

Purulent Pericarditis: Acute Infections and Chronic Complications

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Purulent (or suppurative) pericarditis is defined as an infection of the pericardial space that produces pus that is found on gross examination of the pericardial sac or on tissue microscopy. In most cases, pericardial infection does not produce a purulent effusion. Viral infection, which together with “idiopathic” pericarditis account for 90% of pericarditis cases,¹ rarely produces purulent effusions and is typically self-limited, with only a small effusion that is asymptomatic and resolves spontaneously. In contrast, bacterial infections of the pericardium are relatively uncommon but are much more likely to produce purulent effusions and to proceed to cardiac tamponade and pericardial constriction.^{2,3} Purulent pericarditis occurs almost exclusively as a secondary infection in patients with serious underlying disease, including patients with AIDS and those undergoing hemodialysis, thoracic surgery, and chemotherapy.⁴⁻⁷

Prompt diagnosis is important as purulent pericarditis requires specific therapy targeting the causative agent. However, recognizing purulent pericardial infection in a patient with multiple comorbidities can be clinically challenging. In addition, bacterial pericarditis has a high mortality rate despite appropriate therapy (30%–50%), with the majority of deaths due to cardiac tamponade.^{4,8} This article reviews the structure and function of the pericardium, the etiology of infectious pericarditis with a focus on causes of purulent infections, and the diagnosis and treatment modalities for pericarditis and its potential sequelae.

ANATOMY AND FUNCTION

The pericardial sac is formed by 2 distinct structures: the visceral and parietal pericardium, which are continuous with each other at the attachment of the great vessels to the heart. The visceral component is a single mesothelial cell layer with a submesothelium that is invested directly against the myocardium. The visceral pericardium is thought to form the pericardial fluid, an ultrafiltrate of plasma contained within the potential space separating the visceral and parietal layers. The pericardium normally contains 20 to 50 mL of pericardial fluid, which is drained via the parietal

TAKE HOME POINTS

- Purulent pericarditis is nearly always a complication of another infection, and a high level of suspicion is needed to make the diagnosis.
- In treating suspected bacterial pericarditis, broad-spectrum antibiotics with anaerobic coverage should be used until the microbe is identified.
- Tachycardia is a sensitive but nonspecific sign of pericardial disease that may signal early tamponade physiology.
- Hypotensive patients should be checked for pulsus paradoxus (especially if they have jugular venous distention); if present, an echocardiogram should be obtained.
- A multidisciplinary approach including infectious disease, cardiology, and cardiothoracic surgery is optimal for making the diagnosis of and providing the treatment for complex pericardial infections.

pericardium to the thoracic duct. The parietal component is approximately 1 mm thick and comprises 3 layers: *serosa* comprised of mesothelium; *fibrosa* of dense, wavy collagen fibers and interspersed elastic fibers as well as fibroblasts, mast cells, nerves, blood vessels, and lymphatics; and *epipericardium* of collagen, elastin, and adipose. The epipericardium forms the ligaments that are connected inferiorly to the diaphragm, superiorly to the deep cervical fascia, anteriorly to the manubrium and sternum, and posteriorly to the vertebral column.^{3,9,10} The pericardium is relatively avascular but is well innervated; therefore, inflammation produces severe pain and may trigger vagal-mediated reflexes.²

Although there are many recognized functions of

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Table 1. Microbiology of Infectious Pericarditis

Viral	Anaerobic
HIV	<i>Clostridium</i>
Coxsackievirus A and B	<i>Peptostreptococcus</i>
Epstein-Barr virus	Mycobacterial
Echovirus	Tuberculosis
Influenza	<i>Mycobacterium avium-intracellulare</i> complex
Paramyxovirus (mumps)	Rickettsial
Adenovirus	Typhus
Varicella	Q fever
Bacterial	Fungal
<i>Staphylococcus</i>	<i>Histoplasma</i>
<i>Streptococcus</i>	<i>Candida</i>
<i>Pneumococcus</i>	<i>Coccidioides</i>
Gram-negative bacilli	<i>Blastomyces</i>
<i>Meningococcus</i>	<i>Aspergillus</i>
<i>Gonococcus</i>	Protozoal
<i>Haemophilus influenzae</i>	<i>Toxoplasma gondii</i>
<i>Bordetella pertussis</i>	<i>Entamoeba</i>
<i>Francisella tularensis</i>	<i>Trypanosoma cruzi</i>
<i>Salmonella</i>	Parasitic
<i>Campylobacter</i>	<i>Trichinella</i>
<i>Listeria</i>	<i>Filarioidea</i> (microfilaria)
<i>Legionella</i>	<i>Echinococcus</i>
<i>Mycoplasma</i>	
<i>Nocardia</i>	
<i>Actinomyces</i>	

the pericardium, its removal or congenital absence is well tolerated. The tensile strength of the pericardium is greater than that of the myocardium, and it retracts when incised, suggesting that it is under tension. It maintains the heart in proper position, acts as a barrier to infection, and prevents overdistention of the chambers in response to hypervolemia. Intrapericardial pressure approximates pleural pressure, varying with respiration to aid in venous return and atrial filling. The pericardial fluid decreases friction, disperses gravitational and inertial forces around the heart, and distributes hydrostatic forces, giving uniform stretch of myofibrils to allow Frank-Starling mechanics to operate over a range of pressures.

The pericardium, circumferential myocardial fibers, and a compliant septum together allow for ventricular interdependence. This mechanism mostly affects diastolic interactions and balances output from both ventricles over several cycles based on the volume-pressure relationship. As the pressure in 1 ventricle increases due to volume filling, the compliance of the

other ventricle decreases, restricting filling. An example of ventricular interdependence is the increase in right heart filling with inspiration (negative intrapericardial pressure and increased venous return, with increased pulmonary vascular capacity) evidenced by increased tricuspid and pulmonic valve flow velocities, and simultaneous decreased left heart filling with decreased mitral and aortic valve flow velocities. The opposite dynamics occur with expiration. These volume-pressure effects are exaggerated by hypervolemia and minimized by hypovolemia.

ETIOLOGY OF PURULENT PERICARDITIS

Numerous microbes are capable of causing pericardial infection (Table 1). Viral agents are a commonly identified cause of pericarditis as documented by rising antibody titers, and they probably account for many cases in which a cause is not identified (ie, idiopathic cases). Viral and idiopathic pericarditis account for 90% of cases of acute pericarditis.¹ Enteroviridae (coxsackievirus B), Adenoviridae, Echoviridae, and Retroviridae are usually responsible, and pericardial involvement typically occurs 1 to 3 weeks following a gastrointestinal or upper respiratory tract infection. Viral pericarditis is rarely a primary infection, and typically is “dry” with a rub present; in some cases, a small asymptomatic effusion may develop, which resolves spontaneously.³

Bacterial

Bacterial pericarditis is not typically a primary infection but is almost exclusively a complication from an underlying infection. In the pre-antibiotic era, patients most frequently developed bacterial pericarditis due to pneumonia with empyema, and the most common organism was *Streptococcus pneumoniae*.¹¹ In the antibiotic era, the most common causative organism is *Staphylococcus aureus*.¹² Recent studies have noted a trend toward involvement of more diverse microbes, and anaerobes have been reported as a common cause of pericardial infections.^{13,14} A retrospective study found primary anaerobic infections in 40% of cases and mixed infections (aerobic/anaerobic) in 13%; however, there were no clinical or diagnostic differences between these types of infections.¹³ The current etiologies of bacterial pericarditis include seeding from circulating bacteremia, contiguous intrathoracic source (empyema), penetrating trauma, surgical wounds (sternal osteomyelitis), intracardiac source, esophageal rupture with fistula formation, retropharyngeal abscess, and hepatic/subdiaphragmatic abscess.^{2,4,15}

The recognized risk factors for bacterial pericarditis include advanced age, diabetes mellitus, untreated

infection (eg, pneumonia), extensive burns, an immunosuppressed state, cardiac surgery, thoracic trauma, and a preexisting pericardial effusion (renal failure, congestive heart failure).^{4,6} The risk for pericardial disease in patients with infectious endocarditis was demonstrated by a series of 26 patients with bacterial endocarditis in which 13% of the patients had purulent pericarditis and 20% had a myocardial abscess; the rate of myocardial abscess increased to 36% in those with *S. aureus* infection.¹²

Fungal

Although many fungi are known to cause purulent pericarditis, *Histoplasma* and *Candida* are the most common. Patients who develop illness from infection with these organisms are usually immunosuppressed (eg, leukemia, organ transplant, AIDS, long hospital stay on multiple antibiotics). *H. capsulatum* spores are found in the soil of the Ohio and Mississippi river valleys. The spores may cause pneumonitis when inhaled and may spread hematogenously from the lungs to the mediastinal nodes and reticuloendothelial system until cellular immunity develops. In immunocompetent individuals, this process takes approximately 10 to 14 days and gives a self-limited course. Pericardial disease can occur in an immunosuppressed individual from the primary infection or at a later time from reactivation; the source is typically adjacent mediastinal nodes, although rarely it is from disseminated disease. Approximately 10% of patients clinically infected will develop pericardial disease.^{3,9,16}

C. albicans and *C. tropicalis* are common host flora that can cause infection even in immunocompetent individuals under certain circumstances, such as intravenous drug abuse, indwelling venous catheters (particularly for parenteral nutrition with lipids), thoracic surgery, and prosthetic heart valves. The route is typically hematogenous, intracardiac, or contiguous spread from a surgical site.¹⁰

Tuberculosis

Tuberculosis is estimated to cause 2% to 4% of all admitted cases of pericarditis in the United States and 5% to 6% of cases in which there is pericardial constriction.^{17,18} The reported incidence of pericardial involvement among patients with pulmonary tuberculosis ranges from 1% to 8%; however, evidence of active pulmonary disease is uncommon, with only 11% to 50% of patients with tuberculous pericarditis having positive sputum cultures.^{19,20} Pericardial involvement can occur with a primary infection, reactivation of latent infection, and during appropriate antitubercular therapy. The most common pathway is retrograde

extension via lymphatics from peribronchial and mediastinal nodes; other recognized pathways include hematogenous spread from a distant foci (genitourinary or skeletal) and direct extension from a contiguous source (lymph nodes, lung, pleura, spine).^{3,21}

Four pathologic stages of tuberculous pericarditis have been identified: (1) fibrin deposition with many polymorphonuclear neutrophils and abundant organisms as well as loose granuloma formation; (2) accumulation of serosanguinous effusion with predominating lymphocytes and monocytes; (3) absorption of the effusion, with a reduction in the number of *Mycobacterium tuberculosis* organisms and thickening of the pericardium due to the formation of dense caseating granulomas; and (4) replacement of granulomas by fibrous tissue, which begins to contract. Calcification may occur at any pathologic stage.^{9,19}

HIV Infection

An estimated 6% to 7% of patients with HIV infection experience significant HIV-related cardiac morbidity, and pericardial effusion and myocarditis are the most common.^{22,23} At autopsy, 40% of patients with AIDS have large effusions.²⁴ The annual incidence of pericardial effusion in asymptomatic individuals with advanced HIV infection is 11%.²² In 1 study, approximately 25% of HIV patients with advanced disease had an effusion by echocardiography, and 20% of these effusions were large.²⁵ The majority of patients were asymptomatic, and at follow-up 42% of the effusions had resolved spontaneously.²⁵ In a series of patients requiring intervention for tamponade, the most common underlying disorders were malignancy and HIV.²⁶

Pericardial disease can result from opportunistic infections, medical treatment of HIV infection, and the HIV infection itself. In these immunocompromised patients, one must consider not only viral and bacterial pathogens, but also fungal, mycobacterial, and parasitic (*Toxoplasma gondii*) infections. Noninfectious causes include lymphoma and Kaposi sarcoma. In 1 study, the risk factors associated with moderate-severe pericardial effusion in patients with HIV infection were tuberculosis (odds ratio [OR], 47.2), heart failure (OR, 30.3), other pulmonary infection (OR, 15.0), and Kaposi sarcoma (OR, 8.6).¹⁸ Thus, it is prudent to initiate empiric treatment for tuberculosis in a patient with HIV who is symptomatic with a persistent pericardial effusion until that diagnosis can be confirmed or excluded.²⁷

CLINICAL PRESENTATION

Bacterial pericarditis often is not readily apparent as it is almost exclusively a complication from an

Table 2. Electrocardiography Findings in Pericarditis

Stage	ST Segment	T Waves	PR Segment
I	Elevated	Upright	Depressed or isoelectric
II early	Isoelectric	Upright	Isoelectric or depressed
II late	Isoelectric	Low to flat to inverted	Isoelectric or depressed
III	Isoelectric	Inverted	Isoelectric
IV	Isoelectric	Upright	Isoelectric

underlying condition rather than a primary infection. Comorbidities associated with bacterial pericarditis include renal failure, AIDS, immunosuppression (due to chemotherapy or intrinsic disease), alcoholism, diabetes, preexisting pericardial effusion, and indwelling venous access, particularly if the patient is receiving total parenteral nutrition.^{2,4} Bacterial pericarditis typically presents with fever and chills, chest pain (often with dyspnea), and tachycardia. The presentation is always acute, with fevers occurring at regular intervals and frank rigors. Tachycardia is often due to the febrile response, but it may be an effort to compensate for decreased cardiac output from reduced ventricular filling due to cardiac tamponade. Tamponade can develop rapidly, as an effusion of 500 mL can accumulate over several days. It is important to note that because the pericardium is not typically closed after cardiac surgery, a purulent infection will not result in tamponade, making the diagnosis even more occult in these patients.

Features of the underlying infection also may be present, such as cough with purulent sputum and findings of lung consolidation if pneumonia is the source, or skin findings of injection drug use and a cardiac murmur if bacterial endocarditis is the source.^{3,4} Arsura et al²⁸ found purulent pericarditis confirmed by pericardial fluid analysis or at autopsy in 13% of patients admitted to the intensive care unit with a diagnosis of sepsis. Thus, it is important to maintain a high index of suspicion for pericardial involvement in patients with a septic presentation (fever and hypotension).

The presenting complaint in patients with pericarditis with effusion is usually substernal chest pain, often radiating to the scapular ridges due to the phrenic nerves passing through the anterior pericardium and innervating the trapezius ridges.²⁹ The pain is typically pleuritic and may be relieved by the patient leaning forward, as the inferior portion of the parietal pericardium has more afferent (sensory) innervation than the anterior, posterior, or superior portions. Symptoms caused by compression of adjacent structures as an effusion develops include dyspnea, cough, dysphagia, hiccups, and dysphonia.²⁴ An

evanescent, 3-component pericardial rub (early diastole, late diastole, and systole) is found in approximately one third of pericarditis cases.⁴

The presentation for fungal pericarditis is similar to that of bacterial pericarditis, but the course is slightly slower in terms of effusion accumulation and pericardial thickening and scarring. Unlike with bacterial pericarditis, patients with tuberculous pericarditis have a subacute/chronic course. The onset is insidious, with nonspecific features only until late in the course when tamponade or constriction occurs.

DIAGNOSTIC TESTS

The diagnosis of purulent pericarditis is based on high clinical suspicion from an accurate history and a thorough physical examination and is confirmed with a positive stain or culture of pericardial aspirate. Electrocardiography can suggest the diagnosis. The 5 stages of electrocardiogram (ECG) findings commonly seen with pericarditis were initially based on supposed viral etiologies (Table 2). It is important to remember that patients may present at any stage of the ECG findings. Electrocardiography can help distinguish pericarditis-related chest pain from acute coronary syndrome since ST-segment elevation and PR-segment depression (the atrial counterpart) occurring in multiple coronary artery distributions is unlikely to be due to acute cardiac ischemia/infarction.³⁰ Although atrial arrhythmias, most commonly atrial fibrillation, can be seen with constrictive disease, patients with uncomplicated pericarditis predominantly remain in sinus rhythm and have no significant arrhythmias. When arrhythmias occur, an underlying conductive disease or an associated myocarditis is usually responsible.⁹ The classic example is Lyme carditis, a pancarditis involving all heart layers that can cause a bundle branch block or atrioventricular nodal block.³¹

Chest radiographs should be performed initially for suspected pericardial infections. They may reveal abnormal cardiac/pericardial silhouettes (often described as a water-bottle or flask-shaped appearance on anterior-posterior view), pulmonary infiltrates, pleural effusions (if pneumonia or empyema is the infectious source), or mediastinal irregularities (indicating lymphadenopathy from tuberculosis or fungal disease).⁴

Patients with pericarditis have evidence of systemic inflammation on blood testing, including leukocytosis and an elevated C-reactive protein level and erythrocyte sedimentation rate.⁴ Troponin levels are elevated in 35% to 50% of pericarditis cases (creatinine kinase-MB fraction less often) due to epicardial inflammation and typically return to baseline within 1 to 2 weeks.^{32,33}

The rise in troponin level appears to correlate with the height of the ST-segment elevation but does not necessarily predict an adverse outcome.¹ Serum troponin levels remaining elevated for more than 2 weeks suggests an associated myocarditis, which has a worse prognosis.¹

If purulent pericarditis is being considered, the pericardium must be aspirated to obtain a diagnostic sample for Gram, fungal, and acid-fast stains, white blood cell count, and culture. Biochemical analysis (glucose, protein, lactate dehydrogenase, cholesterol) may be indicated to differentiate a transudative from an exudative effusion and assist in identifying underlying causes of the pericardial effusion.¹ A diagnosis of tuberculous pericarditis can be made by acid-fast stain or culture of pericardial fluid, although such testing is positive in only 15% of patients clinically diagnosed with tuberculous pericarditis. The yield from culture can be increased by using Kirchner media rather than standard culture media.³ Performing polymerase chain reaction (PCR) and adenosine deaminase activity (ADA) assays on the fluid will also increase the diagnostic sensitivity for tuberculous pericarditis.²¹ PCR has a sensitivity of 50%, while ADA has a sensitivity of 90% and a specificity of 74%.^{34,35} Pericardial biopsy is thought to have the highest diagnostic yield, with a sensitivity of up to 64% and a specificity of 100%, and is dependent on the stage of disease and the amount of tissue obtained.³⁶ Purified protein derivative testing is not necessarily helpful since patients may be anergic or reactive but have no pericardial involvement.

TREATMENT

Nonsteroidal anti-inflammatory drugs (NSAIDs) are commonly used to treat viral/idiopathic pericarditis. Indomethacin should be avoided because of its toxicity, while ibuprofen is the recommended NSAID for the treatment of pericarditis.³⁷

Optimal medical therapy for bacterial pericarditis is immediate administration of appropriate broad-spectrum empiric agents such as an antistaphylococcal agent plus an aminoglycoside, typically followed by 4 weeks of a bactericidal drug targeting the pathogen with the microbe's sensitivity known.^{38,39} Intravenous therapy should continue until fever and leukocytosis resolve. The recommended empiric treatment of a critically ill patient is vancomycin, a third-generation cephalosporin, and a fluoroquinolone.⁴ When selecting drug regimens for individual patients, local patterns of microbial disease and antibiotic resistance as well as specific host factors such as recent antibiotic use or immunosuppression should be taken into

consideration.^{38,39} Because antibiotics penetrate well into the pericardial sac, intrapericardial instillation is not necessary.

Surgical pericardial drainage is necessary to eradicate the infection and prevent constriction (a late complication with a variable time course). The usual method of surgical drainage is subxiphoid pericardiectomy, which creates a window in the pericardium to prevent reaccumulation of an effusion.⁴⁰ An alternative method is the use of video-assisted thoracoscopic surgery in place of open thoracotomy.⁴¹ For patients unable to tolerate these procedures, intrapericardial catheter placement is advised. Catheter drainage is an older therapy that has had a resurgence with recent studies demonstrating its effectiveness and safety.^{42,43} Streptokinase and streptodornase can be instilled and allowed to dwell for 1 hour, then flushed or allowed to drain for the next 3 hours; this process can be repeated until there is resolution of the collection.⁴³ These substances aid in the drainage of clotted blood and thickened nucleoproteins (pus) and significantly improve resolution of loculated effusions. This procedure prevents the development of constrictive disease, does not affect systemic coagulation studies, and is not associated with increased bleeding events.^{43–45}

Therapy for pericardial fungal infections includes systemic antifungal therapy with amphotericin B for 4 to 6 weeks and open drainage/pericardial resection.^{3,9,46} Treatment for tuberculous pericarditis consists of 4-drug therapy (isoniazid, rifampin, ethambutol, and pyrazinamide) for at least 1 month, followed by 2-drug therapy (isoniazid and rifampin) for 6 months to 2 years.^{4,47,48} Careful follow-up is needed to monitor for signs of constriction, and some recommend pericardiectomy as initial therapy due to the high percentage (30%–50%) of patients who develop constriction by 4 months despite adequate treatment.^{3,21} Steroids should be given in the first month as they have been shown to significantly decrease mortality and improve patient symptoms; however, they have little effect on pericardial constriction.^{19,21}

COMPLICATIONS

Cardiac Tamponade

Cardiac tamponade is a true emergency that occurs when accumulation of fluid with the pericardium causes pericardial pressure to exceed cardiac chamber diastolic pressure, preventing cardiac filling. Three factors determine the clinical presentation: volume of fluid, rate at which the fluid accumulates, and pericardial compliance. The pericardial pressure-volume curve is nonlinear, with the initial flat section reflecting

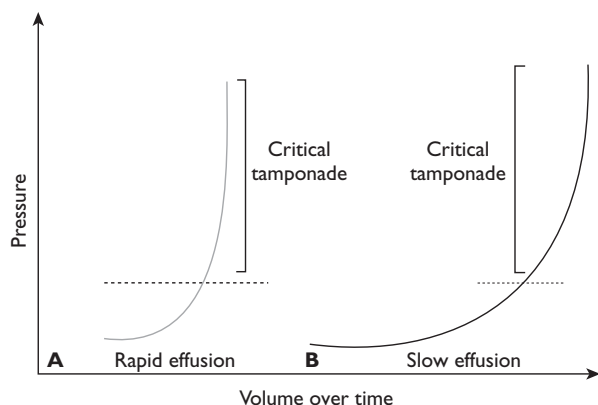


Figure 1. Pericardial pressure-volume curves in which the volume increases slowly or rapidly over time. **(A)** Rapidly increasing pericardial fluid reaches the limit of the pericardial reserve volume (the initial flat segment) and then quickly exceeds the limit of parietal pericardial stretch, causing a steep rise in pressure. **(B)** With a slower rate of pericardial filling, the pericardium has an opportunity to stretch and for compensatory mechanisms to become activated. (Adapted with permission from Spodick DH. Acute cardiac tamponade. *N Engl J Med* 2003;349:685. Copyright © 2003 Massachusetts Medical Society. All rights reserved.)

the pericardial reserve volume, which is made up of the recesses and sinuses of the sac (**Figure 1**).^{10,49} The gradual up-slope of the curve is due to the stretching of the elastic fibers and the straightening of the wavy collagen fibers of the pericardium. The steep slope is due to the exhaustion of these mechanisms, and any further increase in volume causes severe increases in pressure, which are transduced as compressive forces on the heart. If the fluid accumulates rapidly or if the pericardium is pathologically stiff, then relatively small amounts of fluid can result in marked elevations in pressure. In contrast, if the effusion grows slowly, the pericardium can gradually stretch to accommodate the volume, causing the pressure-volume curve to shift to the right.

Clinical features. Symptoms of tamponade include dyspnea, tachypnea, and fatigue, while common signs include tachycardia, jugular venous distension, a quiet precordium, hypotension, and *pulsus paradoxus*. Another notable finding is the Bamberger-Pins-Ewart sign, which is dullness to percussion at the left scapular angle with bronchial breath sounds due to compressive atelectasis from the effusion. Although a pericardial rub typically disappears when an effusion develops, a rub caused by pericardial-pleural friction may still be present (typically on inspiration). The elevated pericardial pressure resulting in elevated right atrial and venous pressure causes a characteristic jugular venous

waveform lacking the Y descent. These changes result from decreased right atrial emptying due to impaired ventricular expansion and filling.

The description of *pulsus paradoxus* by Kussmaul in 1873 was of the “paradox” of not palpating a pulse despite detecting a heart beat during inspiration. Since then, it has been determined that there is a consistent inspiratory decrease in left ventricular stroke volume (7%) and arterial pressure (3%) in normal patients.^{9,50} These effects are due to ventricular interdependence but can be accentuated in pericardial disease, leading to the suggested renaming of the finding as *pulsus exaggeratus*. *Pulsus paradoxus* (inspiratory drop in systolic blood pressure of 10% or 10 mm Hg) is thought to be pathognomonic of tamponade, but there can be false positives as well as false negatives. A pulsus may be present without tamponade in severe chronic obstructive pulmonary disease/asthma or a large pulmonary embolism; exaggeration of intrathoracic pressures is believed to be responsible.^{3,10,51,52} Tamponade may be present without a pulsus in hypovolemia (ie, low-pressure tamponade), as minimal increases in pericardial pressure can limit right-sided filling without causing an effect on left-sided function if blood volume/preload is already diminished. Conditions that limit ventricular interdependence and therefore limit the formation of a pulsus include atrial septal defect; right ventricular hypertrophy, which causes a thick, non-compliant septum; and aortic regurgitation, congestive heart failure, and severe left ventricular hypertrophy, which increase left ventricular end diastolic pressure.^{3,10}

Diagnostic tests. Although cardiac tamponade is a clinical diagnosis, echocardiography and right heart catheterization can assist in the diagnosis. Echocardiography is a valuable noninvasive means to evaluate a patient for tamponade, and it should be performed without delay when tamponade is suspected. Echocardiography can show the presence and size of an effusion, graded as small (posterior only), moderate (anterior and posterior but < 1 cm), or large (> 1 cm), and help determine its hemodynamic consequences (**Figure 2**). Except in rare cases of loculated effusions, tamponade is caused by a circumferential effusion.^{2,51,52} Diastolic collapse of the free walls of the right atrium or right ventricle point to the presence of tamponade.⁵³ Right atrial diastolic collapse is more sensitive (92%) but less specific for tamponade than right ventricular diastolic collapse (approaching 100% specificity). Although left atrial diastolic collapse has only a 25% sensitivity, it is virtually pathognomonic.^{3,24,51–53} The absence of inferior vena cava plethora and normal respiratory variations in caliber suggests that right atrial

pressure is normal and makes the diagnosis of tamponade unlikely.⁵¹⁻⁵³

Like the pulsus, flow velocity paradoxus, the immediate marked decrease in transmitral (and increase in transtricuspid) Doppler flow with inspiration, is an accentuation of normal physiology that occurs with tamponade. Because the intrapericardial volume is fixed, the right and left side fill at the expense of each other. During inspiration when right-sided filling increases, there is increased flow across the tricuspid valve but a drastic drop in left-sided filling and therefore a marked decrease in flow across the mitral valve; these effects are reversed during expiration.^{52,53}

On right heart catheterization, pulmonary artery wedge pressure and atrial and ventricular end-diastolic pressures are elevated and equalized (within 5 mm Hg) in tamponade.^{51,53} These values reflect the elevated intrapericardial pressure. Other conditions that can cause diastolic equalization of pressure include restrictive cardiomyopathy, atrial septal defect, hyperinflated lungs, severe hypovolemia (all pressures low), and end-stage dilated cardiomyopathy (all pressures high).

Neither chest radiography nor electrocardiography is helpful in the diagnosis of cardiac tamponade. The pericardial silhouette will be normal acutely, requiring approximately 250 mL of fluid to gather before it assumes a globular shape. Also, this finding can be present with effusions that do not cause any pathologic effects. Likewise, findings suggestive of an effusion on ECG, such as low voltages due to insulating effects and electrical alternans, are not helpful in diagnosing tamponade since they indicate that a large effusion may be present but do not indicate tamponade physiology.

Treatment. There is no effective medical therapy for cardiac tamponade, although intravenous fluids may be of transient benefit if the patient is hypovolemic.^{2,51} Inotropic agents do not add to the intense endogenous adrenergic stimulation since the heart rate and cardiac contractility will already be at maximum. For a hemodynamically stable patient, controlled drainage of the effusion under guided imaging is preferable. This procedure can be done with echocardiography or in the cardiac catheterization lab under fluoroscopy while monitoring right and left heart pressures. A catheter is usually left in the pericardium to continue draining any recurrent effusion; surgical drainage employing either a subxiphoid pericardial window or an open thoracotomy is also an option.

If the patient is unstable, immediate relief of the tamponade by percutaneous subxiphoid needle aspiration is required. The patient should be positioned upright at 45 degrees in order to have gravity assist the fluid into a

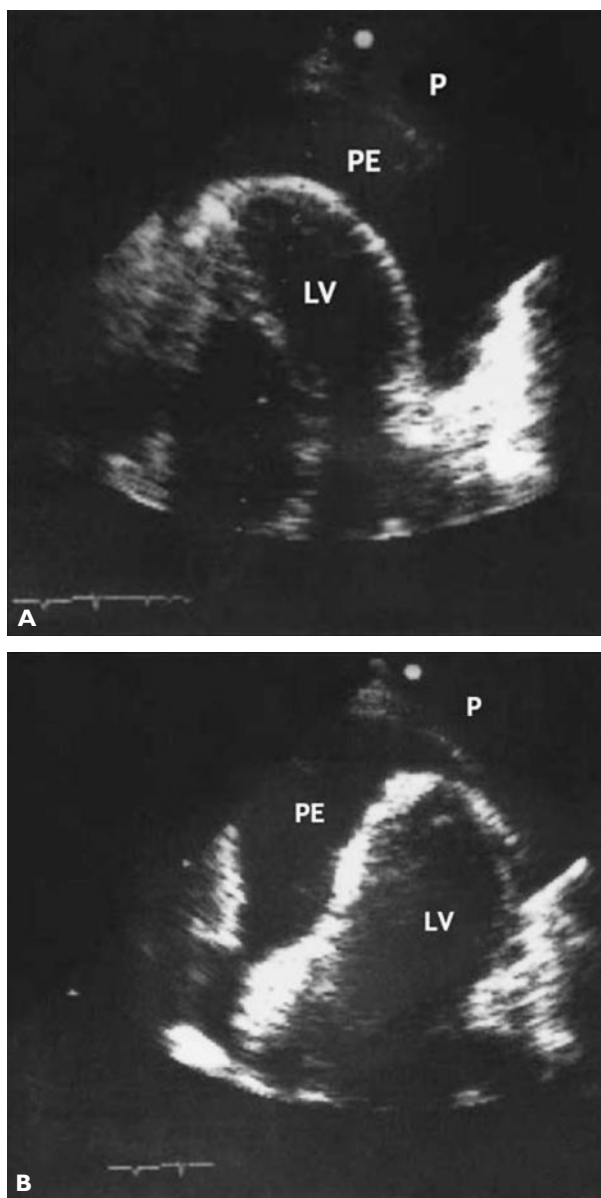


Figure 2. Swinging of the heart with a large pericardial effusion (PE) causing electrical alternation and consequent tamponade. Apical 4-chamber 2-dimensional echocardiograms show the extremes of oscillation and the resultant effect on the QRS complex. (A) The heart swings to the right, and lead II shows a small QRS complex. (B) The heart swings to the left, and the QRS complex is larger. LV = left ventricle; P = pericardium. (Adapted with permission from Spodick DH. Acute cardiac tamponade. *N Engl J Med* 2003;349:687. Copyright © 2003 Massachusetts Medical Society. All rights reserved.)

dependent position anteriorly. A precordial lead can be clipped to the metal hub of the needle with a continuous ECG strip running during aspiration; epicardial contact is indicated by ST-segment elevation or premature

ventricular contraction. Potential serious complications include ventricular puncture, coronary artery laceration, and pneumothorax.

Constriction

Pathophysiology and clinical features. Pericardial constriction has numerous etiologies, with postinfection (bacterial, tuberculous, fungal), postradiation, and chronic inflammation due to autoimmune and collagen-vascular disease being the most common. The result of each is thickening and scarring of the pericardial layers, which become adherent, obliterating the pericardial space.⁵⁴ The fibrotic encasement causes a fixed diastolic chamber volume with impaired expansion and isolation of the cardiac chambers from intrathoracic pressure changes. Normally, the majority of ventricular filling occurs in phase 2 (rapid filling) of diastole, with up to 20% occurring during phase 4 (atrial contraction); increasing heart rate shortens diastole, thereby decreasing filling.^{2,3,10} With constriction, elevated atrial pressures cause increased ventricular filling (75%) in the first phase of diastole, which is then halted abruptly by mid diastole, and increasing heart rate actually improves cardiac output since very little filling occurs in the shortened late diastole. With the abrupt cessation of filling, a “knock” is produced in 30% to 70% of patients; it is a loud diastolic sound heard 0.06 to 0.12 seconds after S₂, but of higher frequency than S₃.^{2,3}

In constrictive pericarditis, respiratory pressure variations are transmitted to other intrathoracic structures (vena cava, pulmonary vasculature) but not to the heart. Inspiration reduces the pressure gradient between the pulmonary veins and the left heart, resulting in decreased diastolic flow and ventricular filling; based on accentuated ventricular interdependence, the septum shifts to the left allowing a simultaneous increase in right ventricular filling. The opposite effects are seen with expiration. In pure constrictive pericarditis, the pulsus is usually less than 10 mm Hg, and if greater, it suggests concomitant tamponade (effusive-constrictive pericarditis).⁵⁴

The onset of constrictive pericarditis is typically insidious, with symptoms developing from weeks to decades after the inciting event. Peripheral edema, abdominal swelling (from hepatomegaly or ascites), dyspnea, and orthopnea are common initial complaints, which can cause constrictive pericarditis to be confused with intrinsic liver disease.³³ Physical examination reveals elevated jugular venous pressure (JVP) in 96% of patients, and Kussmaul’s sign (paradoxical increase in JVP with inspiration due to the right atrium’s inability to accommodate the increased venous return) may be

present.^{54,55} However, Kussmaul’s sign is not specific for constriction and may be seen in any condition with elevated right-heart pressures, including right-ventricular infarct, pulmonary hypertension, tricuspid stenosis, and restrictive cardiomyopathy. Early cessation of diastolic filling produces Friedreich’s sign (a rapid Y descent of the JVP) and was seen in 94% of cases in 1 series.⁵⁵ A dampened apical impulse and a pericardial knock more prominent with squatting but attenuated by nitroglycerin are also common findings.^{3,10,54} Pulsatile hepatomegaly with ascites was found in 70% of patients with constrictive pericarditis in 1 study, but there are differences in the liver function tests and ascitic fluid analysis of these patients with passive congestion compared with those of cirrhotic patients.⁵⁶

Diagnostic tests. ECG findings include low voltages (60%) and atrial fibrillation in the late stages (25%), although these findings are insensitive and nonspecific.⁵⁴ Diagnosis can be made by computed tomography or magnetic resonance imaging, which demonstrate a pericardial thickness of greater than 4 mm, sometimes with calcifications.^{2,3,50} However, there may be focal disease only, and relying on these modalities can miss a certain percentage of cases. Echocardiography can be useful in evaluating for constriction, with transthoracic echocardiography being superior to transthoracic echocardiography in detecting pericardial thickening.⁵⁷ Other echocardiographic findings include preserved systolic function with rapid diastolic filling causing exaggerated posterior wall and septal motion (septal bounce), early closure of the mitral valve, and premature opening of the tricuspid valve.^{9,57} Restrictive cardiomyopathy due to amyloidosis, sarcoidosis, hemochromatosis, glycogen storage diseases, and endomyocardial elastosis may have a clinical presentation and echocardiographic abnormalities similar to constrictive pericarditis, and differentiating among these entities remains a challenge for cardiologists (short of sending a patient for a thoracotomy).⁵⁷

Cardiac catheterization also can be used to help make the diagnosis, but many of the findings with restrictive cardiomyopathy overlap. Right atrial pressure tracings show the typical M or W pattern formed by the prominent Y descent.^{3,58} Diastolic pressures are elevated and approximately equal in all 4 chambers, with simultaneous ventricular tracings giving a characteristic dip and plateau pattern (square root sign); right ventricular end-diastolic pressure has been found to be at least one third of right ventricular systolic pressure in 95% of constrictive pericarditis cases.⁵⁸ If all chamber diastolic pressures are low and there is clinical suspicion of constrictive pericarditis, a rapid infusion of

1 L of saline may be given to identify occult disease; in a normal patient, the pressures should rise and separate, but with constrictive pericarditis they remain equal as they rise.

Treatment. Medical therapy using diuretics may be attempted initially, but most patients will require pericardiectomy as definitive therapy. Operative mortality is based on New York Heart Association functional class status, illustrating the importance of making an early diagnosis.^{54,55}

CONCLUSION

Purulent pericarditis should be suspected in ill patients with thoracic infections. Patients will often be febrile and tachycardic. If hypotension is present with jugular venous distention, the patient should be examined for a pulsus paradoxus and an echocardiogram should be obtained. Along with supportive care, broad-spectrum antibiotics with anaerobic coverage should be administered until the microbe and sensitivities are determined. Optimal care of these complicated infections requires a multidisciplinary approach. **HP**

**Test your knowledge and
comprehension of this article with the
Clinical Review Quiz on page 18.**

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