The Cardiovascular System

4 The Heart, Coronary Vessels, and Pericardium

Chapter Outline

THE HEART

Chordae Tendineae and Papillary Muscle Rupture

Rupture of the chordae tendineae by disease, such as acute bacterial endocarditis, may cause sudden valvular insufficiency and cardiac decompensation. Rupture of a papillary muscle, since each has many chordae attached to its apex, is much more serious. Rupture of a papillary muscle may occur in penetrating wounds of the heart.

Mitral Valve Prolapse

In this condition, one or both mitral valve cusps balloon up into the left atrium during ventricular systole. The valve cusps are larger than normal and the chordae tendineae may be excessively long. The posterior cusp is always involved; the anterior cusp is involved less frequently.

Accessory Atrioventricular Bundles

Accessory atrioventricular bundles are thought to exist. They are believed to be slender and normally have no functional significance. However, in the condition of accelerated atrioventricular conduction, the aberrant connection (bundle of Kent) permits one ventricle to be excited early. In this condition the PR interval is shortened and a delta wave appears on the initial part of the QRS complex. Another aberrant connection (bundle of Mahaim) bypasses the atrioventricular node and inserts just distal to the node. In this condition, known as the Lown-Ganong-Levine syndrome, the PR interval is short but the QRS complex is normal.

Circus Movement

This abnormal form of conduction allows a wave of excitation to travel continuously in a circle. This ring may occur in the atrioventricular node, causing abnormal atrial contractions and paroxysmal nodal tachycardia. If the individual has an accessory atrioventricular bundle, the circus

movement may pass in one direction through the atrioventricular node and in the opposite direction through the bundle of Kent.

Failure of Conduction System

The sinuatrial node is the spontaneous source of the cardiac impulse. The atrioventricular node is responsible for picking up the cardiac impulse from the atria. The atrioventricular bundle is the only route by which the cardiac impulse can spread from the atria to the ventricles. Failure of the bundle to conduct the normal impulses results in alteration in the rhythmic contraction of the ventricles (arrhythmias) or, if complete bundle block occurs, complete dissociation between the atria and ventricular rates of contraction. The common cause of defective conduction through the bundle or its branches is atherosclerosis of the coronary arteries, which results in a diminished blood supply to the conducting system.

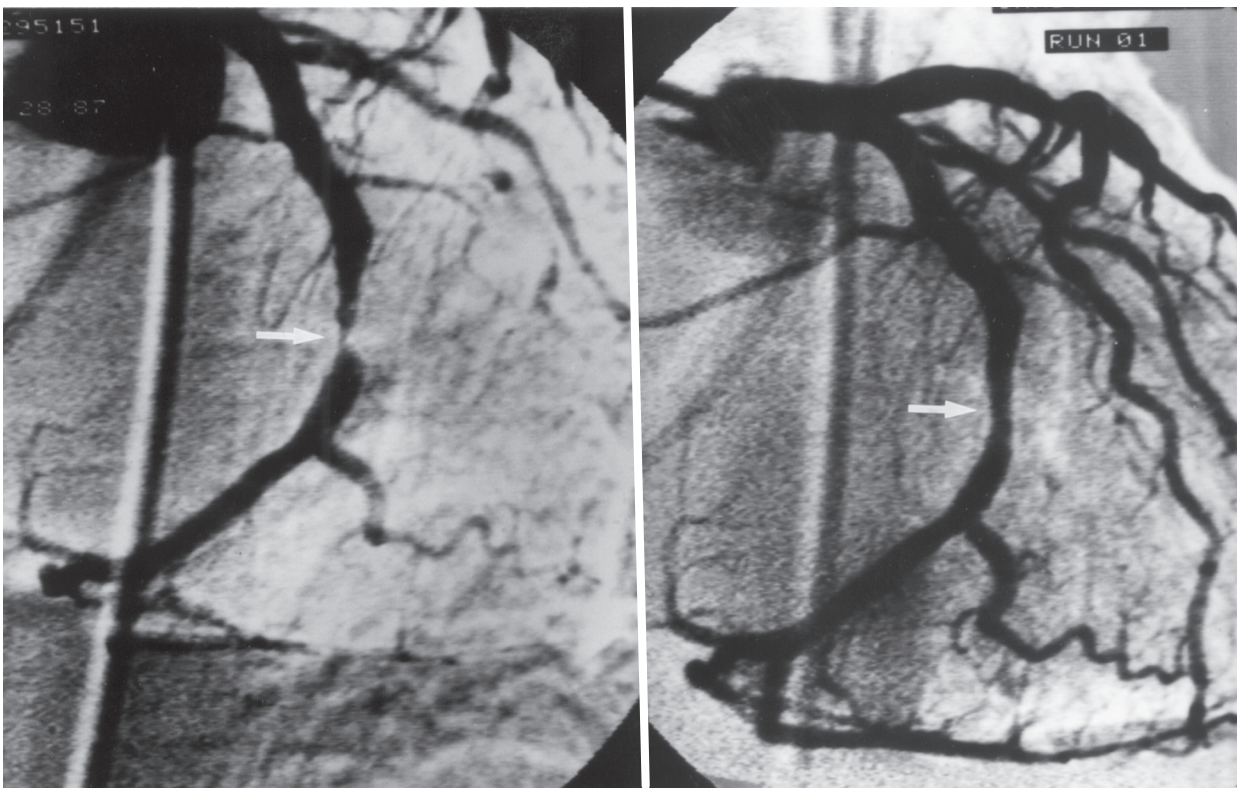
Coronary Angiography

The coronary arteries can be visualized by the introduction of radiopaque material into their lumen. Under fluoroscopic control, a long narrow catheter is passed into the ascending aorta via the femoral artery in the leg. The tip of the catheter is carefully guided into the orifice of a coronary artery and a small amount of radiopaque material is injected to reveal the lumen of the artery and its branches. The information can be recorded on radiographs (CD Fig. 4–1) or by cineradiography. Using this technique, pathologic narrowing or blockage of a coronary artery can be identified.

Coronary Artery Disease

The myocardium receives its blood supply through the right and left coronary arteries. Although the coronary arteries have numerous anastomoses at the arteriolar level, they are essentially functional end arteries. A sudden block of one of the large branches of either coronary artery will usually lead to necrosis of the cardiac muscle (myocardial infarction) in that vascular area, and often the patient dies. Most cases of coronary artery blockage are caused by an acute thrombosis on top of a chronic atherosclerotic narrowing of the lumen.

Arteriosclerotic disease of the coronary arteries may present in three ways, depending on the rate of narrowing of the lumina of the arteries: (1) General degeneration and fibrosis



A B

CD Figure 4-1 Coronary angiograms. **A.** An area of extreme narrowing of the circumflex branch of the left coronary artery (white arrow). **B.** The same artery after percutaneous transluminal coronary angioplasty. Inflation of the luminal balloon has dramatically improved the area of stenosis (white arrow).

CD Table 4-1 Coronary Artery Lesions, Infarct Location, and ECG Signature

Coronary Artery	Infarct Location	ECG Signature
Proximal LAD	Large anterior wall	ST elevation: I, L, V1–V6
More distal LAD	Anteroapical	ST elevation: V2–V4
	Inferior wall if wraparound LAD	ST elevation: II, III, F
Distal LAD	Anteroseptal	ST elevation: V1–V3
Early obtuse, marginal	High lateral wall	ST elevation: I, L, V4–V6
More distal marginal branch, circumflex	Small lateral wall	ST elevation: I, L, or V4–V6, or no abnormality
Circumflex	Posterolateral	ST elevation: V4–V6; ST depression: V1–V2
Distal RCA	Small inferior wall	ST elevation: II, III, F; ST depression: I, L
Proximal RCA	Large inferior wall and posterior wall	ST elevation: II, III, F; ST depression: I, L, V1–V3
	Some lateral wall	ST elevation: V5–V6
RCA	Right ventricular	ST elevation: V2R–V4R; some ST elevation: V1, or ST depression: V2–V3
	Usually inferior	ST elevation: II, III, F

ECG, electrocardiographic; LAD, left anterior descending (interventricular); RCA, right coronary artery.

of the myocardium occur over many years and are caused by a gradual narrowing of the coronary arteries. (2) Angina pectoris is cardiac pain that occurs on exertion and is relieved by rest. In this condition, the coronary arteries are so narrowed that myocardial ischemia occurs on exertion but not at rest. (3) Myocardial infarction occurs when coronary flow is suddenly reduced or stopped and the cardiac muscle undergoes necrosis. Myocardial infarction is the major cause of death in industrialized nations.

CD Table 4-1 shows the different coronary arteries that supply the different areas of the myocardium. This information can be helpful when attempting to correlate the site of myocardial infarction, the artery involved, and the electrocardiographic signature.

Because coronary bypass surgery, coronary angioplasty, and coronary artery stenting are now commonly accepted methods of treating coronary artery disease, it is incumbent on the student to be prepared to interpret still- and motion-picture angiograms that have been carried out before treatment. For this reason, a working knowledge of the origin, course, and distribution of the coronary arteries should be memorized.

Myocardial Infarction and Papillary Muscle Rupture

Rarely, in acute myocardial infarction involving the left ventricle, a papillary muscle may rupture. Rupture of the posteromedial papillary muscle is more common since it is supplied by a single artery, the right coronary artery. The anterolateral papillary muscle is less likely to rupture since it has a dual blood supply from the anterior interventricular and circumflex branches of the left coronary artery.

Chest Pain

The presenting symptom of chest pain is a common and classic problem in medicine. Unfortunately, chest pain is a symptom common to a large number of conditions and may be caused by disease in the thoracic and abdominal walls or in many different chest or abdominal viscera. The severity of the pain is often unrelated to the seriousness of the cause. Myocardial pain may mimic esophagitis, musculoskeletal chest wall pain, and other non–life-threatening causes. Unless medical personnel are astute, a patient may be discharged from the hospital with a more serious condition than the symptoms indicate. It is not good enough to have a correct diagnosis only 99% of the time with chest pain. An understanding of the anatomy of chest pain will help the physician in the systematic consideration of the differential diagnosis.

Somatic Pain

Pain arising from the chest or abdominal walls is intense and discretely localized. Somatic pain arises in sensory nerve endings in these structures and is conducted to the central nervous system by somatic segmental spinal nerves.

Visceral Pain

Visceral pain is diffuse and poorly localized. It is conducted to the central nervous system along afferent autonomic nerves. Most visceral pain fibers ascend to the spinal cord along sympathetic nerves and enter the cord through the posterior nerve roots of segmental spinal nerves. Some pain fibers from the pharynx and upper part of the esophagus and the trachea enter the central nervous system through the parasympathetic nerves via the glossopharyngeal and vagus nerves. The descending colon, the pelvic colon and rectum, and the bladder reach the sacral spinal cord through the parasympathetic nerves.

Referred Pain

Visceral pain frequently is referred to skin areas that are innervated by the same segment of the spinal cord as is the painful viscus. The explanation for referred pain is not known. One theory is that the nerve fibers from the viscus and the dermatome ascend in the central nervous system along a common pathway and the cerebral cortex is incapable of distinguishing between the sites of origin. Another theory is that under normal conditions the viscus does not give rise to painful stimuli, whereas the skin area repeatedly receives noxious stimuli. Because both afferent fibers enter the spinal cord at the same segment, the brain interprets the information as coming from the skin rather than the viscus. Pain arising from the gastrointestinal tract is referred to the midline. This can probably be explained since the tract arises embryologically as a midline structure and receives a bilateral nerve supply.

Clinical Significance of Thoracic Dermatomes Relative to Chest Pain

The dermatomes on the anterior and posterior chest walls are shown in CD Figs. 1-2 and 1-3. A dermatome is an area of skin supplied by a single spinal nerve and, therefore, a single segment of the spinal cord. On the trunk, adjacent dermatomes overlap considerably and a given area of skin is innervated by three adjacent spinal nerves.

Each thoracic spinal nerve innervates a large number of structures, including the vertebrae; the ribs and costal cartilages and their joints; the postvertebral, intercostal, and abdominal muscles; and the costal parietal pleura and parietal peritoneum. Any one of these structures could be the source of chest pain.

The skin of the anterior and posterior chest walls, down as far as the sternal angle in front and the spine of the scapula behind, is supplied by the supraclavicular nerves (C3 and C4). The phrenic nerves (C3, C4, and C5) supply the parietal pleura over the central part of the diaphragm and a corresponding area of parietal peritoneum over the lower surface of the diaphragm. Irritation of these areas by disease of neighboring viscera, such as the gallbladder, liver, or stomach, could send afferent impulses up to the central nervous system. Because of the phenomenon of referred pain, the patient would presume that the cause of the pain was located over the upper part of the chest wall or shoulder.

Below the level of the sternal angle and the spine of the scapula, the chest skin is innervated by the thoracic segments of the spinal cord. The anterior chest wall is supplied by the intercostal nerves T2 through T6; the seventh intercostal nerve enters the anterior abdominal wall to supply the skin in the xiphoid area. The posterior chest wall is supplied by the posterior primary rami of the thoracic spinal nerves T2 through T11. Remember that the seventh to the eleventh intercostal nerves cross the costal margin and innervate the full thickness of the anterior abdominal wall including the parietal peritoneum. This would explain how irritation of the parietal peritoneum caused by disease of abdominal viscera could give rise to pain referred to the chest wall.

Note also the distribution of the T1 and T2 dermatomes; they extend down the medial side of the upper limbs. The second thoracic nerve reaches the skin of the axilla and the medial (ulnar) side of the arm via the intercostobrachial nerve (a branch of the second intercostal nerves). T1 reaches the ulnar side of the forearm via the medial cutaneous nerve of the forearm from the brachial plexus.

Cardiac Pain

Pain originating in the heart as the result of acute myocardial ischemia is assumed to be caused by oxygen deficiency and the accumulation of metabolites, which stimulate the sensory nerve endings in the myocardium. The afferent nerve fibers ascend to the central nervous system through the cardiac branches of the sympathetic trunk and enter the spinal cord through the posterior roots of the upper four thoracic nerves. The nature of the pain varies considerably, from a severe crushing pain to nothing more than mild discomfort.

The pain is not felt in the heart, but is referred to the skin areas supplied by the corresponding spinal nerves. The skin areas supplied by the upper four intercostal nerves and by the intercostobrachial nerve (T2) are therefore affected. The intercostobrachial nerve communicates with the medial cutaneous nerve of the arm and is distributed to skin on the medial side of the upper part of the arm. A certain amount of spread of nervous information must occur within the central nervous system, for the pain is sometimes felt in the neck and the jaw.

Myocardial infarction involving the inferior wall or diaphragmatic surface of the heart often gives rise to discomfort in the epigastrium. One must assume that the afferent pain fibers from the heart ascend in the sympathetic nerves and enter the spinal cord in the posterior roots of the seventh, eighth, and ninth thoracic spinal nerves and give rise to referred pain in the T7, T8, and T9 thoracic dermatomes in the epigastrium.

Because the heart and the thoracic part of the esophagus probably have similar afferent pain pathways, it is not surprising that painful acute esophagitis can mimic the pain of myocardial infarction.

Auscultation of Heart Valves

On listening to the heart with a stethoscope, one can hear two sounds: lūb-dŭp. The first sound is produced by the contraction of the ventricles and the closure of the tricuspid and mitral valves. The second sound is produced by the sharp closure of the aortic and pulmonary valves. It is important for a physician to know where to place the stethoscope on the chest wall so that he or she will be able to hear sounds produced at each valve with the minimal distraction or interference (CD Fig. 4-2).

- The **tricuspid valve** is best heard over the right half of the lower end of the body of the sternum.
- The **mitral valve** is best heard over the apex beat, that is, at the level of the fifth left intercostal space, 3.5 in. (9 cm) from the midline.
- The **pulmonary valve** is heard with least interference over the medial end of the second left intercostal space.
- The **aortic valve** is best heard over the medial end of the second right intercostal space.

Valvular Disease of the Heart

Inflammation of a valve can cause the edges of the valve cusps to stick together. Later, fibrous thickening occurs, followed by loss of flexibility and shrinkage. Narrowing (stenosis) and valvular incompetence (regurgitation) result, and the heart ceases to function as an efficient pump. In rheumatic disease of the mitral valve, for example, not only do the cusps undergo fibrosis and shrink, but also the chordae tendineae shorten, preventing closure of the cusps during ventricular systole.

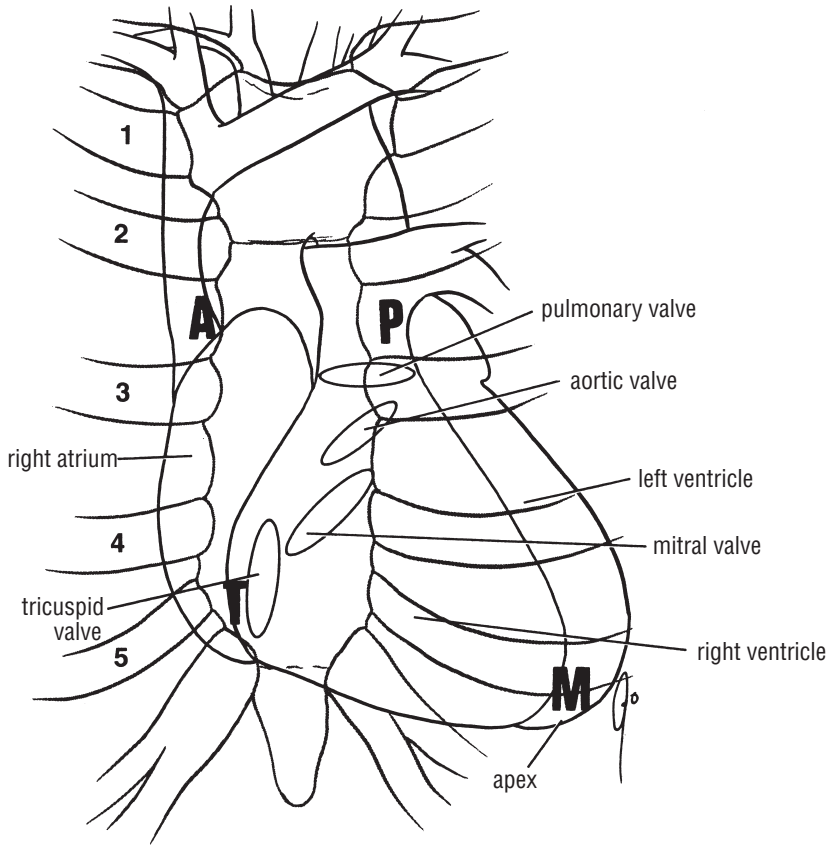
Valvular Heart Murmurs

Apart from the sounds of the valves closing, lūb-dŭp, the blood passes through the normal heart silently. Should the valve orifices become narrowed or the valve cusps distorted and shrunken by disease, however, a rippling effect would be set up, leading to turbulence and vibrations that are heard as heart murmurs.

Cardiac Injuries

Cardiac Contusion

The heart, although protected by the thoracic cage, can be squeezed between the sternum and the vertebral column



CD Figure 4-2 Surface anatomy of the heart and great blood vessels. Note the position of the heart valves relative to the chest wall. The bold letters indicate positions where valves may be heard with least interference. A = aortic valve, M = mitral valve, P = pulmonary valve, T = tricuspid valve.

(see text Fig. 4-8) when the thorax is subjected to a severe frontal impact. Moreover, if the force is also applied to the anterior abdominal wall, the diaphragm is thrust upward, impinging on the heart from below. The highly flexible rib cage present in children makes myocardial contusion a common occurrence in this age group. The result of heart muscle damage is precordial pain, similar in nature to a myocardial infarction. Tachycardia often occurs and, if enough cardiac muscle is contused, cardiac output may decrease. Depending on the severity of the injury, there may be arrhythmias and evidence of heart block.

Valve and Septal Injuries

In both blunt and penetrating injuries to the heart, the valve cusps, the papillary muscles, and the chordae tendineae can be damaged. The incidence of valve involvement is in the following order: aortic, mitral, and pulmonary. Acute valvular insufficiency can be diagnosed clinically, but it should be confirmed by cardiac catheterization. In severe cases prompt surgical repair may be necessary.

Penetrating Injuries to the Heart

The anatomy of the heart relative to the front of the thoracic cage determines the common sites of injury. The anterior surface of the heart is formed largely by the right ventricle; the left border is formed by the left ventricle and the right border is formed by the right atrium. The right ventricle is most commonly injured, followed by the left ventricle and the right atrium. The anterior interventricular branch of the left coronary artery is the most common artery to be damaged.

Since the pericardium has to be penetrated for the heart to be injured, cardiac tamponade is often present. The hemopericardium quickly presses on the thin-walled atria and large veins and compromises the venous return. The classic triad of (1) distension of the jugular veins of the neck, (2) faint heart sounds (damped down by blood in the pericardial sac), and (3) hypotension may all be present. If there is substantial concomitant blood loss or volume depletion, the jugular veins may not be enlarged. Do not expect to see a greatly enlarged heart shadow on a chest radiograph. Even though the blood in the pericardial sac may be under high pressure caused by a ventricular leak, the tough fibrous tissue in the wall of the fibrous pericardium prevents its undue distension. Hemopericardium must be relieved surgically.

Congenital Anomalies

Atrial Septal Defects

After birth, the foramen ovale becomes completely closed as the result of the fusion of the septum primum with the septum secundum. In 25% of hearts, a small opening persists, but this is usually of such a minor nature that it has no clinical significance. Occasionally, the opening is much larger and results in oxygenated blood from the left atrium passing over into the right atrium (CD Fig. 4-3).

Ventricular Septal Defects

The ventricular septum is formed in a complicated manner and is complete only when the membranous part fuses with the muscular part. Ventricular septal defects are less frequent than atrial septal defects. They are found in the membranous part of the septum and can measure 1 to 2 cm in diameter. Blood under high pressure passes through the defect from left to right, causing enlargement of the right ventricle. Large defects are serious and can shorten life if surgery is not performed.

Tetralogy of Fallot

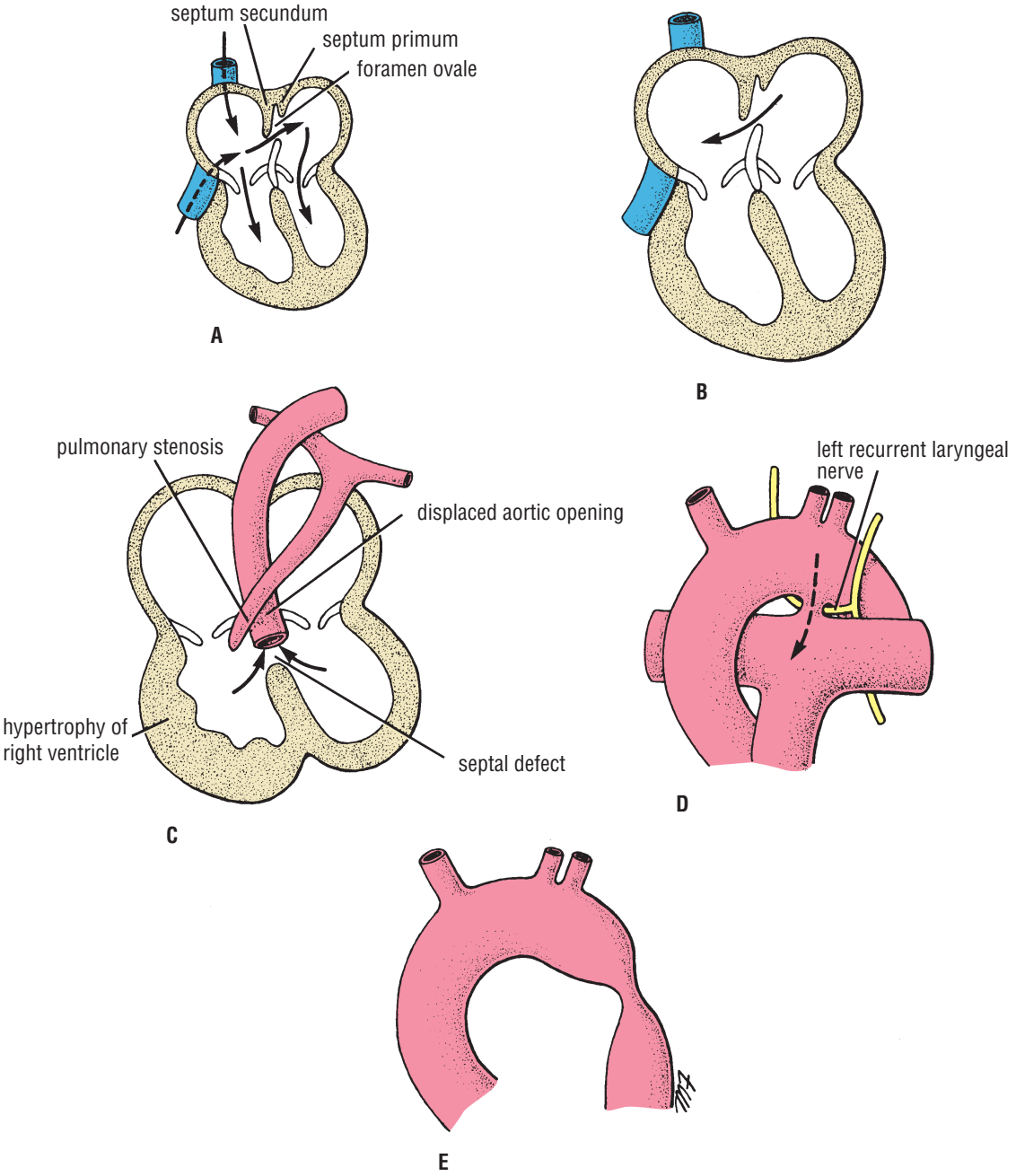
Normally, the bulbus cordis becomes divided into the aorta and pulmonary trunk by the formation of the spiral aorticopulmonary septum. This septum is formed by the fusion of the bulbar ridges. If the bulbar ridges fail to fuse correctly, unequal division of the bulbus cordis may occur, with consequent narrowing of the pulmonary trunk and resulting in interference with the right ventricular outflow.

This congenital anomaly is responsible for about 9% of all congenital heart disease (see CD Fig. 4-3). The anatomic abnormalities include large ventricular septal defect; stenosis of the pulmonary trunk, which can occur at the infundibulum of the right ventricle or at the pulmonary valve; exit of the aorta immediately above the ventricular septal defect (instead of from the left ventricular cavity only); and severe hypertrophy of the right ventricle, because of the high blood pressure in the right ventricle. The defects cause congenital cyanosis and considerably limit activity; patients with severe untreated abnormalities die. Once the diagnosis has been made, most children can be successfully treated surgically.

Most children find that assuming the squatting position after physical activity relieves their breathlessness. This happens because squatting reduces the venous return by compressing the abdominal veins and increasing the systemic arterial resistance by kinking the femoral and popliteal arteries in the legs; both these mechanisms tend to decrease the right-to-left shunt through the ventricular septal defect and improve the pulmonary circulation.

Mitral Valve Prolapse

In this condition, one or both mitral valve cusps balloon up into the left atrium during ventricular systole. The valve cusps are larger than normal and the chordae tendineae may be excessively long. The posterior cusp is always involved; the anterior cusp is involved less frequently. The majority of the patients are female, and there may be a familial incidence of the syndrome. The typical symptoms are chest pain and palpitations, and dysrhythmias may occur.



CD Figure 4-3 **A.** Normal fetal heart. **B.** Atrial septal defect. **C.** Tetralogy of Fallot. **D.** Patent ductus arteriosus (note the close relationship to the left recurrent laryngeal nerve). **E.** Coarctation of the aorta.

Bicuspid Aortic Valve

This is a congenital anomaly occurring in 1% to 2% of the population. At first it causes no functional problems. However, with advancing years and continued wear and tear, the valve cusps become damaged and undergo fibrosing stenosis and calcification. The valve is also prone to the development of infective endocarditis.

Persistent Truncus Arteriosus

This condition represents about 1% of all congenital heart defects. Only one artery arises from the heart, the pulmonary artery and aorta sharing a common trunk. A large ventricular septal defect is usually present. The child exhibits mild cyanosis and heart failure. Surgical correction of the ventricular septal defect and the

establishment of a separate pulmonary and aortic outflow are necessary.

Patent Ductus Arteriosus

The ductus arteriosus represents the distal portion of the sixth left aortic arch and connects the left pulmonary artery to the beginning of the descending aorta (see CD Fig. 4-3). During fetal life, blood passes through it from the pulmonary artery to the aorta, thus bypassing the lungs. After birth, it normally constricts, later closes, and becomes the ligamentum arteriosum.

Failure of the ductus arteriosus to close may occur as an isolated congenital abnormality or may be associated with congenital heart disease. A persistent patent ductus arteriosus results in high-pressure aortic blood passing into the pulmonary artery, which raises the pressure in the pulmonary circulation. A patent ductus arteriosus is life threatening and should be ligated and divided surgically.

THE PERICARDIUM

Traumatic Injury to the Pericardium

Pericardial Disruption

This may occur from blunt trauma from a puncture following penetration by a fractured rib and rupture from a sudden increase in pressure. The most common location of rupture is along the lateral margins, especially on the left side. The phrenic nerve may be involved, as it is situated between the mediastinal parietal pleura and the pericardium (CD Fig. 4-4)

Hemopericardium

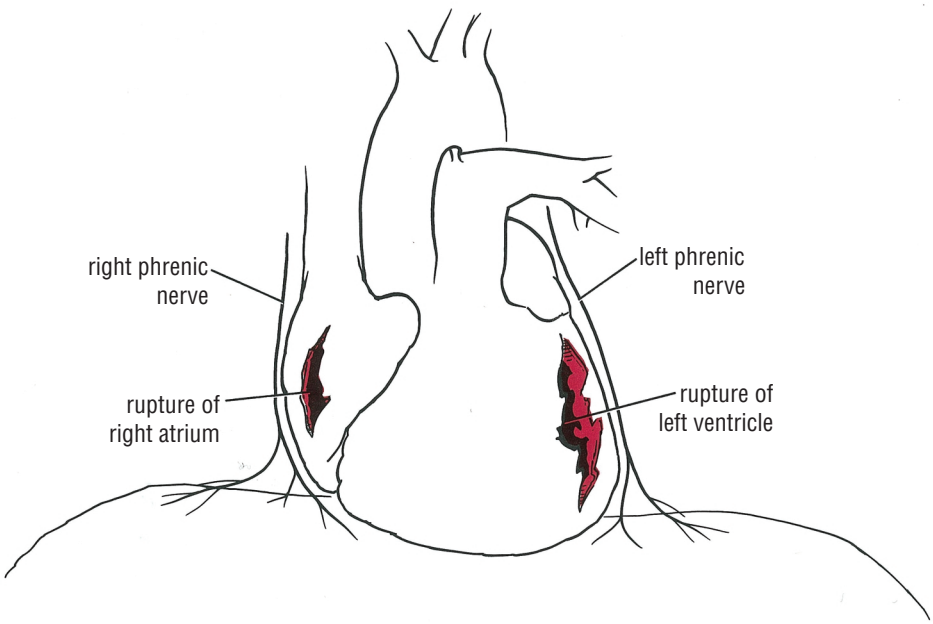
With blunt or penetrating injuries to the heart, blood can escape into the pericardial cavity. The normal volume of pericardial fluid, about 50 mL, is used to lubricate the apposing surfaces of the serous pericardium during heart movements. Once the fluid in the cavity exceeds about 250 mL, the diastolic filling is compromised, a condition known as **cardiac tamponade**.

Pericardiocentesis

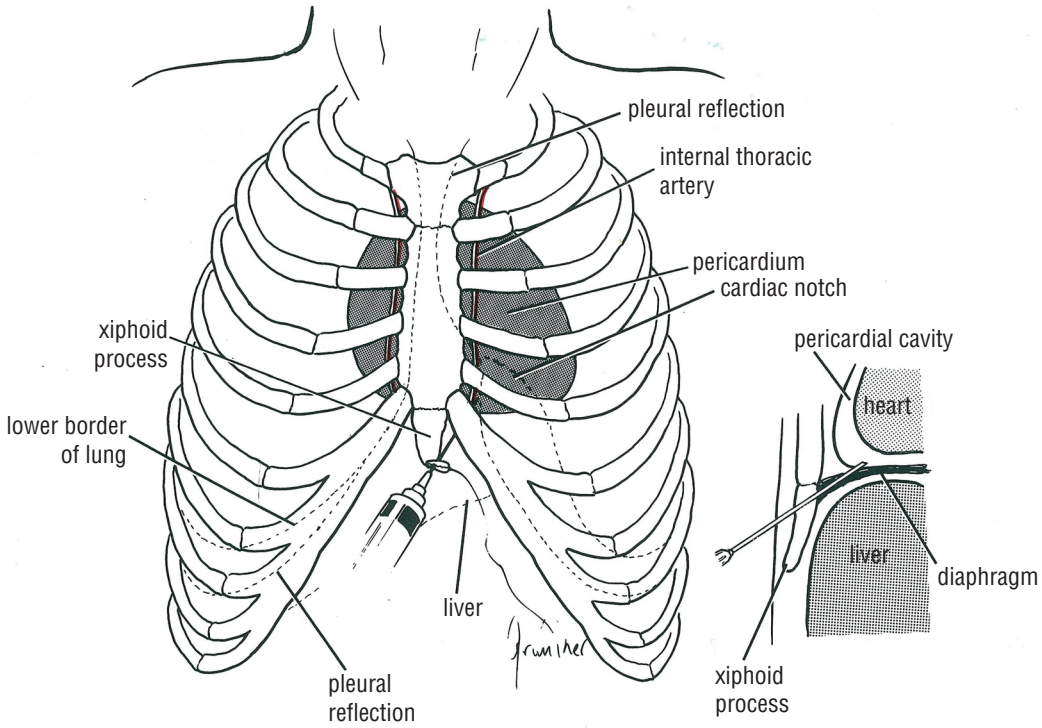
This procedure is used in the treatment of cardiac tamponade.

The patient is placed in a supine position with the shoulders raised 60° from the horizontal position. The usual skin preparation is now completed. The needle is inserted in the angle between the xiphoid process and the left costal margin. With the positions of the cardiac notches of the lungs and pleura in mind (CD Fig. 4-5), the tip of the needle is directed upward, backward, and to the left in the left xiphocostal angle, that is, toward the left shoulder. The following structures will be penetrated by the needle:

1. Skin
2. Subcutaneous tissue
3. Aponeurosis of the external oblique muscle of the abdomen
4. Anterior lamina of the aponeurosis of the internal oblique muscle of the abdomen
5. Rectus abdominis muscle



CD Figure 4-4 Anterior view of the heart showing common sites for rupture of the pericardium on the anterior surface. Note the position of the right and left phrenic nerves.



CD Figure 4-5 **A and B.** The xiphisternal approach for pericardiocentesis. Note that the needle is aimed upward and backward in the direction of the left shoulder.

6. Posterior lamina of the aponeurosis of the internal oblique and the transversus abdominis muscles
7. Extraperitoneal fat; avoid entering the peritoneal cavity
8. Diaphragm
9. Pericardium (fibrous pericardium and parietal serous pericardium)

The long large-bore needle is advanced through the above structures and when pericardial penetration is achieved there is a sudden "give." The needle is connected to a 20-mL syringe with a three-way stopcock to permit aspiration of the fluid.

Anatomy of Complications

1. The needle is advanced too far and enters the myocardium of the right ventricle.
2. The needle pierces the anterior descending branch of the left coronary artery.
3. The needle enters the pleural cavity, producing a pneumothorax or a hydropneumothorax.
4. The needle pierces the liver.

Clinical Problem Solving Questions

Read the following case histories/questions and give the best answer for each.

A 61-year-old man was seen in the emergency department complaining of a feeling of pressure within his chest. On questioning, he said that he had several attacks before and that they had always occurred when he was climbing stairs or digging in the garden. He found that the discomfort disappeared with rest after about 5 minutes. The reason he came to the emergency department was that the chest discomfort had occurred with much less exertion.

1. The following comments concerning this case are correct **except** which?
   A. The diagnosis is a classic case of angina pectoris.

B. The sudden change in history, that is, pain caused by less exertion, should cause the physician concern that the patient now has unstable angina or an actual myocardial infarction.
C. The afferent pain fibers from the heart ascend to the central nervous system through the cardiac branches of the sympathetic trunk to enter the spinal cord.
D. The afferent pain fibers enter the spinal cord via the posterior roots of the tenth to the twelfth thoracic nerves.
E. Pain is referred to dermatomes supplied by the upper four intercostal nerves and the intercostal brachial nerve.

A 55-year-old woman has severe aortic incompetence, with the blood returning to the cavity of the left ventricle during ventricular diastole.

2. To hear the aortic valve with the least interference from the other heart sounds, the best place to place your stethoscope on the chest wall is
A. the right half of the lower end of the body of the sternum.
B. the medial end of the second right intercostal space.
C. the medial end of the second left intercostal space.
D. the apex of the heart.
E. the fifth left intercostal space 3.5 in. (9 cm) from the midline.

A 33-year-old woman was jogging across the park at 11 PM when she was attacked by a gang of youths. After she was brutally mugged and raped, one of the youths decided to stab her in the heart to keep her silent. Later in the emergency department she was unconscious and in extremely poor shape. A small wound about 0.5 in. in diameter was present in the left fifth intercostal space about 0.5 in. from the lateral sternal margin. Her carotid pulse was rapid and weak, and her neck veins were distended. No evidence of a left-sided pneumothorax existed. A diagnosis of cardiac tamponade was made.

3. The following observations are in agreement with the diagnosis **except** which?
A. The tip of the knife had pierced the pericardium.
B. The knife had pierced the anterior wall of the left ventricle.
C. The blood in the pericardial cavity was under right ventricular pressure.
D. The blood in the pericardial cavity pressed on the thin-walled atria and large veins as they traversed the pericardium to enter the heart.
E. The backed-up venous blood caused congestion of the veins seen in the neck.
F. The poor venous return severely compromised the cardiac output.
G. A left-sided pneumothorax did not occur because the knife passed through the cardiac notch.

A 38-year-old woman was taken from the scene of an automobile accident to the local hospital. She had been driving her car without a seat belt on and had hit a utility pole head on. On examination she was conscious and alert but had sustained severe facial and chest injuries. A careful examination of the chest cage revealed the presence of a sternal fracture (middle of the body) and fractures of the third and fourth left ribs near their costochondral junctions. After an extensive workup it was decided that the patient had a ruptured pericardium.

4. The following observations are in agreement with the diagnosis **except** which?
A. Blunt trauma had been applied to the anterior chest wall.
B. The fractures of the third and fourth left ribs were situated over the anterior surface of the heart.
C. The left dome of the diaphragm was paralyzed.
D. The patient had tachycardia.
E. The right lateral margin of the pericardium was the site of the rupture.
F. There were diminished breath sounds over the lower lobe of the left lung.

A 21-year-old man was walking along a city street when suddenly a burst of automatic gunfire came from a passing car. The man, who was an innocent bystander, was struck in the front of the chest by a stray bullet. He was rushed to the emergency department by an ambulance. The position of the entry wound was the fourth left intercostal space about 3 in. from the midline.

5. The following observations are in agreement with the findings in this patient **except** which?
A. The right ventricle is the most likely chamber of the heart to be injured should a bullet enter the frontal surface of the chest.
B. If the bullet continues on its path, the left ventricle is also damaged, since the left ventricle lies posterior to the right ventricle.
C. The circumflex branch of the left coronary artery may be damaged by the bullet as it runs down the anterior surface of the heart.
D. The chordae tendineae of the anterior cusp of the tricuspid valve could be injured.

A 5-year-old boy was seen in the emergency room following an attack of breathlessness during which he had lost consciousness. The mother, on questioning, said that her child had had several such attacks before and sometimes his skin had become bluish. Recently she had noticed that he breathed more easily when he was playing in a squatting position; he also seemed to sleep more easily with his knees drawn up. On physical examination, the child was found to be thinner and shorter than normal. His lips were cyanotic, and his fingers and toes were clubbed. A systolic murmur was

present along the left border of the sternum, and the heart was considerably enlarged to the right. An extensive workup, including angiography, demonstrated tetralogy of Fallot.

6. Using your knowledge of cardiac development, critically read the following observations made in this case and determine the one that is **incorrect**.
   A. The systolic murmur heard along the left border of the sternum was caused by the pulmonary stenosis.
   B. A right-to-left shunt of blood occurs through the large ventricular septal defect.
   C. The aortic blood is poorly oxygenated resulting in the impaired growth of the child, the cyanosis of the lips, and the clubbing of the fingers and toes
   D. Maintaining the squatting position during play and sleeping with the knees drawn up increases the peripheral resistance in the systemic circulation and decreases the right-to-left shunt through the ventricular septum.
   E. If the patient had a large ductus arteriosus as well as the tetralogy of Fallot, the cyanosis would be much worse.

A 43-year-old woman was seen in the emergency department complaining of a severe localized pain over the left side of the chest. She stated that the pain started quite suddenly, about 1 hour previously, when she was reaching for a book on a high shelf. On further questioning she disclosed that she had been sailing with her husband the previous day and that they had been caught in a storm. She described the pain as a continuous dull ache that was made worse by taking deep breaths and using the left arm. She indicated that the pain was localized over the sixth left costal cartilage about 2 in. to the left of the sternum, which corresponded to an area of tenderness over the sixth left costochondral junction.

7. The following possible conditions could explain the severe chest pain. Choose the **most likely** diagnosis based on your knowledge of anatomy.
   A. Myocardial infarction
   B. Lobar pneumonia of the left lung
   C. Tearing of muscle fibers in the chest wall, possibly the serratus anterior muscle
   D. Separation of the sixth left costochondral joint or an acute costochondritis
   E. Left-sided pleurisy

8. The following anatomic structures are penetrated by a needle when performing a pericardiocentesis **except** which?
   A. Skin and subcutaneous tissue
   B. The aponeuroses of the external and internal oblique muscles
   C. The left parietal and visceral layers of pleura
   D. The rectus abdominis muscle
   E. The diaphragm and fibrous pericardium

Answers and Explanations

1. **D** is the correct answer. The afferent pain fibers from the heart enter the spinal cord via the posterior nerve roots of the upper four thoracic spinal nerves.
2. B is the correct answer. The best location to place your stethoscope on the chest wall to hear the aortic valve is the medial end of the second right intercostal space (see CD Fig. 4-2).
3. **B** is the correct answer. The knife had pierced the anterior wall of the right ventricle.
4. **E** is the correct answer. The left lateral margin of the pericardium had ruptured, injuring the left phrenic nerve; this resulted in the paralysis of the left dome of the diaphragm and the diminished breathing heard over the lower lobe of the left lung.
5. **C** is the correct answer. The anterior interventricular (descending) branch of the left coronary artery is the most likely artery to be damaged in such a wound through the frontal surface of the chest.
6. **E** is the correct answer. The tetralogy of Fallot consists of the following: (1) a large ventricular septal defect, (2) a stenosis of the pulmonary trunk or the pulmonary valve, (3) an exit of the aorta that lies immediately above the ventricular septal defect and thus communicates with both ventricles, and (4) a right ventricular hypertrophy secondary to the ventricular septal defect and pulmonary stenosis. Should the child have a large patent ductus arteriosus, cyanosis is reduced to a minimum. This is because a large patent ductus allows aortic blood to enter the pulmonary trunk distal to the stenosis of the pulmonary artery or valve and, in this way, enables the blood to enter the pulmonary circulation for oxygenation.
7. **D** is the correct answer. Separation of the sixth left costochondral joint or an acute costochondritis can be extremely painful conditions. The injury must have occurred when the patient was pulling on the ropes of the sailing boat during the storm on the previous day. The

joint is innervated by the sixth intercostal nerve and the pain is localized over the affected joint. This case is a good example of somatic pain that may be intense and localized, in contradistinction to visceral pain, which is diffuse and poorly localized.

8. **C** is the correct answer. By placing the needle correctly in the angle between the xiphoid process and the left costal margin and directing the tip of the needle upward, backward, and to the left toward the left shoulder, the left pleura is not pierced. By passing the needle through the cardiac notches of the left lungs and pleura both these structures are avoided (see CD Fig. 4-5). Entry of the needle into the pleural cavity produces a pneumothorax or hydropneumothorax.