14 Diseases of the Pericardium

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Chapter Outline

Diseases of the pericardium form a spectrum that ranges from benign, self-limited pericarditis to life-threatening cardiac tamponade. The clinical manifestations of these disorders and approaches to their management can be predicted from an understanding of pericardial anatomy and pathophysiology, as presented in this chapter.

ANATOMY AND FUNCTION

The pericardium is a two-layered sac that encircles the heart. The inner serosal layer (visceral pericardium) adheres to the outer wall of the heart and is reflected back on itself, at the level of the great vessels, to line the tough fibrous outer layer (parietal pericardium). A thin film of pericardial fluid slightly separates the two layers and decreases the friction between them.

The pericardium appears to serve three functions: (1) it fixes the heart within the mediastinum and limits its motion, (2) it prevents extreme dilatation of the heart during sudden rises of intracardiac volume, and (3) it may function as a barrier to limit the spread of infection from the adjacent lungs. However, patients with complete absence of the pericardium (either congenitally or after surgical removal) are generally asymptomatic, casting doubt on its actual importance in normal physiology. Yet like the unnecessary appendix, the pericardium can become diseased and cause great harm.

In the healthy heart, intrapericardial pressure varies during the respiratory cycle from −5 mm Hg (during inspiration) to +5 mm Hg (during expiration) and nearly equals the pressure within the pleural space. However, pathologic changes in pericardial stiffness, or the accumulation of fluid within the pericardial sac, may profoundly increase this pressure.

ACUTE PERICARDITIS

The most common affliction of the pericardium is acute pericarditis, which refers to inflammation of its layers. Many disease states and etiologic agents can produce this syndrome (Table 14-1), the most frequent of which are described here.

Etiology

Infectious

Idiopathic and Viral Pericarditis

Acute pericarditis is most often of idiopathic origin, meaning that the actual cause is unknown. However, serologic studies have demonstrated that many such episodes are actually caused by viral infection, especially by echovirus or coxsackievirus group B. Although a viral origin could be confirmed in infected patients by comparing antiviral titers of acute and convalescent serum, this is rarely done in the clinical setting because the patient has usually recovered by the time those results would be available. Thus, idiopathic and viral pericarditis are considered similar clinical entities, and the terms are used interchangeably.

Other viruses known to cause pericarditis include those responsible for influenza, varicella, mumps, hepatitis B, and infectious mononucleosis. Pericarditis is the most common manifestation of cardiovascular disease in patients with AIDS, arising from HIV infection itself or from superimposed tuberculous or other bacterial infections in this immunocompromised population.

Tuberculous Pericarditis

Although tuberculosis remains a worldwide problem, its incidence in the United States is low. It is, however, an important cause of pericarditis in immunosuppressed patients. Tuberculous pericarditis arises from reactivation of the organism in mediastinal lymph nodes, with spread into the pericardium. It can also extend directly from a site of tuberculosis within the lungs, or the organism can arrive at the pericardium by hematogenous dissemination.

Nontuberculous Bacterial Pericarditis (Purulent Pericarditis)

Bacterial pericarditis is a fulminant illness but is rare in otherwise healthy persons; it is most likely to occur in immunocompromised patients, including those with severe burns and malignancies. Pneumococci and staphylococci are responsible most frequently, whereas

TABLE 14-1 Causes of Acute Pericarditis

Infectious
Viral
Tuberculosis
Pyogenic bacteria
Noninfectious
Postmyocardial infarction or after cardiac surgery
Uremia
Neoplastic disease
Radiation induced
Connective tissue diseases
Drug induced

gram-negative infection occurs less often. Mechanisms by which bacterial invasion of the pericardium develops include (1) perforating trauma to the chest (e.g., stab wound); (2) contamination during chest surgery; (3) extension of an intracardiac infection (i.e., infective endocarditis); (4) extension of pneumonia or a subdiaphragmatic infection; and (5) hematogenous spread from a remote infection.

Noninfectious

Pericarditis following Myocardial Infarction

There are two forms of pericarditis associated with acute myocardial infarction (MI). The early type occurs within the first few days after an MI. It likely results from inflammation extending from the epicardial surface of the injured myocardium to the adjacent pericardium; therefore, it is more common in patients with transmural (as opposed to subendocardial) infarctions. The prognosis following acute MI is not affected by the presence of pericarditis; its major importance is in distinguishing it from the pain of recurrent myocardial ischemia. This form of pericarditis occurs in fewer than 5% of patients with acute MI who are treated with acute reperfusion strategies (see Chapter 7), but it is more common in those who are not (and who, therefore, sustain larger infarctions).

The second form of post-MI pericarditis is known as Dressler syndrome, which can develop 2 weeks to several months following an acute infarction. Its cause is unknown, but it is thought to be of autoimmune origin, possibly directed against antigens released from necrotic myocardial cells. Dressler syndrome has become very rare since the advent of reperfusion therapies for acute MI. A clinically similar form of pericarditis may occur weeks to months following heart surgery, termed postpericardiotomy pericarditis.

Uremic Pericarditis

Pericarditis is a potentially serious complication of untreated chronic renal failure. While its pathogenesis in this setting is unknown, it has become uncommon with the widespread availability of dialysis. Pericarditis may also appear for the first time in patients already treated with chronic dialysis therapy, and often responds to intensification of dialysis.

Neoplastic Pericarditis

Tumor involvement of the pericardium most commonly results from metastatic spread or local invasion by cancer of the lung, breast, or lymphoma. Primary tumors of the pericardium are rare. Neoplastic effusions are usually large and hemorrhagic and frequently lead to cardiac tamponade, a life-threatening complication described later in the chapter.

Radiation-Induced Pericarditis

Pericarditis may complicate radiation therapy to the thorax (e.g., administered for the treatment of certain tumors), especially if the cumulative dose has exceeded 4,000 cGy. Radiation-induced damage causes a local inflammatory response that can result in pericardial effusions and ultimately fibrosis. Cytologic examination of the pericardial fluid helps to distinguish radiation-induced pericardial damage from that of tumor invasion.

Pericarditis Associated with Connective Tissue Diseases

Pericardial involvement is common in many connective tissue diseases, including systemic lupus erythematosus (SLE), rheumatoid arthritis, and progressive systemic sclerosis. For example, 20% to 40% of patients with SLE experience clinically detectable pericarditis during

the course of the disease. Customary treatment of the underlying connective tissue disease usually ameliorates the pericarditis as well.

Drug-Induced Pericarditis

Several pharmaceutical agents can cause pericarditis as a side effect, often by inducing a systemic lupus-like syndrome (Table 14-2). These drugs include the antiarrhythmic procainamide and the vasodilator hydralazine. Drug-induced pericarditis usually abates when the causative agent is discontinued.

Pathogenesis

Similar to other inflammatory processes, pericarditis is characterized by three stages: (1) local vasodilation with transudation of protein-poor, cell-free fluid into the pericardial space; (2) increased vascular permeability, with leak of protein into the pericardial space; and (3) leukocyte exudation, initially by neutrophils, followed later by mononuclear cells.

The leukocytes are of critical importance because they help contain or eliminate the offending infectious or autoimmune agent. However, metabolic products released by these cells may prolong inflammation, cause pain and local cellular damage, and mediate somatic symptoms such as fever. Therefore, the immune response to pericardial injury may signif cantly contribute to tissue damage and symptomatology.

Pathology

The pathologic appearance of the pericardium depends on the underlying cause and severity of inflammation. **Serous pericarditis** is characterized by scant polymorphonuclear leukocytes, lymphocytes, and histiocytes. The exudate is a thin fluid secreted by the mesothelial cells lining the serosal surface of the pericardium. This likely represents the early inflammatory response common to all types of acute pericarditis.

Serof brinous pericarditis is the most commonly observed morphologic pattern in patients with pericarditis. The pericardial exudate contains plasma proteins, including f brinogen, yielding a grossly rough and shaggy appearance (termed “bread and butter” pericarditis). Portions of the visceral and parietal pericardium may become thickened and fused. Occasionally, this process leads to a dense scar that restricts movement and diastolic f lling of the cardiac chambers, as described later in the chapter.

Suppurative (or purulent) pericarditis is an intense inflammatory response associated most commonly with bacterial infection. The serosal surfaces are erythematous and coated with purulent exudate. **Hemorrhagic pericarditis** refers to a grossly bloody form of pericardial inflammation and is most often caused by tuberculosis or malignancy.

TABLE 14-2 Examples of Drug-Induced Pericarditis

Related to drug-induced SLE-like syndrome
Procainamide
Hydralazine
Methyldopa
Isoniazid
Phenytoin
Not related to drug-induced SLE-like syndrome
Anthracycline antineoplastic agents (doxorubicin, daunorubicin)
Minoxidil

SLE, systemic lupus erythematosus.

TABLE 14-3 Clinical Features of Acute Pericarditis
Pleuritic chest pain
Fever
Pericardial friction rub
ECG abnormalities

ECG, electrocardiogram.

Clinical Features

History

The most frequent symptoms of acute pericarditis are chest pain and fever (Table 14-3). The pain may be severe and usually localizes to the retrosternal area and left precordium; it may also radiate to the back and to the ridge of the left trapezius muscle. What differentiates it from myocardial ischemia or infarction is that the pain of pericarditis is typically sharp, pleuritic (it is aggravated by inspiration and coughing), and positional (e.g., sitting and leaning forward often lessen the discomfort). Dyspnea is common during acute pericarditis but is not exertional and probably results from a reluctance of the patient to breathe deeply because of pleuritic pain.

Patients with idiopathic or viral pericarditis are typically young and previously healthy. Pericarditis of other causes should be suspected in patients with the underlying conditions listed in Table 14-1 who develop the typical sharp, pleuritic chest pains and fever.

Physical Examination

A scratchy pericardial friction rub is common in acute pericarditis and is believed to be produced by the movement of the inflamed pericardial layers against one another. Auscultation of the rub is best heard using the diaphragm of the stethoscope with the patient leaning forward while exhaling (which brings the pericardium closer to the chest wall and stethoscope). In its full form, the rub consists of three components, corresponding to the phases of greatest cardiac movement: ventricular contraction, ventricular relaxation, and atrial contraction. Characteristically, the pericardial rub is evanescent, coming and going from one examination to the next.

Diagnostic Studies

The presence of pleuritic, positional chest pain and the characteristic pericardial friction rub implicate the presence of acute pericarditis. However, certain laboratory studies are helpful to confirm the diagnosis and to assess for impending complications.

The electrocardiogram (ECG) is abnormal in 90% of patients with acute pericarditis and helps to distinguish it from other forms of cardiac disease, such as an acute coronary syndrome. The most important ECG pattern, which reflects inflammation of the adjacent myocardium, consists of diffuse ST-segment elevation in most of the ECG leads, usually with the exception of aVR and V1 (Fig. 14-1). In addition, PR-segment depression in several leads is often evident, reflecting abnormal atrial repolarization related to atrial epicardial inflammation. These abnormalities are in contrast to the ECG of acute ST-segment elevation MI, in which the ST segments are elevated only in the leads overlying the region of infarction, and PR depression is not expected.

Blood studies typically reveal signs of acute inflammation, including an increased white blood cell count (usually a mild lymphocytosis in acute viral/idiopathic pericarditis) and

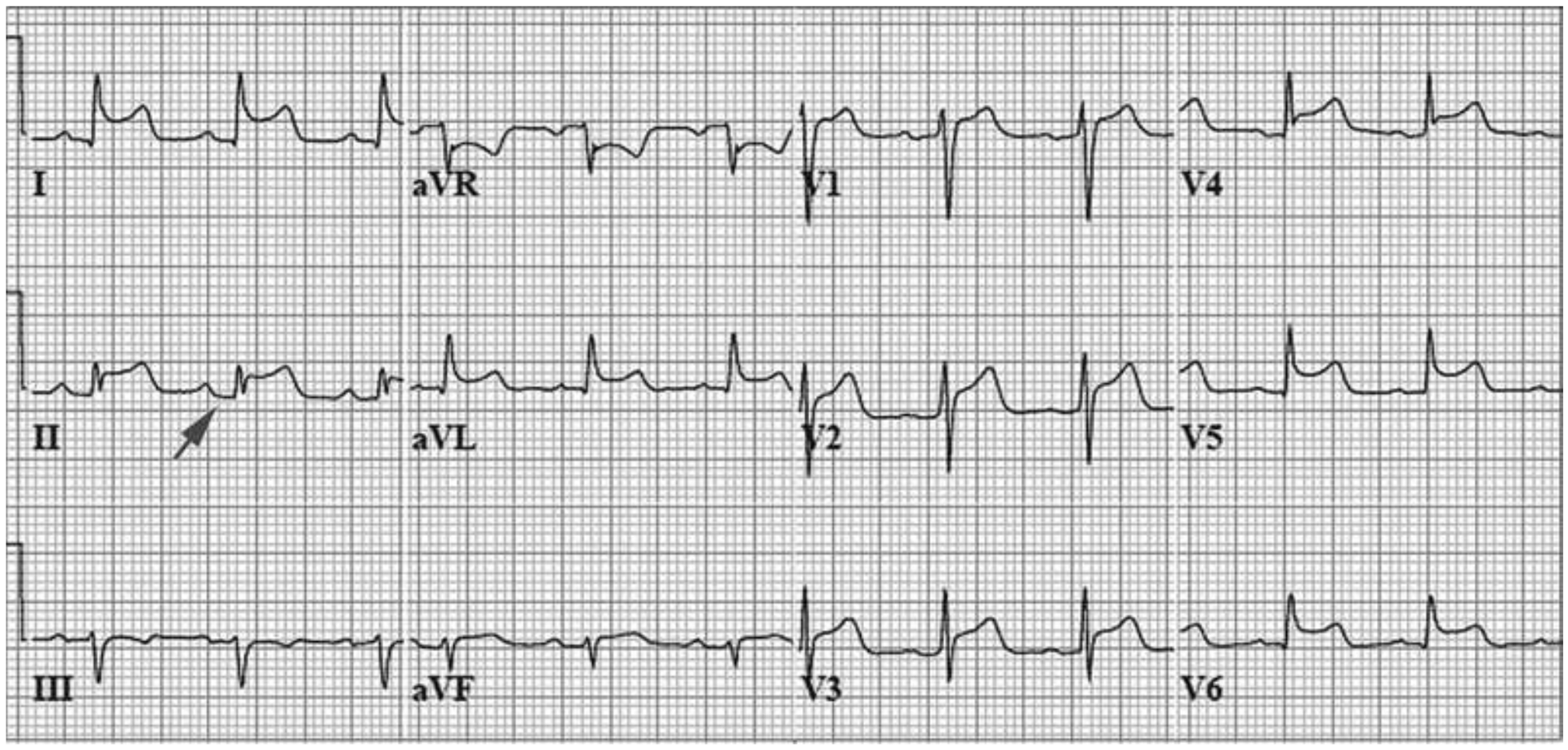

FIGURE 14-1. Electrocardiogram in acute pericarditis. Diffuse ST-segment elevation is present. Also notice depression of the PR segment (arrow).

elevation of serum inflammatory markers (e.g., erythrocyte sedimentation rate and C-reactive protein). Some patients with acute pericarditis also demonstrate elevated serum cardiac biomarkers (e.g., cardiac troponins), suggesting inflammation of the neighboring myocardium.

Further testing in acute pericarditis often includes echocardiography to evaluate for the presence and hemodynamic signif cance of a pericardial effusion. Additional studies that may be useful in individual cases to def ne the cause of pericarditis include (1) purif ed protein derivative skin test for tuberculosis, (2) serologic tests (antinuclear antibodies and rheumatoid factor) to screen for connective tissue diseases, and (3) a careful search for malignancy, especially of the lung and breast (physical examination supplemented by chest radiography and mammography). The yield of diagnostic pericardiocentesis (removal of pericardial fluid through a needle) in uncomplicated acute pericarditis is low and should be reserved for patients with very large effusions or evidence of cardiac chamber compression, as described below.

Treatment

Idiopathic or viral pericarditis is a self-limited disease that usually runs its course in 1 to 3 weeks. Management consists of rest, to reduce the interaction of the inflamed pericardial layers, and pain relief by analgesic and anti-inflammatory drugs (aspirin, ibuprofen, and other nonsteroidal anti-inflammatory agents). Colchicine, a drug with anti-inflammatory properties usually used to treat gout, may be useful as an additional agent in acute pericarditis. It has been shown to decrease the recurrence rate after an initial episode. Oral corticosteroids are effective for severe or recurrent pericardial pain but should not be used in uncomplicated cases because of potentially signif cant side effects and because steroid use is associated with an increased rate of recurrent episodes of pericarditis.

The forms of pericarditis related to MI are treated in a similar fashion, with rest and aspirin. Other nonsteroidal anti-inflammatory agents are often avoided immediately following an MI because of experimental evidence linking them to delayed healing of the infarct.

Purulent pericarditis requires more aggressive treatment, including catheter drainage of the pericardium and intensive antibiotic therapy. Nevertheless, even with such therapy, the mortality rate is very high. Tuberculous pericarditis requires prolonged multidrug antituberculous therapy. Pericarditis in the setting of uremia often resolves following intensive dialysis. Neoplastic pericardial disease usually indicates widely metastatic cancer, and therapy is unfortunately only palliative.

PERICARDIAL EFFUSION

Etiology

The normal pericardial space contains 15 to 50 mL of pericardial fluid, a plasma ultraf ltrate secreted by the mesothelial cells that line the serosal layer. A larger volume of fluid may accumulate in association with any of the forms of acute pericarditis previously described.

In addition, noninflammatory serous effusions may result from conditions of (1) increased capillary permeability (e.g., severe hypothyroidism), (2) increased capillary hydrostatic pressure (e.g., congestive heart failure), or (3) decreased plasma oncotic pressure (e.g., cirrhosis or the nephrotic syndrome). Chylous effusions may occur in the presence of lymphatic obstruction of pericardial drainage, most commonly caused by neoplasms and tuberculosis.

Pathophysiology

Because the pericardium is a relatively stiff structure, the relationship between its internal volume and pressure is not linear, as shown in curve A in Figure 14-2. Notice that the initial portion of the curve is nearly flat, indicating that at the low volumes normally present within the pericardium, a small increase in volume leads to only a small rise in pressure. However, when the intrapericardial volume expands beyond a critical level (see Fig. 14-2, arrow), a dramatic increase in pressure is incited by the nondistensible sac. At that point, even a minor increase in volume can translate into an enormous compressive force on the heart.

Three factors determine whether a pericardial effusion remains clinically silent or whether symptoms of cardiac compression ensue: (1) the volume of fluid, (2) the rate at which the fluid accumulates, and (3) the compliance characteristics of the pericardium.

A sudden increase of pericardial volume, as may occur in chest trauma with intrapericardial hemorrhage, results in marked elevation of pericardial pressure (see Fig. 14-2, steep portion of curve A) and the potential for severe cardiac chamber compression. Even lesser amounts of fluid may cause signif cant elevation of pressure if the pericardium is pathologically

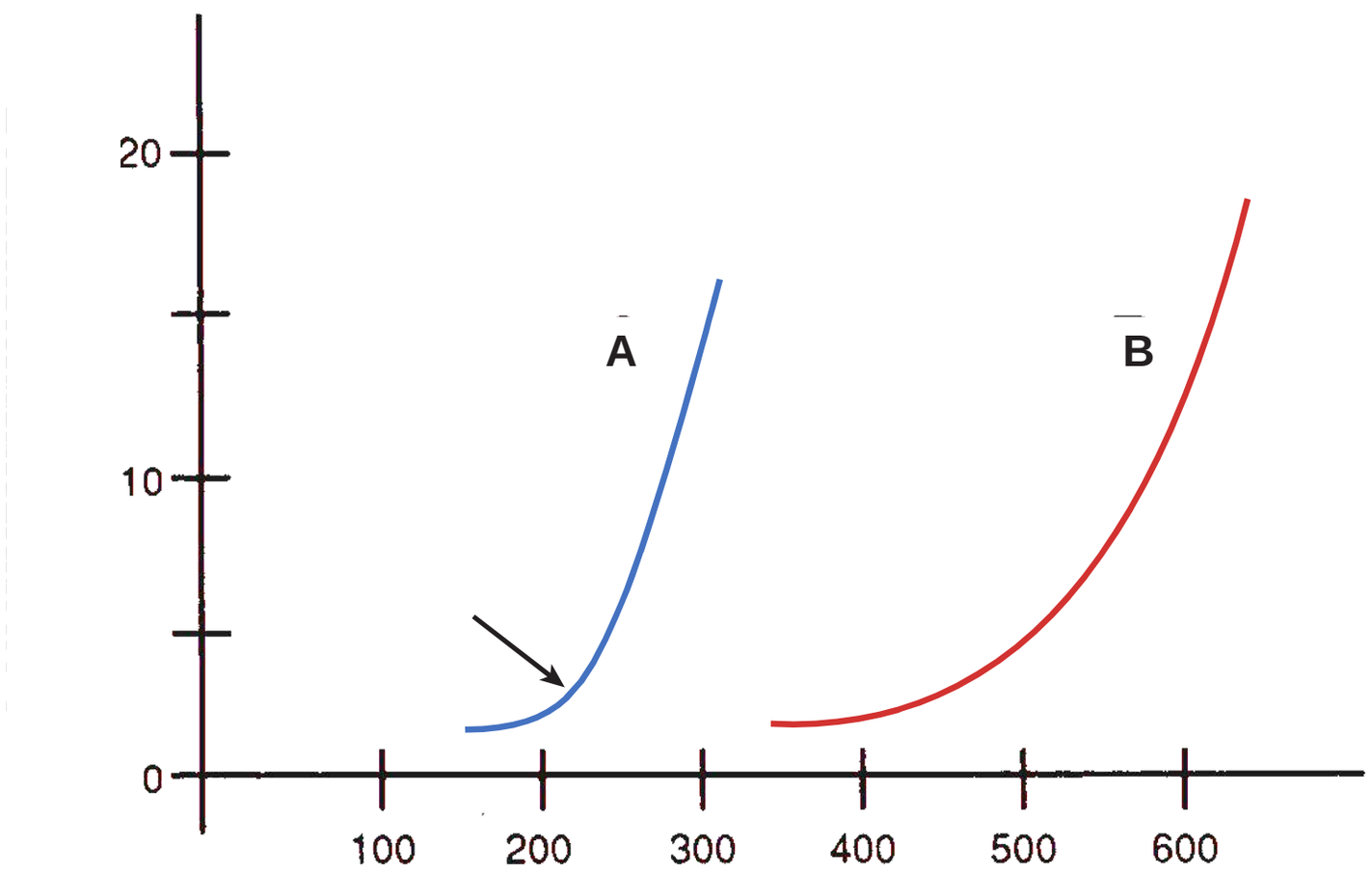

FIGURE 14-2. Schematic representation of the volume–pressure relationship of normal pericardium. **A.** At the very lowest levels, a small rise in volume results in a small rise in pressure. However, when the limits of pericardial stretch are reached (arrow), the curve becomes very steep, and a further small rise in intrapericardial volume results in signif cantly increased pressure. **B.** Chronic slow accumulation of volume allows the pericardium to gradually stretch over time; thus, the curve shifts to the right and much larger volumes are accommodated at lower pressures. (Modif ed from Freeman GL, LeWinter MM. Pericardial adaptations during chronic dilation in dogs. Circ Res. 1984;54:294.)

TABLE 14-4 Clinical Features of Large Pericardial Effusion

Soft heart sounds
Reduced intensity of friction rub
Ewart sign (dullness over posterior left lung)

noncompliant and stiff, as may occur in the presence of tumor or fibrosis of the sac. In contrast, if the pericardial effusion accumulates slowly, over weeks to months, the pericardium gradually stretches, such that the volume–pressure relationship curve shifts toward the right (see Fig. 14-2, curve B). With this adaptation, the pericardium can accommodate larger volumes without marked elevation of intrapericardial pressure.

Clinical Features

A spectrum of possible symptoms is associated with pericardial effusions. For example, the patient with a large effusion may be asymptomatic, may complain of a dull constant ache in the left side of the chest, or may present with findings of cardiac tamponade, as described later in the chapter. In addition, the effusion may cause symptoms resulting from compression of adjacent structures, such as dysphagia (difficulty swallowing because of esophageal compression), dyspnea (shortness of breath resulting from lung compression), hoarseness (due to recurrent laryngeal nerve compression), or hiccups (resulting from phrenic nerve stimulation).

On examination (Table 14-4), a large pericardial fluid "insulates" the heart from the chest wall, and the heart sounds may be muffled. In fact, a friction rub that had been present during the acute phase of pericarditis may disappear if a large effusion develops and separates the inflamed layers from one another. Dullness to percussion of the left lung over the angle of the scapula may be present (known as the Ewart sign) owing to compressive atelectasis by the enlarged pericardial sac.

Diagnostic Studies

The chest radiograph may be normal if only a small pericardial effusion is present. However, if more than approximately 250 mL has accumulated, the cardiac silhouette enlarges in a globular, symmetric fashion. In large effusions, the ECG may demonstrate reduced voltage of the complexes. In the presence of very large effusions, the height of the QRS complex may vary from beat to beat (electrical alternans), a result of a constantly changing electrical axis as the heart swings from side to side within the large pericardial volume (Fig. 14-3).

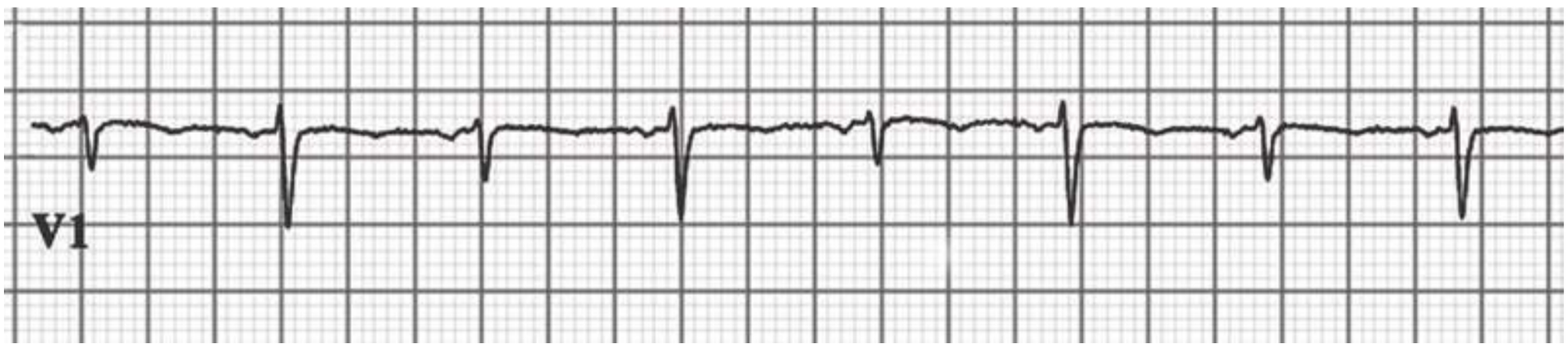

FIGURE 14-3. Electrical alternans. Rhythm strip of lead V1 showing alternating height of the QRS complex from beat to beat, due to shifting of the cardiac axis as the heart swings within a large pericardial effusion.

One of the most useful laboratory tests in the evaluation of an effusion is echocardiography (Fig. 14-4), which can identify pericardial collections as small as 20 mL. This noninvasive technique can quantify the volume of pericardial fluid, determine whether ventricular f lling is compromised, and when necessary, help direct the placement of a pericardiocentesis needle.

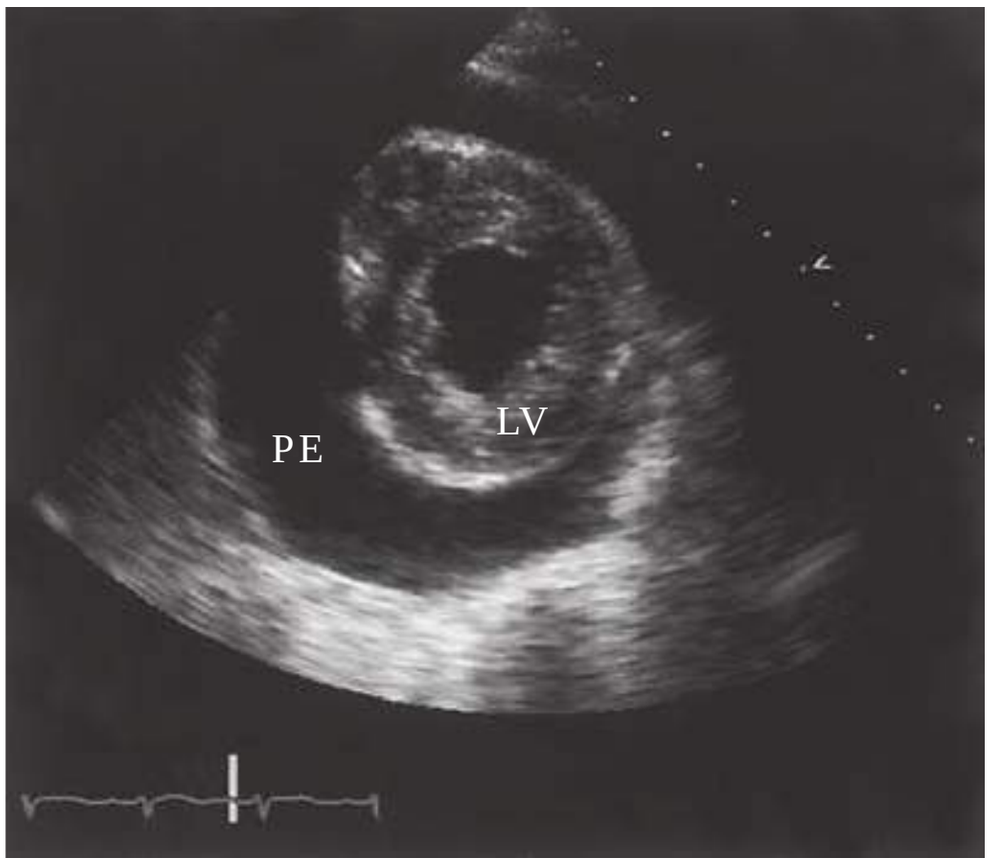

FIGURE 14-4. Two-dimensional echocardiogram (parasternal short-axis view) of a pericardial effusion (PE) surrounding the heart. LV, left ventricle.

Treatment

If the cause of the effusion is known, therapy is directed toward the underlying disorder (e.g., intensive dialysis for uremic effusion). If the cause is not evident, the clinical state of the patient determines whether pericardiocentesis (removal of pericardial fluid) should be undertaken. An asymptomatic effusion, even of large volume, can be observed for long periods without specif c intervention. However, if serial examination demonstrates a precipitous rise in pericardial volume or if hemodynamic compression of the cardiac chambers becomes evident, then pericardiocentesis should be performed for therapeutic drainage and for analysis of the fluid.

CARDIAC TAMPONADE

At the opposite end of the spectrum from the asymptomatic pericardial effusion is cardiac tamponade. In this condition, pericardial fluid accumulates under high pressure, compresses the cardiac chambers, and severely limits f lling of the heart. As a result, ventricular stroke volume and cardiac output decline, potentially leading to hypotensive shock and death.

Etiology

Any etiology of acute pericarditis (see Table 14-1) can progress to cardiac tamponade, but the most common causes are neoplastic, postviral, and uremic pericarditis. Acute hemorrhage into the pericardium is also an important cause of tamponade, which can result (1) from blunt or penetrating chest trauma, (2) from rupture of the left ventricular (LV) free wall following MI (see Chapter 7), or (3) as a complication of a dissecting aortic aneurysm (see Chapter 15).

Pathophysiology

As a result of the surrounding tense pericardial fluid, the heart is compressed, and the diastolic pressure within each chamber becomes elevated and equal to the pericardial pressure. The pathophysiologic consequences of this are illustrated in Figure 14-5. Because the compromised cardiac chambers cannot accommodate normal venous return, the systemic and pulmonary venous pressures rise. The increase of systemic venous pressure results in signs of right-sided heart failure (e.g., jugular venous distention), whereas elevated pulmonary venous pressure leads to pulmonary congestion. In addition, reduced f lling of the ventricles during diastole decreases the systolic stroke volume, and the cardiac output declines.

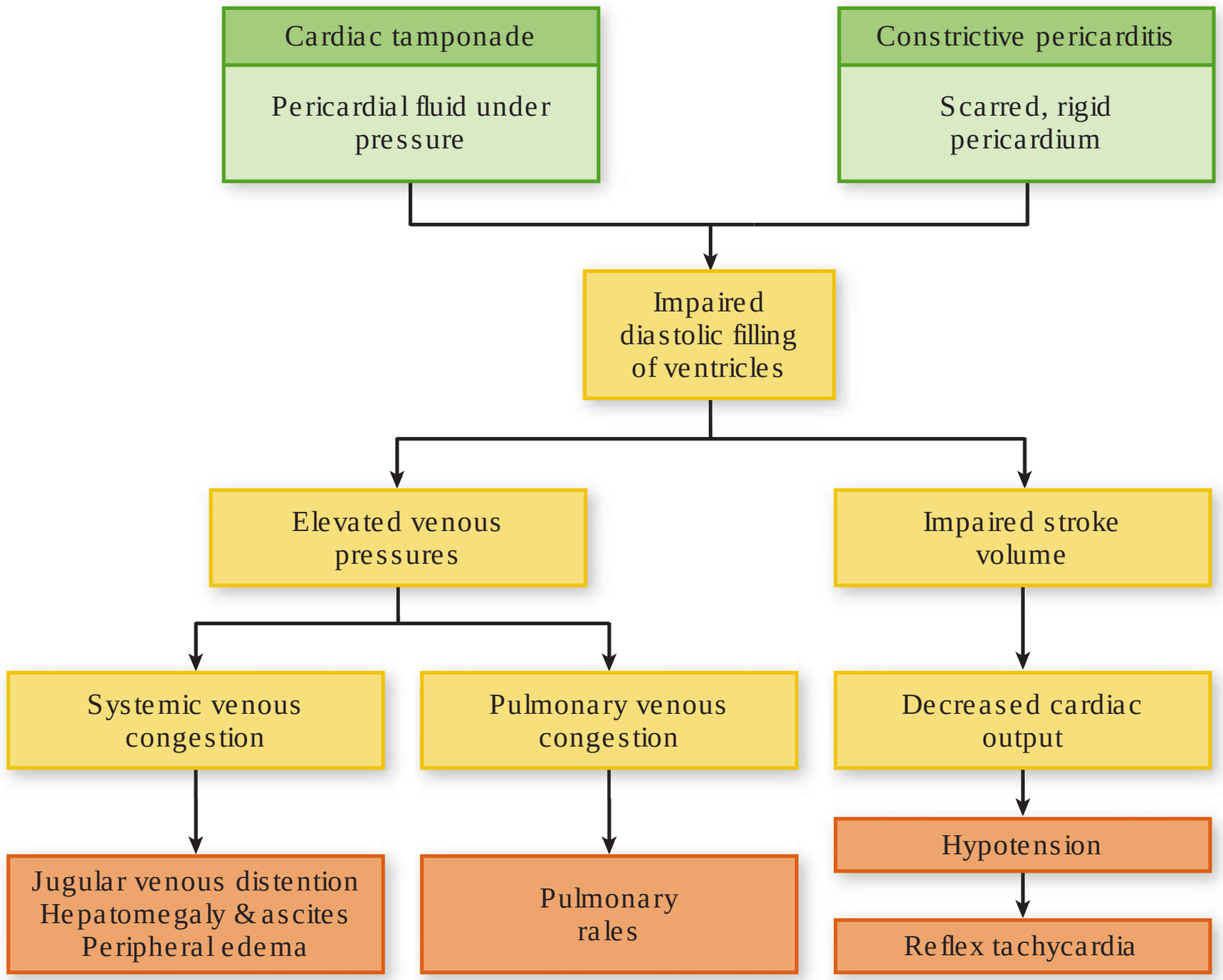

FIGURE 14-5. Pathophysiology of cardiac tamponade and constrictive pericarditis. The symptoms and signs (orange boxes) arise from impaired diastolic filling of the ventricles in both conditions.

These derangements trigger compensatory mechanisms aimed at maintaining tissue perfusion, initially through activation of the sympathetic nervous system (e.g., increased heart rate and contractility). Nonetheless, failure to evacuate the effusion leads to inadequate perfusion of vital organs, shock, and ultimately death.

Clinical Features

Cardiac tamponade should be suspected in any patient with known pericarditis, pericardial effusion, or chest trauma who develops signs and symptoms of systemic vascular congestion and decreased cardiac output (Table 14-5). The key physical findings include (1) jugular venous distention, (2) systemic hypotension, and (3) a "small, quiet heart" on physical examination, a result of the insulating effects of the effusion. Other signs include sinus tachycardia and pulsus paradoxus (described later). Dyspnea and tachypnea reflect pulmonary congestion and decreased oxygen delivery to peripheral tissues.

If tamponade develops suddenly, symptoms of profound hypotension are evident, including confusion and agitation. However, if the effusion develops more slowly, over a period of weeks, then fatigue (caused by low cardiac output) and peripheral edema (owing to right-sided heart failure) may be the presenting complaints.

TABLE 14-5 Clinical Features of Cardiac Tamponade

Jugular venous distention
Hypotension with pulsus paradoxus
Quiet precordium on palpation
Sinus tachycardia

BOX 14-1 Measurement of Pulsus Paradoxus at the Bedside

Pulsus paradoxus is an exaggeration of the normal decline in systolic blood pressure that occurs with inspiration. It can be measured at the bedside using a manual sphygmomanometer. First, inf ate the sphygmomanometer to a level greater than the patient's systolic pressure. As the cuff is slowly def ated, carefully listen for the appearance of the first Korotkoff sounds. This level marks the maximum systolic pressure and occurs during expiration. If the pressure is held at that level (i.e., if you stop def ating the cuff) in a patient with pulsus paradoxus, the Korotkoff sounds will drift in and out, audible with expiration, and absent with inspiration. That is, the systolic pressure will fall during inspiration to a level below the cuff's pressure and no sound will be heard during that time. Next, slowly def ate the cuff and continue listening. When the cuff pressure falls to the level just below the patient's systolic pressure during inspiration, the Korotkoff sounds stop drifting in and out (i.e., they are audible during both inspiration and expiration). Pulsus paradoxus is calculated as the difference between the initial systolic pressure (when the intermittent Korotkoff sounds are first heard) and this pressure (when the sounds are first audible throughout the respiratory cycle). In the presence of cardiac tamponade, this pressure difference is greater than 10 mm Hg.

Pulsus paradoxus is an important physical sign in cardiac tamponade that can be recognized at the bedside using a standard blood pressure cuff. It refers to a decrease of systolic blood pressure (more than 10 mm Hg) during normal inspiration (see Box 14-1).

Pulsus paradoxus is not really "paradoxical"; it is just an exaggeration of appropriate cardiac physiology. Normally, expansion of the thorax during inspiration causes the intrathoracic pressure to become more negative compared with the expiratory phase. This facilitates systemic venous return to the chest and augments f lling of the right ventricle (RV). The transient increase in RV size shifts the interventricular septum toward the left, which diminishes LV f lling. As a result, in normal persons, LV stroke volume and systolic blood pressure decline slightly following inspiration.

In cardiac tamponade, this situation is exaggerated because both ventricles share a reduced, f xed volume as a result of external compression by the tense pericardial fluid. In this case, the inspiratory increase of RV volume and bulging of the interventricular septum toward the left have a proportionally greater effect on the limitation of LV f lling. Thus, in tamponade, there is a more substantial reduction of LV stroke volume (and therefore systolic blood pressure) following inspiration.

Pulsus paradoxus may also be manifested by other conditions in which inspiration is exaggerated, including severe asthma and chronic obstructive airway disease.

Diagnostic Studies

Echocardiography is the most useful noninvasive technique to evaluate whether pericardial effusion has led to cardiac tamponade physiology. An important indicator of high-pressure pericardial fluid is compression of the RV and right atrium during diastole (see Fig. 3-12). In addition, echocardiography can differentiate between cardiac tamponade and other causes of low cardiac output, such as ventricular contractile dysfunction. The def nitive diagnostic procedure for cardiac tamponade is cardiac catheterization with measurement of intracardiac and intrapericardial pressures, usually combined with therapeutic pericardiocentesis, as described in the next section.

Treatment

Removal of the high-pressure pericardial fluid is the only intervention that reverses the life-threatening physiology of this condition. Pericardiocentesis is best performed in the cardiac catheterization laboratory, where the hemodynamic effect of fluid removal can be assessed. The patient is positioned head up at a 45-degree angle to promote pooling of the effusion, and

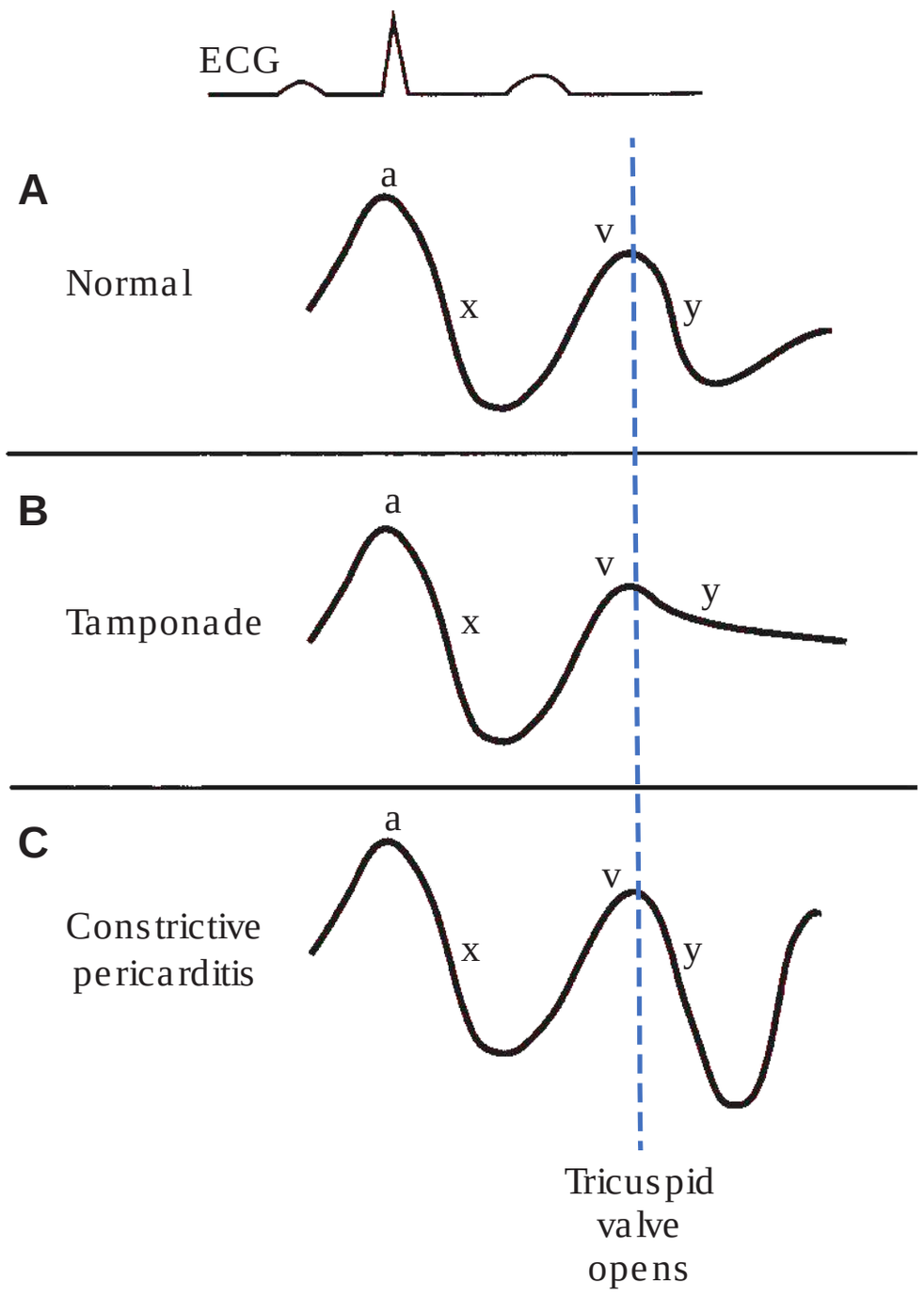

FIGURE 14-6. Schematic diagrams of right atrial (or jugular venous) pressure recordings. A. Normal. The initial a wave represents atrial contraction. The v wave reflects passive filling of the atrium during systole, when the tricuspid valve is closed. After the tricuspid valve opens, the right atrial pressure falls (y descent) as blood empties into the right ventricle. **B.** Cardiac tamponade. High-pressure pericardial fluid compresses the heart, impairing right ventricular filling, so that the y descent is blunted. **C.** Constrictive pericarditis. The earliest phase of diastolic filling is not impaired so that the y descent is not blunted. The y descent appears accentuated because it descends from a higher-than-normal right atrial pressure. The right atrial c wave (described in Chapter 2) is not shown.

a needle is inserted into the pericardial space through the skin, usually just below the xiphoid process (which is the safest location to avoid piercing a coronary artery). A catheter is then threaded into the pericardial space and connected to a transducer for pressure measurement. Another catheter is threaded through a systemic vein into the right side of the heart, and simultaneous recordings of intracardiac and intrapericardial pressures are compared. In tamponade, the pericardial pressure is elevated and is equal to the diastolic pressures within all of the cardiac chambers, reflecting the compressive force of the surrounding effusion.

In addition, the right atrial pressure tracing, which is equivalent to the jugular venous pulsation observed on physical examination, displays a characteristic abnormality (Fig. 14-6). During early diastole in a normal person, as the RV pressure falls and the tricuspid valve opens, blood quickly flows from the right atrium into the RV, leading to a rapid decline in the right atrial pressure (the y descent). In tamponade, however, the pericardial fluid compresses the RV and prevents its rapid expansion. Thus, the right atrium cannot empty quickly, and the y descent is blunted.

Following successful pericardiocentesis, the pericardial pressure falls to normal and is no longer equal to the diastolic pressures within the heart chambers, which also decline to their appropriate levels. After initial aspiration of fluid, the pericardial catheter may be left in place for 1 to 2 days to allow more complete drainage.

When pericardial fluid is obtained for diagnostic purposes, it should be stained and cultured for bacteria, fungi, and acid-fast bacilli (tuberculosis), and cytologic examination should be performed to evaluate for malignancy. Other common measurements of pericardial fluid include cell counts (e.g., white cell count is elevated in bacterial infections and other inflammatory conditions) and protein and lactate dehydrogenase levels. If the concentration ratio of pericardial protein to serum protein is greater than 0.5, or that of pericardial LDH to serum LDH is greater than 0.6, then the fluid is consistent with an exudate; otherwise, it is more likely a transudate. When tuberculosis is suspected, it is also useful to measure the level of adenosine deaminase in the pericardial fluid. Studies have indicated that an elevated level is highly sensitive and specific for tuberculosis.

If cardiac tamponade recurs following pericardiocentesis, the procedure can be repeated. In some cases, a more definitive surgical undertaking (removal of part or all of the pericardium) is required to prevent reaccumulation of the effusion.

CONSTRICTIVE PERICARDITIS

The other major potential complication of pericardial diseases is constrictive pericarditis. This is a condition not frequently encountered but is important to understand, because it can masquerade as other more common disorders. In addition, it is an affliction that may cause profound symptoms yet is often fully correctable if recognized.

Etiology and Pathogenesis

In the early part of the 20th century, tuberculosis was the major cause of constrictive pericarditis but that is much less common today in industrialized societies. The most frequent cause now is “idiopathic” (i.e., months to years following presumed idiopathic or viral acute pericarditis). However, any etiology of pericarditis can lead to this complication, including prior radiation therapy to the left side of the chest.

Pathology

Following an episode of acute pericarditis, any pericardial effusion that has accumulated usually undergoes gradual resorption. However, in patients who later develop constrictive pericarditis, the fluid undergoes organization, with subsequent fusion of the pericardial layers, followed by f brous scar formation. In some patients, calcif cation of the adherent layers ensues, further stiffening the pericardium.

Pathophysiology

The pathophysiologic abnormalities in constrictive pericarditis occur during diastole; systolic contraction of the ventricles is usually normal. In this condition, a rigid, scarred pericardium encircles the heart and inhibits normal f lling o*f* the cardiac chambers. For example, as blood passes from the right atrium into the RV during diastole, the RV size expands and quickly reaches the limit imposed by the constricting pericardium. At that point, further f lling is suddenly arrested, and venous return to the right heart ceases. Thus, systemic venous pressure rises, and signs of right-sided heart failure ensue. In addition, the impaired f lling of the left ventricle causes a reduction in stroke volume and cardiac output, which leads to lower blood pressure.

Clinical Features

The symptoms and signs of constrictive pericarditis usually develop over months to years. They result from (1) reduced cardiac output (fatigue, hypotension, and reflex tachycardia) and (2) elevated systemic venous pressures (jugular venous distention, hepatomegaly with ascites, and peripheral edema). Because the most impressive physical f ndings are often the insidious development of hepatomegaly and ascites, patients may be mistakenly suspected of having hepatic cirrhosis or an intra-abdominal tumor. However, careful inspection of the elevated jugular veins can point to the correct diagnosis of constrictive pericarditis.

On cardiac examination, an early diastolic “knock” may follow the second heart in patients with severe calcif c constriction. It represents the sudden cessation of ventricular diastolic f lling imposed by the rigid pericardial sac.

In contrast to cardiac tamponade, pericardial constriction results in pulsus paradoxus less frequently. Recall that in tamponade, this f nding reflects inspiratory augmentation of RV f lling, at the expense of LV f lling. However, in constrictive pericarditis, the negative intrathoracic pressure generated by inspiration is not easily transmitted through the rigid pericardial shell to the right-sided heart chambers; therefore, inspiratory augmentation of RV f lling is more limited. Rather, when a patient with severe pericardial constriction inhales, the negative intrathoracic pressure draws blood toward the thorax, where it cannot be accommodated by the constricted right-sided cardiac chambers. As a result, the increased venous return accumulates in the intrathoracic systemic veins, causing the jugular veins to become more distended during inspiration (**Kussmaul sign**). This is the opposite of normal physiology, in which inspiration results in a decline in jugular venous pressure,

as venous return is drawn into the heart. Thus, typical findings in pericardial disease can be summarized as follows:

	Constrictive Pericarditis	Cardiac Tamponade
Pulsus paradoxus	+	+++
Kussmaul sign	+++	−

Diagnostic Studies

The chest radiograph in constrictive pericarditis shows a normal or mildly enlarged cardiac silhouette. Calcification of the pericardium can be detected in some patients with severe chronic constriction. The ECG generally shows nonspecific ST and T-wave abnormalities; atrial arrhythmias are common.

Echocardiographic evidence of constriction is subtle. The pericardium, if well imaged, is thickened. The ventricular cavities are small and contract vigorously, but ventricular filling terminates abruptly in early diastole, as the chambers reach the limit imposed by the surrounding rigid shell. Aberrant diastolic motion of the interventricular septum, and alterations of LV inflow velocities during respiration assessed by Doppler, also reflect the abnormal pattern of diastolic filling.

Computed tomography or magnetic resonance imaging is superior to echocardiography in the assessment of pericardial anatomy and thickness. The presence of normal pericardial thickness (less than 2 mm) by these modalities makes constrictive pericarditis a much less likely diagnosis.

The diagnosis of constrictive pericarditis can be confirmed by cardiac catheterization, which reveals four key features:

1. Elevation and equalization of the diastolic pressures in each of the cardiac chambers.
2. An early diastolic "dip and plateau" configuration in the RV and LV tracings (Fig. 14-7). This pattern reflects blood flow into the ventricles at the very onset of diastole, just after the tricuspid and mitral valves open, followed by sudden cessation of filling as further expansion of the ventricles is arrested by the surrounding rigid pericardium.

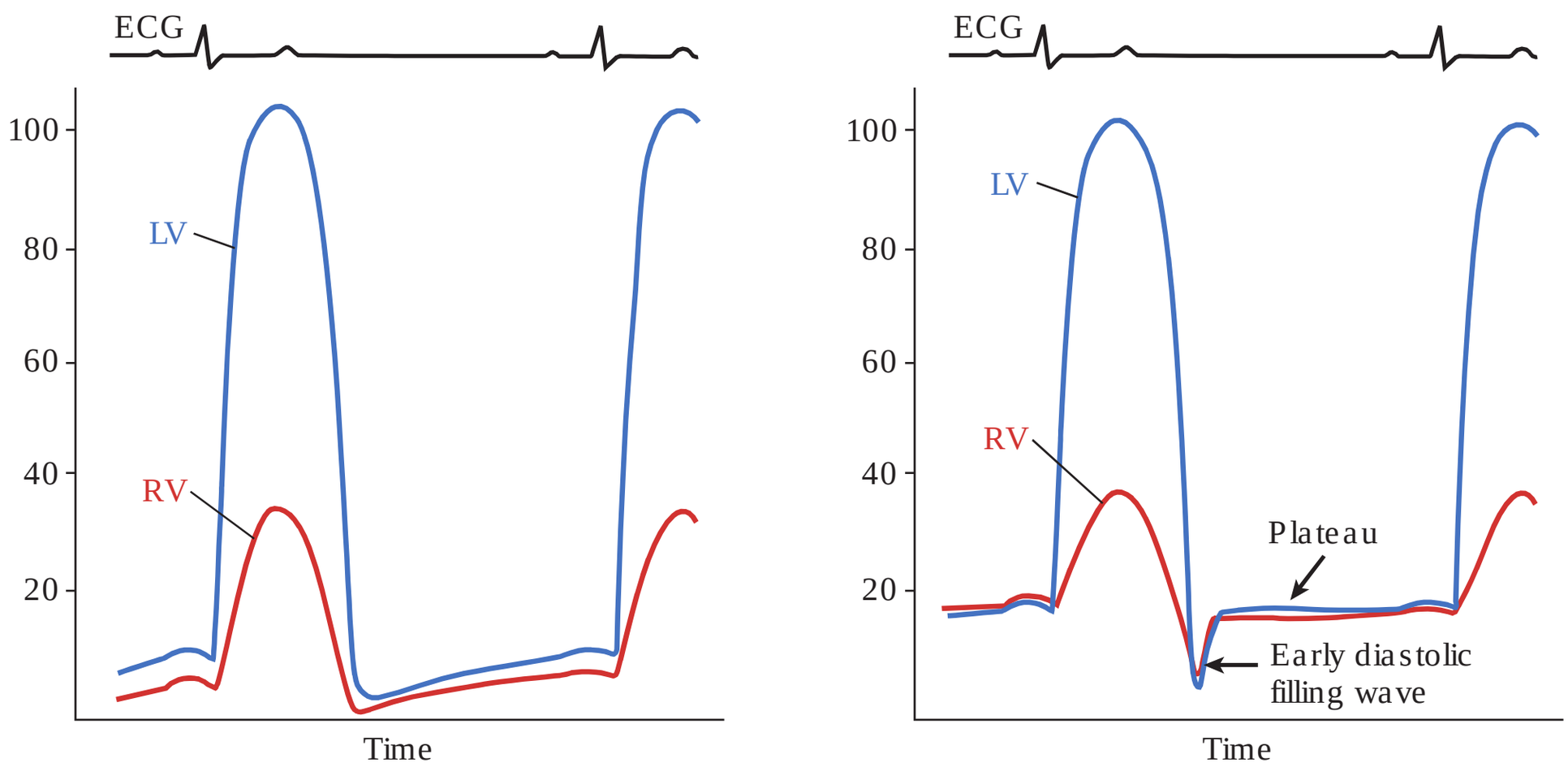

FIGURE 14-7. Schematic tracings of left ventricular (LV) and right ventricular (RV) pressures in a normal heart (A) and in constrictive pericarditis (B). In the latter situation, early diastolic ventricular filling abruptly halts as the volume in each ventricle quickly reaches the limit imposed by the constricting pericardium. Throughout most of diastole, the LV and RV pressures are abnormally elevated and equal.

3. A prominent y descent in the right atrial pressure tracing (see Fig. 14-6). After the tricuspid valve opens, the right atrium quickly empties into the RV (and its pressure rapidly falls) during the very brief period before filling is arrested. This is in contrast to cardiac tamponade, in which the external compressive force throughout the cardiac cycle prevents rapid ventricular filling, even in early diastole, such that the y descent is blunted.
4. During the respiratory cycle, there is discordance in the RV and LV systolic pressures (the RV systolic pressure rises with inspiration, while that of the LV declines). This is explained as follows: in normal persons, the negative intrathoracic pressure induced by inspiration causes the systolic pressure of both ventricles to decline slightly. In contrast, in constrictive pericarditis, the heart is isolated from the rest of the thorax by the surrounding rigid shell. In this circumstance, negative intrathoracic pressure induced by inspiration decreases the pressure in the pulmonary veins but not in the left-sided cardiac chambers. This causes a decline in the pressure gradient driving blood back to the left side of the heart from the pulmonary veins, such that left ventricle filling is diminished. Less ventricular filling reduces the stroke volume and results in a lower LV systolic pressure (and is the likely mechanism of pulsus paradoxus in some patients with constrictive pericarditis). Simultaneously, because the two ventricles share a fixed space limited by the rigid pericardium, the reduced LV volume allows the interventricular septum to shift toward the left, which enlarges the RV (this reciprocal behavior is termed ventricular interdependence). The subsequent increase in RV filling augments systolic pressure during inspiration. During expiration, the situation is reversed, with the RV systolic pressure declining and that of the LV increasing.

The clinical and hemodynamic findings of constrictive pericarditis are often similar to those of restrictive cardiomyopathy (see Chapter 10), another uncommon condition. Distinguishing between these two syndromes is important because pericardial constriction is often correctable, whereas most cases of restrictive cardiomyopathy have very limited effective treatments (Table 14-6). An endomyocardial biopsy is sometimes necessary to distinguish between these (the biopsy results are normal in constriction but usually abnormal in restrictive cardiomyopathy; see Chapter 10).

TABLE 14-6 Differences between Constrictive Pericarditis and Restrictive Cardiomyopathy

Feature	Constrictive Pericarditis	Restrictive Cardiomyopathy
Chest radiography		
• Pericardial calcifications	Yes (25%–30% of patients)	Absent
CT or MRI		
• Thickened pericardium	Yes	No
Echocardiography		
• Thickened pericardium	Yes (but difficult to visualize)	No
• Respiratory cycle effect on transvalvular Doppler velocities	Exaggerated variations	Normal
Cardiac catheterization		
• Equalized LV and RV diastolic pressures	Yes	Often, LV > RV
• Elevated PA systolic pressure	Uncommon	Common
• Effect of inspiration on systolic pressures	Discordant : LV↓, RV↑	Concordant: LV↓, RV↓
Endomyocardial biopsy	Normal	Abnormal (e.g., amyloid)

CT, computed tomography; LV, left ventricle; MRI, magnetic resonance imaging; PA, pulmonary artery; RV, right ventricle.

Treatment

The only effective treatment of severe constrictive pericarditis is surgical removal of the pericardium. Symptoms and signs of constriction may not resolve immediately after surgery because of the associated stiffness of the neighboring outer walls of the heart, but subsequent clinical improvement is the rule in patients with otherwise intact cardiac function. The degree of improvement depends on the underlying etiology, with the most favorable outcomes in patients with an idiopathic/post–viral pericarditis origin, and the least favorable benef t when prior radiation therapy is the cause.

SUMMARY

- Acute pericarditis is characterized by three stages: (1) local vasodilation with transudation of protein-poor, cell-free fluid into the pericardial space; (2) increased vascular permeability, with leak of protein into the pericardial space; and (3) leukocyte exudation, initially by neutrophils, followed later by mononuclear cells.
- Acute pericarditis is most often of idiopathic or viral cause and is usually a self-limited illness.
- Common clinical f ndings in acute pericarditis include pleuritic chest pain, fever, pericardial friction rub, and diffuse ST-segment elevation on the ECG, often accompanied by PR-segment depression.
- Treatment of common acute pericarditis (i.e., viral or idiopathic pericarditis) consists of a nonsteroidal anti-inflammatory drug; the addition of colchicine may reduce the frequency of recurrences and shorten the duration of the acute illness.
- Glucocorticoid drugs should not be used as initial therapy for acute pericarditis as they increase the likelihood of recurrences.
- Complications of pericarditis include cardiac tamponade (accumulation of pericardial fluid under high pressure, which compresses the cardiac chambers) and constrictive pericarditis (restricted f lling of the heart because of the surrounding rigid pericardium).
- Distinguishing between constrictive pericarditis and restrictive cardiomyopathy is important because pericardial constriction is often correctable with surgical removal of the pericardium, whereas most cases of restrictive cardiomyopathy have very limited effective treatments.

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Additional Reading

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