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Pericardiocentesis

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Pericardiocentesis is an important and potentially life-saving procedure performed in the critical care setting. It is not carried out with enough frequency, however, to allow most physicians to master the procedure. This chapter reviews the indications for emergent and urgent pericardiocentesis, summarizes the pathobiology of pericardial effusions, and provides a step-by-step approach to pericardiocentesis, including management of patients after the procedure.

Indications for Pericardiocentesis

The initial management of a patient with known or suspected pericardial effusion is largely determined by overall clinical status. In the absence of hemodynamic instability or suspected purulent bacterial pericarditis, there is no need for emergent or urgent pericardiocentesis. It may, however, be performed for diagnostic purposes. A thorough noninvasive workup should be completed before consideration of an invasive diagnostic procedure [1]. Whenever possible, elective pericardiocentesis should be performed using ultrasonography or fluoroscopic guidance.

In contrast, the management of hemodynamically compromised patients requires *emergent* removal of pericardial fluid to restore adequate ventricular filling (pre-load) and hasten clinical stabilization. The exact method and timing of pericardiocentesis is ultimately dictated by the patient's overall degree of instability. Patients with hypotension unresponsive to fluid resuscitation and vasopressor support require immediate, often unguided (blind), pericardiocentesis. In this setting, there are no absolute contraindications to the procedure, and it should therefore be performed without delay at the patient's bedside.

Urgent pericardiocentesis is indicated for patients who are initially hypotensive but respond quickly to aggressive fluid resuscitation. The procedure should be performed within several hours of presentation while careful monitoring and hemodynamic support continue. As in elective circumstances, pericardiocentesis in these patients should be undertaken with appropriate visual guidance, the method of which depends on the physician's expertise and resources. The modalities used most commonly are ultrasonography, echocardiography, and fluoroscopy.

Three additional points must be stressed regarding patients undergoing expedited pericardiocentesis. First, coagulation parameters—prothrombin time activated, partial thromboplastin time, and platelet count—should be checked and, when possible, quickly normalized prior to the procedure. Second, some critical care authorities advocate performance of all pericardiocentesis procedures in the catheterization laboratory with concomitant right heart pressure monitoring to document efficacy of the procedure and to exclude a constrictive element of pericardial disease (see Chapter 33) [2]. The authors support this approach; however, excessive delays because of scheduling dif- ficulties must be avoided. Finally, efforts to assure a cooperative and stationary patient during the procedure greatly facilitate the performance, safety, and success of pericardiocentesis.

The clinical presentation of hemodynamically significant pericardial effusions varies widely among patients. A comprehensive understanding requires knowledge of normal pericardial anatomy and physiology.

Anatomy

The pericardium is a membranous structure with two layers separated by a small potential space. The *visceral* pericardium is closely but loosely adherent to the epicardial surface. It is a monolayer of mesothelial cells and attaches to the epicardium by a loose collection of small blood vessels, lymphatics, and connective tissue. The *parietal* pericardium is a fibrous structure that defines the outer membrane: Its inner surface is also composed of a monolayer of mesothelial cells. The remainder of the parietal pericardium consists of a dense network of connective tissue that is relatively nondistendible; therefore, it defines the dimensions and shape of the pericardium [3].

Further anatomic definition of the pericardium is derived from multiple attachments of the parietal pericardium in the thorax. Superiorly, the fibrous parietal pericardium attaches to the ascending aorta just below the arch. The inferior portion adheres strongly to the fibrous center of the diaphragm on which it rests. Anteriorly, the outer membrane is anchored to the sternum and costal cartilages by ligaments, as well as by a less-organized collection of connective tissue. The posterior margin of the parietal pericardium abuts the esophagus and pleural sacs; here, the visceral pericardium is absent and the parietal pericardium attaches directly to the epicardium at the borders of the entrance of the inferior and superior vena cavae and pulmonary veins [4]. Beyond providing stability, these multiple attachments also limit the inherent elasticity and distensibility of the pericardium.

This complex anatomic arrangement provides an anchor for the contracting myocardium and results in a small space between the visceral and parietal layers (pericardial space). The pericardial space or sac usually contains a small volume (15 to 50 mL) of clear, serous fluid that is chemically similar to a plasma ultrafiltrate [5,6]. The mechanism responsible for the production of pericardial fluid is not well understood. A homeostasis usually exists between new production of pericardial fluid and its drainage into the venous circulation via lymphatics.

The major determinant of when and how pericardial effusions come to clinical attention is directly related to the speed at which they develop. Effusions that collect rapidly (over minutes to hours) may cause hemodynamic compromise with volumes of 250 mL or less. These effusions are usually located posteriorly and are often difficult to detect without echocardiography. In contrast, effusions developing slowly (over days to weeks) allow for hypertrophy and distention (stretch) of the fibrous parietal membrane. Volumes of 2,000 mL or greater may accumulate without significant hemodynamic compromise. These patients may present with symptoms owing to compression of adjacent thoracic structures, such as cough, dyspnea, dysphagia, or early satiety. Three other clinical conditions promote hemodynamic compromise, even in the absence of large pericardial effusions: intravascular hypovolemia, impaired ventricular systolic function, and ventricular

hypertrophy with decreased elasticity of the myocardium (diastolic dysfunction).

Procedure

Since the first blind or closed pericardiocentesis in 1840 [7], several different approaches have been described [8]. These approaches have varied considerably, particularly in the needle apparatus entry site. Marfan described the subcostal approach in 1911 [9], which then became the standard approach for unguided pericardiocentesis.

The advent of clinically applicable ultrasonography has opened a new chapter in diagnostic and therapeutic approaches to pericardial disease, allowing clinicians to quantitate and localize pericardial effusions quickly and noninvasively [10,11]. Work by Callahan and colleagues at the Mayo Clinic established the efficacy and safety of two-dimensional echocardiography to guide pericardiocentesis [12,13]. This has resulted in two major trends in clinical practice: First, twodimensional echocardiography is commonly used to guide pericardiocentesis. Second, approaches other than the subxiphoid method have been investigated owing to the ability to clearly define the anatomy (location and volume) of each patient's effusion [8,12,13]. Typically, a four-chamber view of the heart is obtained by positioning the transducer at the apex. After insertion of the pericardiocentesis needle (described later), appropriate positioning within the pericardial space can be confirmed by injecting 5 mL of agitated saline (contrast). Echocardiography can also be used to reposition the needle safely if fluid return is suboptimal. Standard fluoroscopy can be used to confirm needle and catheter positioning within the pericardial space.

Formulas for quantitating the amount of pericardial fluid by echocardiographic or fluoroscopic means have not been established. As a rule, however, an effusion of moderate size (at least 250 mL) is required for percutaneous pericardiocentesis.

Regardless of whether echocardiography or another guidance method is used, the subxiphoid approach remains the standard of practice. The materials required for bedside pericardiocentesis are listed in Table 8-1 (Fig. 8-1). Table 8-2 (Fig. 8-2) lists the materials required for simultaneous placement of an intrapericardial drainage catheter. The materials are available in prepackaged kits or individually. The authors do not have a preference; the key to success is immediate availability of the necessary materials.

Table 8-1. Materials for Pericardiocentesis

Fig. 8-1. Materials required for pericardiocentesis (clockwise from upper left): 1% lidocaine solution, suture material, 10-mL syringe with 25-gauge needle, 10-mL syringe with 22-gauge needle, No. 11 blade, 18-gauge 8-cm thin-walled needle, 20-mL syringe, 30-mL syringe, alligator clip, hemostat, three red-top tubes, two purple-top tubes, culture bottles, scissors.

Table 8-2. Materials for Intrapericardial Catheter

Fig. 8-2. Materials required for intrapericardial catheter placement and drainage (clockwise from lower left): Teflon-coated flexible 0.035- inch J-curved guidewire, 8-Fr dilator, 6.3-Fr dilator, 8-Fr catheter with end and side holes (35-cm flexible pigtail catheter not shown), threeway stopcock, 500-mL sterile collecting bag and tubing, suture material.

While the patient is being prepared for emergent or urgent pericardiocentesis, it is imperative that aggressive resuscitation measures are undertaken. Two large-bore peripheral intravenous lines should be placed for infusion of isotonic saline or colloid solutions. The use of inotropic agents and other vasoactive drugs (vasopressors) remains controversial [14,15 and 16], but when fluid resuscitation alone is inadequate, their use should be strongly considered.

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The subxiphoid approach for pericardiocentesis is as follows:

1. *Patient preparation.* Assist the patient in assuming a comfortable supine position with the head of the bed elevated to approximately 45 degrees from the horizontal plane. It is important for the patient to maintain this position during the procedure. Extremely dyspneic patients may need to be positioned fully upright, with a wedge if necessary. Elevation of the thorax allows free-flowing effusions to collect inferiorly and anteriorly, sites that are safest and easiest to access using the subxiphoid approach. The patient's bed should be placed at a comfortable height for the physician performing the procedure.
2. *Needle entry site selection.* Locate the patient's xiphoid process and the border of the left costal margin using inspection and careful palpation. The needle entry site should be 0.5 cm to the (patient's) left of the xiphoid process and 0.5 to 1.0 cm inferior to the costal margin (Fig. 8-3). It is essential that the surface anatomy be accurately defined before proceeding further. It is helpful to estimate (by palpation) the distance between the skin surface and the posterior margin of the bony thorax: This helps guide subsequent needle insertion. The usual distance is 1.0 to 2.5 cm, increasing with obesity or protuberance of the abdomen.

Fig. 8-3. Selected locations for pericardiocentesis. In most cases, the subxiphoid approach (1 to 3) is preferred. (From Spodick DH: *Acute Pericarditis.* New York, Grune & Stratton, 1959, with permission.)

3. *Site preparation.* Strict sterile techniques must be maintained at all times in preparation of the needle entry site. Prepare a wide area in the subxiphoid region and lower thorax with a povidone-iodine solution and drape the field with sterile towels, leaving exposed the subxiphoid region. Raise a 1- to 2-cm subcutaneous wheal by infiltrating the needle entry site with 1% lidocaine solution (without epinephrine). Incise the skin with a No. 11 blade at the selected site after achieving adequate local anesthesia: This facilitates needle entry, which is at times difficult because of the absence of a bevel on the Teflon needle apparatus.

4. *Insertion of the needle apparatus.* Place the needle apparatus in the dominant hand (right-handed operators should stand to the patient's right and left-handed operators to the left) and insert it in the subxiphoid incision. The angle of entry (with the skin) should be approximately 45 degrees. Direct the needle tip superiorly, aiming for the patient's left shoulder. Continue to advance the needle posteriorly while alternating between aspiration and injection of lidocaine, until the tip has passed just beyond the posterior border of the bony thorax (Fig. 8-4). The posterior border usually lies within 2.5 cm of the skin surface. If the needle tip contacts the bony thorax, inject lidocaine after aspirating to clear the needle tip and anesthetize the periosteum. Then, walk the needle behind the posterior (costal) margin.

Fig. 8-4. Insertion of the needle apparatus. After the subxiphoid region and lower thorax are prepared and adequate local anesthesia is given, the pericardiocentesis needle is inserted in the subxiphoid incision. The angle of entry (with the skin) should be approximately 45 degrees. The needle tip should be directed superiorly, toward the patient's left shoulder.

5. *Needle direction.* Reduce the angle of contact between the needle and skin to 15 degrees once the tip has passed the posterior margin of the bony thorax: This will be the angle of approach to the pericardium; the needle tip, however, should

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still be directed toward the patient's left shoulder. A 15-degree angle is used regardless of the height of the patient's thorax (whether at 45 degrees or sitting upright) (Fig. 8-5).

Fig. 8-5. Needle direction. The needle tip should be reduced to 15 degrees once the posterior margin of the bony thorax has been passed. Needle advancement: The needle is advanced toward the left shoulder slowly while alternating between aspiration and injection. A “give” is felt, and fluid is aspirated when the pericardial space is entered.

6. *Needle advancement.* Advance the needle slowly while alternating between aspiration of the syringe and injection of 1% lidocaine solution. If electrocardiographic guidance is used, apply the sterile alligator clip to the needle hub, being certain not to occlude the needle's lumen. Obtain a baseline lead V tracing and monitor a continuous tracing for the presence of ST-segment elevation or premature ventricular contractions (evidence of epicardial contact) as the needle is advanced. Advance the needle along this extrapleural path until either

   a. A “give” is felt, and fluid is aspirated from the pericardial space (usually 6.0 to 7.5 cm from the skin) (Fig. 8-6). Some patients may experience a vasovagal response at this point and require atropine intravenously to increase their blood pressure and heart rate.

   Fig. 8-6. Placement technique. Holding the needle in place, a Teflon-coated, 0.035-in. guidewire is advanced into the pericardial space. The needle is then removed. After a series of skin dilations, an 8-Fr, 35-cm flexible pigtail catheter is placed over the guidewire into the pericardial space. Passage of dilators and the pigtail catheter is facilitated by a gentle clockwise/counterclockwise motion.

   b. ST-segment elevation or premature ventricular contractions are observed on the electrocardiographic lead V tracing when the needle tip contacts the epicardium. If ST-segment elevation or premature ventricular complexes occur, immediately (and carefully) withdraw the needle toward the skin surface while aspirating. Avoid any lateral motion, which could damage the epicardial vessels. Completely withdraw the needle if no fluid is obtained during the initial repositioning.

The patient's hemodynamic status should improve promptly with removal of sufficient fluid. Successful relief of tamponade is supported by (a) a fall of intrapericardial pressure to levels between -3 and +3 mm Hg, (b) a fall in right atrial pressure and a separation between right and left ventricular diastolic pressures, (c) augmentation of cardiac output, (d) increased systemic blood pressure, and (e) reduced pulsus paradoxus to physiologic levels (10 mm Hg or less). An improvement may be observed after removal of the first 50 to 100 mL of fluid. If the right atrial pressure remains elevated after fluid removal, an effusive-constrictive process should be considered. The diagnostic studies performed on pericardial fluid are outlined in Table 8-3. Several options exist for continued drainage of the pericardial space. The simplest approach is to use largevolume syringes and aspirate the fluid by hand. This approach is not always practical (i.e., in large-volume effusions), however, and manipulation of the needle apparatus may cause myocardial trauma. Alternatively, some pericardiocentesis kits include materials and instructions for a catheter-over-needle technique for inserting a pericardial drain. Finally, the Seldinger technique may be used to place an indwelling pericardial drain.

Table 8-3. Diagnostic Studies Performed on Pericardial Fluid

7. *Placement technique.* Create a track for the catheter by passing a 6-Fr dilator over a firmly held guidewire. After removing the dilator, use the same technique to pass an 8-Fr dilator. Then advance an 8-Fr flexible pigtail catheter over the guidewire into the pericardial space. Remove the guidewire. Passage of the dilators is facilitated by use of a torquing (clockwise/counterclockwise) motion. A wider incision at the base of the guidewire may be required to pass the dilators. Proper positioning of the catheter using radiography, fluoroscopy, or bedside echocardiography can be used to facilitate fluid drainage.

8. *Drainage system* [17,18,19 and 20]. Attach a three-way stopcock to the intrapericardial catheter and close the system by attaching the stopcock to the sterile collecting bag with the connecting

tubing. The catheter may also be connected to a transducer, allowing intrapericardial pressure monitoring. The system may be secured as follows:

   a. Suture the pigtail catheter to the skin, making sure the lumen is not compressed. Cover the entry site with a sterile gauze and dressing.

   b. Secure the drainage bag (or bottle) using tape at a level approximately 35 to 50 cm below the level of the heart. This system may be left in place for 48 to 72 hours. Echocardiography or fluoroscopic guidance may be used to reposition the pigtail catheter, facilitating complete drainage of existing pericardial fluid.

   The catheter should be flushed every 4 to 6 hours using 10 to 15 cc of normal saline solution.

Short-Term and Long-Term Management

After pericardiocentesis, close monitoring is required to detect evidence of recurrent tamponade and procedure-related complications. Table 8-4 lists the most common serious complications associated with pericardiocentesis [1,21,22]. Factors associated with an increased risk of complications include (a) small effusion (less than 250 mL), (b) posterior effusion, (c) loculated effusion, (d) maximum anterior clear space (by echocardiography) less than 10 mm, and (e) unguided percutaneous approach. All patients undergoing pericardiocentesis should have a portable chest radiograph performed immediately after the procedure to exclude the presence of pneumothorax. In addition, a transthoracic two-dimensional echocardiogram should be obtained within several hours to evaluate the adequacy of pericardial drainage. Echocardiography can also be used to confirm catheter placement.

Table 8-4. Complications of Pericardiocentesis

Finally, careful technique is required to maintain the sterility of the pericardial catheter drainage system. With meticulous local care, the complication rate is exceptionally low, even when the catheter is left in place for 36 to 48 hours [12,18].

The long-term management of patients with significant pericardial fluid collections is beyond the scope of this chapter (see Chapter 33); however, the role of surgical intervention is reviewed briefly. The indications for surgical intervention are controversial and vary widely (Table 8-5) [2,23,24,25,26,27 and 28]. Several indications that have been established include (a) pericardial disease with concomitant constrictive physiology, (b) known loculated or posteriorly located effusions not amenable to pericardiocentesis, (c) suspected purulent pericarditis, (d) effusions not successfully drained by pericardiocentesis, and (e) rapidly recurring effusions [2,29]. The etiology of the pericardial effusion (Table 8-6) and the patient's functional status are of central importance for determining the preferred treatment. Aggressive attempts at nonsurgical management of chronically debilitated patients or those with metastatic disease involving the pericardium may be appropriate [25,30,31]. Pericardial sclerosis with tetracycline or other agents has benefited carefully selected patients with malignant pericardial disease [30,32,33]. Patients with a guarded prognosis who fail aggressive medical therapy should be offered the least invasive procedure.

Table 8-5. Major Surgical Options for the Management of Pericardial Effusions

Table 8-6. Common Causes of Pericardial Effusion

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