure 6–2. Scanogram of the legs.

Quality control considerations

When evaluating scanograms from a quality control point of view, pay special attention to where the CR was directed. Notice in figure 6–3, the CR for a scanogram was incorrectly directed to points away from the ends of the bone. The result being the length of the image is smaller than that of the actual bone due to the divergence of the primary beam. If the CR were directed to points A and B in the illustration, the image would give a more true measurement of the long bone's actual length. If the CR is not positioned directly over the ends of the bone, the bone will be projected longer or shorter than it actually is.

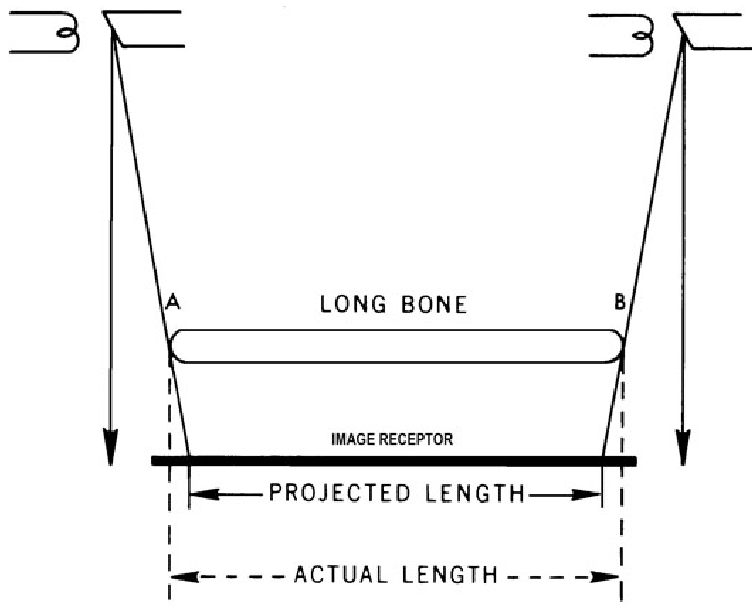

Figure 6–3. Improper alignment of the central ray for a scanogram.

Computed tomography scanograms

An alternative method of obtaining long bone measurements is by using computed tomography. This technique involves performing a CT scout image of the long bone or bones to be measured and using the on-screen cursor to perform digital measurements. Precise cursor placement is critical in this method, and some texts recommend taking the average of several attempted measurements to increase the accuracy of the measurement.

There are two distinct advantages to using CT for long bone measurement: first, the radiation exposure dose to the patient is significantly reduced and secondly, the measurements obtained are more accurate than those obtained with orthoroentgenography.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

832. Basics of scanography

1. What is the purpose of scanography?

2. How often are scanograms normally requested after a growth discrepancy is noted in a patient?

3. What inherent problem must be overcome when measuring structures radiographically?

4. How should we attempt to eliminate the problem named in question 3?

5. How should we project the true length of a long bone onto a radiograph?

833. Basics for performing scanogram procedures

1. When performing scanography with a ruler, which items may be moved between exposures? Which items must not be moved?

2. How should a patient be positioned for a scanogram?

3. Where is the ruler placed in relationship to the affected limb or long bone?

4. When performing a scanogram of both legs simultaneously, where should you direct the CR if the right and left joints do not lie at the same level?

5. What happens if the CR is not directed exactly to the ends of the bone?

6. What are two distinct advantages to using CT for long bone measurement?

6–2. Arthrography

Arthrography, as the name implies, is a radiographic examination of the soft tissue structures inside a joint space. Arthrography is an invasive procedure which requires the injection of a radiographic contrast medium (positive, negative, or both) into the capsule of a joint, with fluoroscopy and sometimes post-injection overhead images if requested by your radiologist. MRI offers a noninvasive method of imaging the soft tissue structures of a joint; it has largely replaced arthrography as the procedure of choice. However, a certain number of arthrograms are still performed by radiologists throughout the AF since MRI is not available in all locations.

Arthrograms are most commonly performed on the shoulder and knee however can be performed on other joints including the ankle, hip, wrist, elbow, and temporomandibular joints (TMJ). No matter the joint, the procedures for performing an arthrogram are the same with some variances due to specific joint anatomy. In this section, you will learn the basic steps to perform arthrograms of the shoulder and knee; but first, it is necessary to outline the soft tissue structures of the knee.

834. Principles of specific knee soft tissue structures

As described previously in this course, the bony structures of the knee are normally well demonstrated on conventional radiographs whereas the soft tissue structures are not. In order to assist your radiologist during an arthrography of the knee, you should have a basic understanding of the soft tissue structures of the knee.

Articular capsule

Diarthrodial joints are designed to allow free movement. As such, they have several mechanisms to reduce the friction created whenever two surfaces rub together. One of these mechanisms is the articular capsule. The articular capsule is a fibrous sac-like structure surrounding the articular ends of bones in a diarthrodial joint that is lined with a synovial membrane to provide lubrication. The synovial membrane is inside this capsule; it secretes synovial fluid (the body’s natural lubricant).

Bursae

Bursae (singular–bursa) are “mini-capsules” which also contain synovial membranes. They are friction reducers and are located in many joints throughout the body where tendons and muscles slide over other structures. There are many bursae located in the knee joint.

Menisci

Menisci (singular–meniscus) are disk-shaped cartilaginous pads that lie between the articular ends of some bones and serve as *shock absorbers*. There are two menisci in each knee joint located between the femoral condyles and the superior articular surfaces of the tibia, medially and laterally. In fact, the menisci are named the medial and lateral menisci according to their relative locations. The menisci are also believed to aid in the production of synovial fluid, which helps to lubricate the articulating ends of the femur and tibia.

Ligaments

A ligament is a band of fibrous connective tissue that connects bone to bone. There are two types of ligaments that hold the knee together and provide stability to the joint: they are the collaterals and the cruciates.

Collateral ligaments

There are two collateral ligaments in each knee. The fibular collateral ligament runs longitudinally along the fibular (lateral) side of the knee and is commonly called the lateral collateral ligament or LCL. The LCL attaches superiorly to the lateral femoral condyle and inferiorly to the head of the fibula. The tibial collateral ligament also runs longitudinally, but along the tibial (medial) side of the knee and is more often referred to as the medial collateral ligament or MCL. The MCL attaches superiorly to the medial femoral condyle and to the proximal, medial surface of the tibia inferiorly. The collateral ligaments provide medial and lateral stability for the joint.

Cruciate ligaments

The anterior and posterior cruciate ligaments stabilize the knee joint anteriorly or posteriorly and prevent the knee from being overextended. The anterior cruciate ligament (ACL) attaches anteriorly to the intercondylar eminence of the tibia, runs posteriorly and laterally through the femoral intercondylar fossa, and attaches to the posterior part of the medial surface of the lateral femoral condyle. The posterior cruciate ligament (PCL) attaches to the posterior intercondylar fossa of the tibia, runs anteriorly and medially through the femoral intercondylar fossa, and attaches to the anterior part of the medial surface of the medial femoral condyle.

835. Procedures for arthrograms of the knee and shoulder

The knee and shoulder joints are used frequently and are often injured. Sports injuries account for most of the trauma imposed on these two joints. Sports like skiing, basketball, racquetball, football and others create the opportunity for an injury to occur. Whether it is an injury to one of the cruciate or collateral ligaments of the knee or the rotator cuff of the shoulder, arthrograms, CT, and MRI are all used to visualize the applicable joint spaces for in some cases, orthopedic surgery intervention.

Arthrogram of the knee joint

An arthrogram of the knee is performed quite simply to evaluate the knee joint and soft-tissue structures for indications of injury or other pathology like a Baker's cyst. When performing an arthrogram, a radiologist injects a contrast media agent *i*nto the joint capsule. Then images are obtained with the use of fluoroscopy, radiography, CT or MRI to document any pathological findings. The type of injury most often evaluated for are tears to the articular capsule, menisci, or ligaments.

Patient and exam preparation

There are no pre-procedural instructions a patient must follow prior to this type of examination; however, it is typical to instruct the patient to wear or bring shorts the day of the exam so that they will not have to change into a gown for the procedure. Screen either when scheduling the arthrogram or upon checking in for the exam for any possible allergy to the iodinated contrast medium and local anesthetics. Review the contrast media questionnaire and discuss any findings with your radiologist.

Next, explain the procedure to the patient and answer any questions they may have. When the radiologist enters the X-ray suite, they too should thoroughly explain the examination along with the risks and potential complications. As a technologist, you should ensure an informed consent form is filled out and signed by the patient, the performing physician (typically your radiologist), and a witness.

The next steps are common to most arthrograms but you should always follow your department's standard operating procedures or radiologists instructions when preparing for the procedure.

1. *Open and prepare a disposable arthrogram tray* for the procedure. This includes drawing up the contrast media agent into a 10 cc syringe; do the same with the local anesthetic.

   NOTE: Most disposable sterile arthrogram trays will include a variety of needles and syringes, local anesthetic, contrast agent(s), sterile gauze, and an adhesive bandage (fig. 6–4.
2. If necessary, *shave the lateral surface of the patient's knee.*
3. *Clean and prepare the skin with surgical soap*, isopropyl alcohol, providone-iodine, or a combination of these antiseptic solutions.
4. *Drape the area with sterile towels or a fenestrated drape* (a drape with an opening in the middle).

Injection procedures

The radiologist usually injects a local anesthetic to numb the injection site. Next, a needle is inserted into the capsule of the joint under fluoroscopic guidance. Any effusion present usually is aspirated to prevent dilution of the contrast medium, which is then injected. For pneumoarthrography, a gaseous contrast medium (e.g., air, oxygen, carbon dioxide) is used; for opaque arthrography, a water-soluble injectable iodinated contrast agent (e.g., Conray, Renografin, Omnipaque, etc.) is used; and for yet other exams, a combination of the two is used for double-contrast arthrographic studies.

If a positive medium is used, the radiologist will inject 10 to 15 cc of the solution. If significant joint effusion is still present, more contrast medium is usually injected (up to twice the normal amount) to prevent dilution of the contrast. Twenty (20) cc or more of a negative medium may be injected if a pneumoarthrogram or double contrast study is to be done.

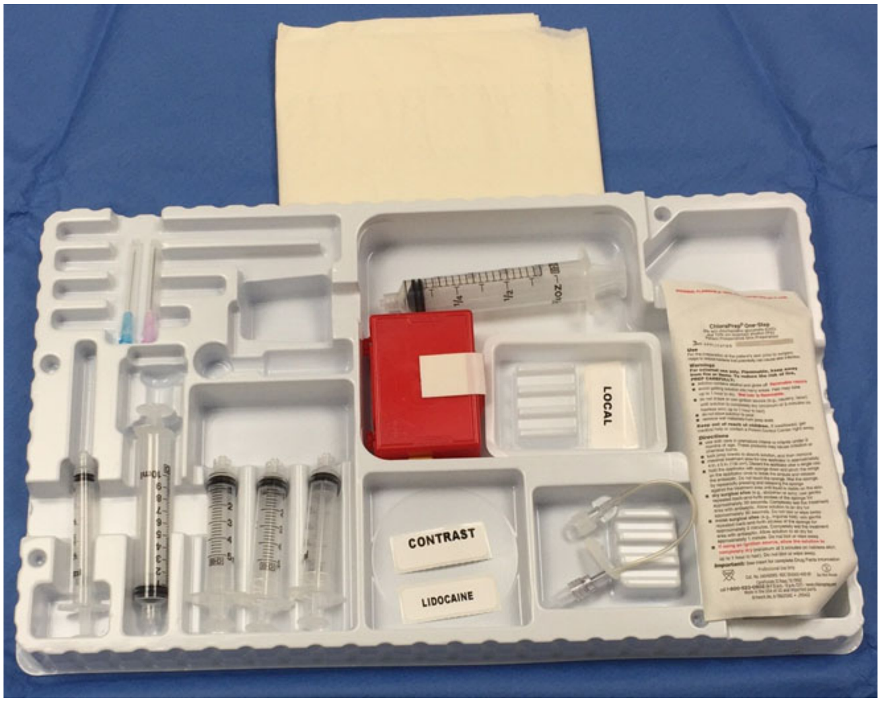

Figure 6–4. Standard arthrogram tray contents.

After covering the injection site with an adhesive bandage, the radiologist usually massages the knee to distribute the contrast medium throughout the joint space. The patient may be asked to stand and exercise the knee to help distribute the contrast. Some radiologists also wrap the knee tightly with an elastic bandage to force the contrast medium out of the quadriceps pouch onto the surfaces of the menisci. The elastic bandage should be removed before the lateral radiographs of the knee are taken to permit visualization of the quadriceps pouch.

At this point, the radiologist generally performs several fluoroscopic spot images of the knee. Some special projections are done with the patient's leg placed in a stress device to widen or "open up" the side of the joint space under investigation. This widening permits better distribution of the contrast medium around a meniscus. To visualize the medial side of the joint, the stress device is placed just above the knee and the lower leg is laterally stressed. The lower leg is medially stressed to widen the lateral aspect of the joint.

After the radiologist finishes the fluoroscopic portion of the exam, you must then perform a series of post-procedural radiographs as determined by the radiologist.

Post-procedural radiographs

Several different projections of the knee normally are done for an arthrogram. Most radiologists request at least standard AP, PA, lateral, and oblique projections. Oblique radiographs may be done with various degrees of rotation—for example, 30, 45, 60, and 75. Usually, the CR is angled five degrees cephalad for AP projections, including AP obliques, to better open the joint space. It is not necessary to angle the CR for the PA projection. Since the tibia and fibula are slightly inclined when the leg is PA, the tibial plateau will be perpendicular to the film.

If a pneumoarthrogram or double contrast study is performed, some projections are made with a horizontal CR to take advantage of the rising air.

Necessity for speed

The contrast medium injected into the joint capsule eventually is absorbed. Absorption *begins a short time after introduction*, and the entire injection can disappear from the joint capsule within 30 minutes. Therefore, you should work quickly to accomplish the radiographs before this happens. You must also make sure the positions, exposure factors, and so forth, are correct the first time because you may not have enough time to repeat the radiographs.

Marking the joint space

To demonstrate the necessary structures properly, you must direct the CR through the joint space when you perform the radiographs. Because some type of bandage usually is applied to the knee after the injection, it may be difficult for you to determine the exact location of the joint. Usually, it's best to have the radiologist mark the joint space under fluoroscopy after the bandage has been applied. If various projections are to be made, a line drawn around the circumference of the knee is helpful.

Arthrograms of the shoulder joint

An arthrogram of the shoulder joint is typically performed to demonstrate rotator cuff (or glenoidal labrum) tears or for a condition known as a frozen shoulder. A frozen shoulder is a condition in which the articular capsule of the shoulder swells and stiffens which causes a reduction in the mobility of the shoulder joint.

Patient and exam preparation

Preparation for a shoulder arthrogram is the same as for a knee. Have the patient fill out the contrast allergy questionnaire, make sure the informed consent form is filled out and signed, prepare the disposable arthrogram tray and contents, and prepare the skin of the shoulder for injection of the contrast media agent.

Injection procedures

The typical injection site is 1 to 2 cm lateral of the coracoids process. A spinal needle is normally used because of how deep the shoulder's joint capsule is located. A positive (e.g., Omnipaque 300), negative (e.g., room air), or combination there-of may be injected. Fluoroscopy is used to confirm correct placement of the needle into the bursa and that enough contrast media is injected for the procedure.

Radiographs obtained

Again, actual radiographs obtained will vary by location; however, the following images may be acquired.

Pre-injection radiographs:

- Scout AP projections with internal and external rotation.
- Possibly a transaxillary and/or intertubercular (bicipital) groove view.

Post-injection radiographs:

- Repeat the pre-injection views.
- Depending upon your radiologist preference, 15 to 23 caudal angulation may be used.

Special imaging

For various arthrogram studies, CT and MRI (if available) are sometimes used to image the joint in question after the injection and acquisition of regular radiographs. The diagnostic medical technologies employed in these two-specialty areas aid radiologists' diagnosing the patient's condition.

Self-Test Questions

After you complete these questions, you may check your answers at the end of the unit.

834. Principles of specific knee soft-tissue structures

1. What is an articular capsule?

2. What is a bursa?

3. What are menisci? How many menisci are in the knee joint?

4. What are ligaments?

5. What purpose do the collateral ligaments serve?

6. What purpose do the cruciate ligaments serve?

7. Where does the anterior cruciate ligament attach?

835. Procedures for arthrograms of the knee and shoulder

1. How is an arthrogram obtained?

2. What the four common steps in preparing to perform an arthrogram procedure of the knee?

3. After the injection of contrast media and covering the injection site with a bandage, what is usually performed next?

4. At what point do you perform a series of post-procedural radiographs?

5. What is a frozen shoulder?

6. Why is a spinal needle normally used for shoulder arthrograms?

7. What kind of pre-injection images may be acquired?

Answers to Self-Test Questions

832

1. The purpose of performing scanography is to radiograph the long bones of the upper or lower limbs absent of magnification to acquire accurate and comparison long bone measurements.
2. Annually unless surgical intervention is performed; in which case more frequent follow-up is warranted.
3. Magnification.
4. By using only the central portion of the beam, where divergence is minimal.
5. By making two exposures with the CR directed perpendicular to each end of the bone.

833

1. The tube and the IR may be moved; the patient and ruler may not be moved.
2. Supine on the radiographic table.
3. Place the ruler directly next to the affected limb or long bone if you are radiographing each limb independently. If radiographing both legs simultaneously, place the ruler centered in-between the limbs.
4. To a level midway between the two joints of interest.
5. The bone will be projected longer or shorter than it actually is.
6. (1) The radiation exposure dose to the patient is significantly reduced; (2) the measurements obtained are more accurate than those obtained with orthoroentgenography.

834

1. A fibrous sac-like structure surrounding the articular ends of bones in a diarthrodial joint which is lined with a synovial membrane to provide lubrication.
2. They are friction reducers and are located in many joints throughout the body where tendons and muscles slide over other structures..
3. Disk-shaped cartilaginous pads that lie in-between the articular ends of some bones and serve as shock absorbers. Two.
4. Bands of fibrous connective tissue that connect bone to bone.
5. They provide medial and lateral stability for the knee joint.
6. They stabilize the knee joint anteriorly or posteriorly and prevent the knee from being overextended.
7. The ACL attaches anteriorly to the intercondylar eminence of the tibia, runs posteriorly and laterally through the femoral intercondylar fossa, and attaches to the posterior part of the medial surface of the lateral femoral condyle.

835

1. A radiologist injects a contrast media agent into the joint capsule. Then images are obtained with the use of fluoroscopy, radiography, CT or MRI to document any pathological findings.
2. Open and prepare a disposable arthogram tray, shave the lateral surface of the patient’s knee, clean and prepare the skin with surgical soap, and drape the area with sterile towels or a fenestrated drape.
3. The radiologist usually massages the knee to distribute the contrast medium throughout the joint space.
4. After the radiologist finishes the fluoroscopic portion of the exam.
5. A frozen shoulder is a condition in which the articular capsule of the shoulder swells and stiffens which causes a reduction in the mobility of the shoulder joint.

6. Because of how deep the shoulder’s joint capsule is located.
7. Scout AP projections with internal and external rotation and possibly a transaxillary and/or intertubercular (bicipital) groove view.

Unit Review Exercises

Note to Student: Consider all choices carefully, select the *best* answer to each question, and *circle* the corresponding letter. When you have completed all unit review exercises, transfer your answers to the Field Scoring Answer Sheet.

Do not return your answer sheet to AFCDA.

91. (832) In performing scanography, we attempt to eliminate
    a. magnification.
    b. focal spot blur.
    c. scatter radiation.
    d. object-image distance.

92. (833) When performing scanography with a radiopaque ruler, what items may *not be moved* in between exposures?
    a. Tube and film.
    b. Tube and ruler.
    c. Patient and film.
    d. Patient and ruler.

93. (833) When performing a bilateral scanogram of both legs simultaneously and the ankle joints do not lie at the same level, you direct the central ray (CR) to
    a. the ankle joint of the longer leg.
    b. the ankle joint of the shorter leg.
    c. a level midway between the ankle joints.
    d. each ankle joint, using separate exposures.

94. (834) Which structures are disk-shaped cartilaginous pads that serve as shock absorbers in diarthrodial joints such as the knee?
    a. Bursae.
    b. Menisci.
    c. Meninges.
    d. Articular capsules.

95. (834) Which structures prevent the knee from being overextended?
    a. Bursae.
    b. Menisci.
    c. Cruciate ligaments.
    d. Collateral ligaments.

96. (834) Which structures of the knee provide medial and lateral stability?
    a. Collateral ligaments.
    b. Cruciate ligaments.
    c. Achilles tendon.
    d. Patellar tendon.

97. (835) When doing a knee arthrogram, the contrast medium is injected into the
    a. menisci.
    b. joint capsule.
    c. popliteal space.
    d. cruciate ligaments.

98. (835) Which step do you perform *first* in getting ready for an arthrogram procedure?
    a. Shave the skin.
    b. Clean the skin with surgical soap.
    c. Draw up contrast and the local anesthetic.
    d. Place a fenestrated drape over the injection area.

99. (835) The knee is sometimes wrapped with an ace bandage during arthrography to
    a. widen the joint space.
    b. stabilize the joint for the stress views.
    c. prevent dilution of the contrast medium.
    d. force the contrast medium out of the quadriceps pouch.

100. (835) Why should you work rapidly when performing an arthrogram?
    a. It is difficult to maintain a sterile field for any length of time.
    b. Absorption of the contrast medium begins shortly after the injection.
    c. The patient is in considerable pain due to the various positions of the knee.
    d. The longer the contrast material stays in the joint capsule, the greater the chance of simulated pathology.

Glossary

Terms

Alimentary—Having to do with the gastrointestinal system.

Bifurcate—To divide into two branches.

Bradycardia—An abnormally slow (below 60 bpm) heart rate.

Caudad or caudal—Toward the feet.

Cephalad or cephalic—Toward the head.

Contraindication—Any system or circumstance indicating a possible reason an exam or treatment should not be accomplished.

Contrast media—A substance introduced into the body to enhance the visual, subject contrast of various soft tissue structures, thereby rendering them more visible on a radiograph.

Diastole—The resting phase of the heart cycle.

Fluoroscopy—A method of real-time, in-motion radiography.

Gangrene—Refers to the necrosis or death of soft tissue usually due to an obstruction which usually results in decomposition.

Hypertension—High blood pressure.

Image receptor—The object which converts the transmitted X-ray beam into a useful image.

Myelography—A radiographic contrast study of the spinal canal.

Osmolality—Refers to the number of particles in a solution per kilogram of water.

Pallor—Refers to extreme paleness resulting from fear, ill health, or death.

Percutaneous—Through the skin.

Peristalsis—A progressive, wavelike muscular contraction in hollow tubes of the body, especially in the alimentary tract.

Peritoneum—The serous membrane lining of the abdomen.

Retrograde—Moving backward or inducing a fluid against the normal flow.

Systole—The working phase of the heart cycle.

Trendelenburg—Lying flat with the head lower than the feet.

Viscosity—A measurement of the thickness of a liquid.

Abbreviations and Acronyms

°C	degrees Celsius
°F	degrees Fahrenheit
ACL	anterior cruciate ligament
AP	anterior-posterior
ASIS	anterior-superior iliac spine
BE	barium enema
bpm	beats per minute
BUN	blood urea nitrogen
cc	cubic centimeters (a unit of volume)
CHCS	Composite Health Care System
cm	centimeters
CNS	central nervous system
CR	central ray (of the x-ray beam)
CSF	cerebrospinal fluid
CT	computed tomography
ECG/EKG	electrocardiogram
ERCP	endoscopic retrograde cholangiopancreatography
GFR	glomerular filtration rate
GI	gastrointestinal
Hg	mercury
HSG	hysterosalpingography
IR	image receptor
IV	intravenous
IVP	intravenous pyelogram
IVU	intravenous urogram
kg	kilogram
KUB	kidneys, ureters, and bladder.
LAO	left anterior oblique (position)

LCL	lateral collateral ligament
LPO	left posterior oblique (position)
MCL	medial collateral ligament
mg	milligram
mg/dL	milligrams per deciliter
ml	milliliter
mm	millimeter
MRI	magnetic resonance imaging
MTF	medical treatment facility
NPO	nothing by mouth (Latin origin: *nil per os*)
OCG	oral cholecystogram
OID	object-to-image distance
OSHA	Occupational Safety and Health Administration
PA	posterior-anterior
PCL	posterior cruciate ligament
psi	pounds per square inch
RAO	right anterior oblique (position)
RLO	right lateral oblique (position)
RPO	right posterior oblique (position)
SID	source-to-image distance
TMJ	temporomandibular joint
VCU	voiding cystourethrogram

Student Notes

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