Pericardiocentesis: A Clinical Anatomy Review

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The safe and successful performance of pericardiocentesis demands a working and specific knowledge of anatomy. Misunderstanding of anatomy may result in failure or serious complications. This review attempts to aid understanding of the anatomical framework, pitfalls, and complications of pericardiocentesis. Pericardiocentesis is carried out for aspiration of blood from the pericardial cavity in cases of cardiac tamponade and symptomatic pericardial effusion. In addition, this technique may be used for the diagnosis of neoplastic effusions, purulent pericarditis, and introduction of cytotoxic agents into the pericardial space. Most complications of the procedure are due to the needle penetrating the heart and surrounding structures such as coronary arteries, lungs, stomach, colon, and liver. These complications, if severe, may result in pneumothorax, hemothorax, arrhythmias, infections or arterial bleeding. Therefore, the more fluid or blood there is between the myocardium and pericardium—within the pericardial cavity—the less chance of complications. With a thorough knowledge of the complications, regional anatomy and rationale of the technique, and adequate experience, a pericardiocentesis can be carried out safely and successfully. Clin. Anat. 25:872–881, 2012. © 2012 Wiley Periodicals, Inc.

Key words: clinical procedures; pericardium; cardiac tamponade; pericardial effusion; pericardiocentesis

INTRODUCTION

The concept of pericardiocentesis dates all the way back to 1653, when Riolanus suggested that the heart may be compressed by pericardial fluid, and that trephining the sternum may help to relieve the pressure. At the turn of the 19th century, the Spanish physician Romero described a procedure in which an intercostal incision was made, providing access to the pericardium for drainage of excess fluid. Franz Schuh, a famous Viennese thoracic surgeon, is credited with the first needle pericardiocentesis in 1840. In the procedure, Schuh inserted a trochar through the 4th intercostal space at the left sternal margin in a young woman with severe dyspnea. After aspirating a large quantity of blood stained fluid, the patient immediately felt much better (Shabetai, 2003).

Since these experimental procedures, the techniques recommended for a safe and successful pericardiocentesis have changed considerably, with the introduction of two-dimensional echocardiography now guiding the current standards (Tsang et al., 1998b). This technique is used mainly for the aspiration of blood or fluids from the pericardial cavity (with the exception of posterior pericardial effusion

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Received 9 August 2011; Revised 20 October 2011; Accepted 19 December 2011
Published online 31 January 2012 in Wiley Online Library (wileyonlinelibrary.com). DOI 10.1002/ca.22032

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focuses on the anatomical pitfalls, hazards, and step-by-step description of the procedure and then reviews the clinical anatomy of pericardiocentesis. Callahan et al., 1985; Levine et al., 1991; Ball and Risks (Krikorian and Hancock, 1978; Becker, 1980; significant incidence of complications due to related pericardial effusions as a result of malignancy, trauma, or rupture of the heart can be life-threatening conditions. When effusions lead to cardiac tamponade, they result in compression of the heart due to pericardial accumulation of fluid, pus, blood, clot, or gas (Spodick, 2003). Compression of the heart therefore results in a decrease in ventricular filling, which in turn leads to a decrease in the stroke volume and cardiac output. These patients can present severely ill and the immediate goal is relief of their symptoms. The main symptoms include: tachycardia (>100 beats/min), arrhythmia, hypotension (systolic blood pressure <100 mm HG), pulsus paradoxus, ECG abnormalities (small complexes, electrical alters), and friction rub (Spodick, 2003). Important clinical signs are congested neck veins and muffled heart sounds (Beck, 1937).

Over the past several years ultrasound-guided pericardiocentesis has become a standard procedure for the management of pericardial effusions and cardiac tamponade. However, there is still a significant incidence of complications due to related risks (Krikorian and Hancock, 1978; Becker, 1980; Callahan et al., 1985; Levine et al., 1991; Ball and Morisson 1997; Tsang et al., 1999). This article reviews the clinical anatomy of pericardiocentesis. It starts with the indications, methods, and a step-by-step description of the procedure and then focuses on the anatomical pitfalls, hazards, and complications.

**CLINICALLY RELEVANT ANATOMY**

The pericardial sac is a double-walled membrane that surrounds the heart and lies in the middle mediastinum along with the ascending aorta, pulmonary trunk, superior vena cava, arch of azygous vein, and main bronchi. It lies at the level of the T5-T8 vertebræ, posterior to the sternum and the 2nd to 6th costal cartilages (Moore and Agur, 2007). The outermost layer of the sac is the fibrous pericardium. The fibrous pericardium fuses with the adventitia of the great vessels superiorly, and has ligamentous attachments to the central tendon of the diaphragm inferiorly and the sternum anteriorly (Mathers, 1996). The internal surface of the fibrous pericardium is lined by the parietal layer of the serous pericardium, which is reflected onto the heart as the visceral layer of serous pericardium. The pericardial cavity, therefore, is the space between the parietal and visceral layers. Normally, a small amount of serous fluid exists in this compartment, allowing the heart to move without friction (Moore and Agur, 2007). The phrenic nerve provides sensory fibers to the pericardium, and travels between the mediastinal layer of the pleura and the fibrous pericardium (Mathers, 1996). Pain experienced as a result of pericardial effusions and cardiac tamponade is primarily a result of this innervation. Several vital organs lie in close proximity to the heart, and thus must be taken into consideration when performing pericardiocentesis. The pleura, lungs, internal thoracic vessels, intercostal nerves/vessels, liver, diaphragm, and myocardium of the heart are all at risk for an aberrant needle location.

**INDICATIONS**

Cardiac tamponade may present as a life-threatening condition, for example, after a knife stab wound of the thorax. Many stab wounds of the heart can be treated initially with pericardiocentesis (Baue and Blakemore, 1972). This procedure is done to relieve pressure in the pericardial sac, while arranging to perform a thoracotomy (Eisenmann et al., 1978). Cardiac tamponade, or compression of the heart by fluid or blood in the pericardial sac, may develop rapidly after heart injury (Baue and Blakemore, 1972). Following tamponade, pericardiocentesis will temporarily improve the patient’s hemodynamic situation. With an acute traumatic cardiac tamponade, aspiration of as little as 10–50 ml may greatly relieve cardiac output (Harper and Callahan, 1998).

A classic example of improved hemodynamic status is illustrated in a case report by Eisenmann et al. (1978). A pericardiocentesis was performed on a patient with an acute hemopericardium secondary to cardiac rupture after a myocardial infarction, with resultant hemodynamic improvement. After performance of the pericardiocentesis, the patient was transferred to the operating room. Typically, a thoracotomy procedure should follow immediately. When done correctly, this procedure can be performed with a low risk of complications (Wong et al., 1979).

Due to the proximity of several vital structures, including the heart itself, diagnostic and therapeutic pericardial effusion drainage should be performed with echocardiographic guidance.

**CONTRAINDICATIONS**

Thrombocytopenia and anticoagulant therapy are clearly contraindications in patients with pericardial effusions without tamponade, as are poor facilities for cardio-respiratory resuscitation (Clarke and Cosgrove, 1987). However, in cases of pericardial tamponade and impending hemodynamic collapse, it is recognized that thrombocytopenia and anticoagulation are only relative contraindications.

**STEP-BY-STEP PROCEDURE**

Occasionally, drainage of cardiac tamponade is performed via the subxiphoid approach as a matter of great urgency (Baue and Blakemore, 1972).
However, usually there is time to perform a complete and controlled aspiration (Treasure and Cotter, 1980). If possible, echocardiographic demonstration of fluid in the pericardial space, to confirm the clinical diagnosis, should be considered before performing the procedure (Krikorian and Hancock, 1978). Other techniques commonly used include the parasternal and apical approaches (Table 1). The parasternal approach, with ultrasound guidance, provides the most controlled approach to pericardiocentesis, and avoids structures such as the diaphragm and phrenic nerve. This procedure, as described by Tsang et al. (1998b), is outlined below:

1. Monitor the patient’s vital signs, CVP and ECG before, during and after the procedure. Send a blood specimen to the laboratory for blood grouping.
2. Perform an echocardiographic examination. In non-emergent situations, the size, distribution, and hemodynamic effect of the effusion should be assessed. In an emergency, ultrasound guidance can still be quickly used to localize the effusion and to determine ideal entry site.
3. Using the transducer, identify an entry site where the fluid collection is maximal and closest to the transducer, and at which vital structures can be effectively avoided. The parasternal approach is often performed at the 5th intercostal space, immediately adjacent to the sternum. The cardiac notch of the left lung leaves the pericardial sac exposed at this site. The needle should be kept against the sternum, as the internal thoracic vessels lie 1 cm or more lateral to this point (Singh, 2007). Gentle aspiration during advancement reveals when the fluid has been reached. At this point the needle should be advanced approximately 2 mm

TABLE 1. Techniques for Pericardiocentesis

<table>
<thead>
<tr>
<th>Technique</th>
<th>Description</th>
<th>Pros</th>
<th>Cons</th>
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<tbody>
<tr>
<td>Subxiphoid</td>
<td>Needle is inserted into angle between xiphisternum and left costal margin at a 45° angle relative to the transverse plane. Needle directed towards left shoulder (Treasure and Cotter, 1980).</td>
<td>Provides the safest approach in emergent situation, when ultrasound is not available for guidance. Needle enters fibrous pericardium where it is in direct contact with diaphragm, and there is therefore less risk of injuring the pleura (Abrahams and Webb, 1975).</td>
<td>Highest rates of morbidity and mortality (Ainsworth, 2011). Irritation to diaphragm and phrenic nerve. Highest risk of liver injury (Clark and Cosgrove, 1987). Possibility of colon or stomach perforation (Abrahams and Webb, 1975).</td>
</tr>
<tr>
<td>Parasternal</td>
<td>Needle is inserted close to the sternum, usually in the 5th intercostal space (Tsang et al., 1998b).</td>
<td>Commonly used with echocardiographic guidance Cardiac notch of left lung leaves pericardium exposed at this site (Tsang et al., 1998b)</td>
<td>Possible higher risk of pneumothorax than with subxiphoid (Brown et al., 1985). Internal thoracic vessels lie close to sternal margin (Tsang et al., 1998b).</td>
</tr>
<tr>
<td>Apical</td>
<td>Needle placed 1 cm outside apex beat in intercostal space. Needle then directed towards right shoulder (Treasure and Cotter, 1980).</td>
<td>Smaller sized vessels near the apex (Treasure and Cotter, 1980). Thicker wall of left ventricle can seal off if punctured. Patient in left lateral position allows pericardial fluid to accumulate around the apex of the heart (Clark and Cosgrove, 1987). Pericardium is superficial (Clark and Cosgrove, 1987). Bare area over cardiac apex where pleura are usually absent (Last, 1984).</td>
<td>Piercing wall of left ventricle results in higher rate of ventricular fibrillation (Wong et al., 1979). Not indicated in emergency situations (Clark and Cosgrove, 1987).</td>
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further, the sheath advanced over the needle, and the needle withdrawn.
7. Agitated saline can be used to confirm the position of the sheath. When injected through the sheath, agitated saline will show up as bubbles up on ultrasound, and if present in the pericardial space, the procedure can be continued. If the sheath is not position, it should be withdrawn and repositioned, or another needle insertion should be performed.
8. Using a guidewire and dilators, introduce the drainage catheter (pigtail angiocatheter) into the pericardial space, removing the sheath and leaving only the smooth-walled pigtail catheter in place. Agitated saline can be injected under ultrasound guidance again to confirm position.
9. The drainage catheter can now be left in place and used intermittently to drain pericardial fluid.

**ALTERNATE METHODS**

**Subxiphoid Approach**

When utilizing the subxiphoid approach, the needle is inserted into the angle between the xiphisternum and the left costal margin at about a 45° angle relative to the anatomical transverse plane (Fig. 1) (Arom et al., 1977; Santos and Frater, 1977; Treasure and Cotter, 1980; Dunmire and Paris, 1994), directing the needle towards the left shoulder. This approach has been criticized by some authors for causing a greater number of injuries, usually to the right atrium. Instead, echocardiographic-directed pericardiocentesis has been proposed in the intercostal space at the parasternal border or near the apex of the heart (Callahan et al., 1985). In addition, a cadaver study demonstrated greater safety with a parasternal approach in the fifth intercostal space (Brown et al., 1985). There are studies, however, showing a greater risk of a pneumothorax when parasternal and intercostal approaches are used (Brown et al., 1985). During a so-called blind pericardiocentesis, in which the needle is not echocardiographically directed, the subxiphoid approach is recommended.

In the subxiphoid approach, the needle pierces lateral to the xiphoid process, and traverses the skin, superficial fascia, anterior rectus sheath (as it comes off the costal cartilage) and the left rectus abdominus muscle (Fig. 2). Thereafter it pierces the posterior rectus sheath (transversus abdominus muscle) and travels over the dome of the diaphragm and through the fibrous and parietal serous pericardium (Abrahams and Webb, 1975). In the supine position, most of the fluid (or blood) in the pericardial space is located laterally, inferior, and posterior to the heart (Fig. 3). The safest access route, without the use of ultrasound guidance, is therefore the subxiphoid route. Furthermore, this approach holds very little risk of injuring the lung (Baue and Blakemore, 1972).

**Apical Approach**

A less commonly used approach places the needle 1 cm outside of the apex beat in the intercostal space, within the area of cardiac dullness. The needle is then directed towards the right shoulder (Treasure and Cotter, 1980). If the apex beat is not palpable, the needle can be inserted through the skin just inside the area of cardiac dullness. This area is close to the lingula and left pleural space, but there is a bare area over the cardiac apex where the pleura are usually absent (Last, 1984). The pericardial sac is superficial here and has a relatively large transverse diameter. There is therefore minimal risk to injure the pleura, myocardium, liver or lung (Clarke and Cosgrove, 1987). Theoretical arguments that vouch for this technique include smaller sized vessels near the heart apex (Treasure and Cotter, 1980) and the thicker wall of the left ventricle that can seal off if punctured. However, piercing the left ventricle has resulted in a higher incidence of ventricular fibrillation and the arteries are by no means invulnerable (Wong et al., 1979). Clarke and Cosgrove (1987) advise the puncture site be identified echocardiographically. They regard the apical approach to be the best in terms of needle insertion site, with the patient in the left posterior oblique position to allow fluid to accumulate around the apex of the heart. This may be done in elective patients, but is not indicated in the emergency situation.

**ECG CHANGES**

Although utilization of ECG to help direct pericardiocentesis is outdated and has been replaced by echocardiography, the changes in the ECG that occur when the needle touches the myocardium are still of interest. If ST segment elevation or PR segment elevation is seen, this may represent contact between the needle and an intact pericardium immediately overlying the heart with no fluid in the pericardial sac. If, however, bloody fluid is obtained from the needle in the absence of these ECG changes, it signifies that fluid has been obtained from the pericardial sac and not from the chambers of the heart (Bishop et al., 1956). If the needle touches the ventricle, marked ST segment elevation (Bishop et al., 1956) or ventricular ectopic beats can be seen (Treasure and Cotter, 1980).

Contact with the atrium can cause atrial dysrythmias, change of P-wave morphology, elevation of the PR segment, atrial arrhythmias or atrioventricular dissociation (Kerber et al., 1970). However, Sobol et al. (1979) reported a case where a myocardial laceration occurred without electrocardiographic recording, due to the needle entering a metastatic tumor, which is electrically silent.

**ULTRASOUND-GUIDED PERICARDIOCENTESIS**

Ultrasound, or echocardiography-guided pericardiocentesis was first developed at the Mayo Clinic in Rochester, MN in the late 1970s. Since then, it has replaced the blind approach for the diagnosis and management of most hemodynamically significant
effusions (Maggiolini et al., 2001; Ainsworth and Salehian, 2011). Blind performance is reported to cause possible perforation of the heart and can lead to death (Krikorian and Hancock, 1978). Therefore, elective pericardiocentesis is currently performed with ultrasound guidance, minimizing cardiac injury by visualizing the relation of the tip of the needle to the surrounding organs (Duvernoy et al., 1992). Furthermore, pericardiocentesis with echocardiography, both diagnostic and therapeutic, is today considered standard clinical practice in the treatment of cardiac and pleural effusions (Osranek et al., 2003).

In significant pericardial effusions, drainage with US guidance exhibits nearly a 100% procedural success rate, as shown in the study from Kil et al. (2007), where 115/116 (99.1%) patients were drained successfully. In addition, ultrasound assistance leads to a low incidence of both minor complications (3.5%), and major adverse events (1.2%) (Ainsworth and Salahien, 2011). On the other hand, bedside pericardiocentesis, when performed blindly, can have a risk of life-threatening complications as high as 20.9% (Kil et al., 2007). Echocardiographic guidance reduces these complications (Kil et al., 2007).

Ultrasound-guided pericardiocentesis differs from the blind approach in many aspects. First off, the site of entry is not set, but instead determined by...
where the fluid or blood is closest to the chest wall and where the needle track avoids any underlying vital structures (Callahan et al., 1985). With echocardiography, a pericardial effusion shows up as a dark or anechoic space between the heart and pericardium (Fig. 4) (Tibbles and Porcaro, 2004). Tsang et al. (1998b) recommend an entry site where the effusion is closest to the transducer and the fluid collection is maximal. In their review, the chest wall was chosen 79% of the time, heavily preferred to the subxiphoid approach (Tibbles and Porcaro, 2004). With ultrasound sheath placement can be verified by injection of saline bubbles (Ainsworth and Salehian, 2011). Saline injection, when viewed on ultrasound, gives off a contrast-like effect.

Ultrasound-guided pericardiocentesis has the advantage that fluid depth and quantity can be assessed and fluid location can be detected (Clarke and Cosgrove, 1987). The site of entry can be determined where the fluid or blood is closest to the chest wall and where the needle track avoids any underlying vital structures (Callahan et al., 1985). Ultrasound proves effective in assessing the volume of effusion, as well as detecting ventricular collapse and abnormal septal movement (Tibbles and Porcaro, 2004).

**Downsides to Echocardiography**

Ultrasound guidance can have limited visualization due to chronic obstructive pulmonary disease, obesity, and an overall restricted field of view. Complication rate has been shown to decrease with US, but difficulties with localizing the needle tip, delineating between myocardium and pericardial fluid, and visualizing the full extent of the effusion can still cause problems with this method (Hoey and Mankad, 2009). In addition, this equipment is not available in many emergency settings and the blind technique will therefore become default. In settings where it is available, both the equipment and an experienced ultrasonographer are required, adding to the expense of the procedure (Chandraratna et al., 2003).

**Fig. 3.** The figure demonstrates a midsagittal section of a cadaver revealing the pericardial cavity, the diaphragm and the contents of the abdominal cavity. In addition, the broken arrow shows the direction of the pericardiocentesis needle. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

**Fig. 4.** This is bedside cardiac ultrasound performed in a 62-year-old male. The figure demonstrates a large pericardial effusion consistent with cardiac tamponade (red star). The broken red line depicts the extended pericardial sac. An 18-gauge 3.5-inch needle was attached to a 60-ml syringe and was advanced between the xiphoid process and left costal margin at a 45° angle directed toward the left shoulder. White line demarcates the borders of the right ventricular apical wall and right ventricular cavity (RV), while yellow line depicts the left ventricular apical wall and left ventricular cavity (LV). Modified with permission from Garth et al. (2009). [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]
ANATOMICAL PITFALLS

Xiphoid Process

The xiphisternum articulates with the posterior aspect of the body of the sternum, occasionally making palpation prior to the subxiphoid approach difficult (Treasure and Cotter, 1980). However, with the easily identifiable costal margin, the position of the xiphisternum can be predicted. Deep palpation in the area may be uncomfortable for the patient.

Pericardium

The pericardium can stretch to accommodate 2–3 l of fluid. If the increase in fluid occurs over a long period of time, there will be a very gradual increase in intrapericardial pressure. However, less than 100 ml of fluid or blood accumulating rapidly may sharply increase intrapericardial pressure and may be fatal. The classical patient presents with shock (arterial hypotension), distended neck veins, and diminished or absent heart sounds. This is also referred to as Beck’s triad (Beck, 1937). Cardiac output may drop acutely, even when arterial pressure stays at reasonable levels. Because of the variability of arterial pressure, venous pressure is regarded as a better indicator for cardiac tamponade (Baue and Blakemore, 1972). The pericardium is extremely sensitive due to its extensive innervation by the phrenic nerve. Therefore, when touching it with the needle pain is experienced. This may also reassure the operator that he is in the correct space (Treasure and Cotter, 1980).

Marginal Artery

The marginal artery courses on the acute angle of the right ventricle, where the pericardium reflects to become the diaphragmatic pericardium. It is at risk of being injured during a subxiphoid procedure (Treasure and Cotter, 1980).

Liver

When entering subxiphoid, an angle of less than 45° to the horizontal plane of entry may cause the needle to enter the peritoneal cavity and injure the liver and stomach (Abrahams and Webb, 1975). Entering at 45°, the needle enters the pericardium at the angle at which it becomes the diaphragmatic pericardium. It thus, avoids the diaphragm and pierces the fibrous pericardium and parietal serous pericardium to enter the cavity.

The left lobe of the liver is situated in close relation to the xiphisternum, especially in the presence of hepatomegaly (Treasure and Cotter, 1980).

Right Ventricle

The needle enters the pericardial sac approximately where the pericardium reflects acutely to become the diaphragmatic pericardium. In this space lies the margin of the rather thin walled right ventricle (Treasure and Cotter, 1980). The right ventricle will also be encountered when performing a pericardiocentesis via the parasternal approach.

Right Atrium

Because of its thin wall, it is extremely dangerous to come in close proximity to the right atrium with the needle. This is effectively avoided if the needle is directed towards the tip of the left scapula during the subxiphoid approach (Brown et al., 1985; American College of Surgeons and Committee on Trauma, 1993). However, ultrasound guidance and entering through the chest wall are the most reliable ways to avoid the right atrium.

Direction of Needle

If the needle is directed towards the tip of the left scapula during the subxiphoid approach, it is more likely to pierce the right ventricle. If it were to pierce the left ventricular wall, a risk when utilizing the apical approach, there is a higher incidence of ventricular fibrillation (Wong et al., 1979). In addition, insertion and removal of the needle should always be performed in a single unchanged plane. Any lateral motion of the needle tip can produce a scalpel-like lacerating effect and must rigorously be avoided.

COMPLICATIONS (ANATOMICALLY RELEVANT)

Anatomically, both the amount and the location of pericardial fluid or blood are important. Most complications of pericardiocentesis are due to the needle either touching or penetrating the heart. Therefore, the more fluid or blood there is between the myocardium and pericardium the less chance of a complication. In an echocardiographic study, Wong et al. (1979) found that the width of the anterior clear space as seen with an echocardiogram (reflecting the amount of pericardial fluid) correlates significantly with the incidence of complications.

Cardiac Muscle Perforation

Most perforations occur in the right ventricle (Kerber et al., 1970). Opinions in literature vary on the adverse effect of ventricular puncture (Harper and Callahan, 1998). Most right ventricular perforations are without adverse effect (Wong et al., 1979), but some are fatal (Krikorian and Hancock, 1978; Ockene, 1979; Duvernoy et al., 1992). The right ventricle is usually punctured on its inferior surface, as a result of the blind subxiphoid technique. Due to the lower pressure in the ventricle, bleeding is not as severe when compared to the left, but the right side is more vulnerable to laceration due to the thinner ventricular wall.

Cardiac puncture with hemopericardium is the primary possible complication, despite the use of echocardiography. Preis et al. (1982) demonstrated the development of an intrapericardial thrombus developing in 24 hr, by slow-motion analysis of a two-dimensional echocardiogram, after a needle had
penetrated the right ventricular myocardium. Duvernoy et al. (1992) reported complications in 352 cases where a pericardiocentesis was performed. They had three cardiac perforations which were regarded as major complications. A total of 23 (6.5%) accidental cardiac perforations occurred.

**Cardiac Arrhythmias**

Arrhythmias may also occur as a result of the cardiac tamponade itself (Duvernoy et al., 1992). Ventricular fibrillation has been reported to occur due to puncture of either the right or left ventricle. Inadvertent right ventricular puncture is less hazardous than left ventricular puncture. This may require DC cardioversion. Premature ventricular contractions occur most commonly. The incidence of ventricular and atrial dysrrhythmias is rare (Wong et al., 1979). Kri-korian and Hancock (1978) report injury to the distal posterior descending branch of the right coronary artery. To avoid injury to this artery if the right atrium poses a greater risk for persistent bleeding after needle injury when compared with the ventricles.

**Puncture of Coronary Arteries**

The right coronary artery is more at risk of injury than the left coronary artery (Duvernoy et al., 1992). One study reports the injury of a coronary vessel with a subsequent hemopericardium (Kri-korian and Hancock, 1978). Lacerations have also been reported in human cadaver studies (Sabin et al., 1983; Brown et al., 1985).

Duvernoy et al. (1992) present a case where the posterior descending branch of the right coronary artery was injured. To avoid injury to this artery if the distal or marginal branches of the right coronary artery in three cases.

**Pneumothorax**

Pericardiocentesis can lead to a pneumothorax because of the close relation of the pleura and the pericardial spaces. Duvernoy et al. (1992), in a series of 352 patients, reported only two cases complicated by a pneumothorax, both children. Since the subxiphoid approach was used, it seems that this is a safe route in adult patients for avoiding the risk of pneumothorax.

Although still possible, this approach makes it unlikely for the lung or pleural tissue to be injured due to the reflection over the cardiac notch (Ford and Munro, 1980). A chest X-ray should be performed after the procedure. Most pneumothoraces that were reported have been without clinical consequences.

**Hypotensive Episodes**

A drop in blood pressure during the pericardiocentesis may occur due to vagal stimulation (Kri-korian and Hancock, 1978). These episodes can be associated with bradycardia, in which case appropriate administration of atropine, intravenous fluid and elevation of the legs are indicated.

**Puncture of Right Atrium**

Puncturing the atria is a major complication and great care should be taken to avoid it. The atria have a thin and poorly contractible myocardium (Duvernoy et al., 1992). However, in most of the cases the canal caused by the aspiration closes after withdrawal of the needle. Still, the right atrium poses a greater risk for persistent bleeding after needle injury when compared with the ventricles.

**Hemothorax**

A hemothorax can develop secondary to arterial injury as well as injury to the myocardium itself (Clarke and Cosgrove, 1987).

**Dry Tap**

If most of the pericardial fluid or blood is situated posteriorly or laterally, it will not be accessible with a subxiphoid approach (Brown et al., 1985). Wong et al. (1979) found four false negative pericardiocenteses in a study of 52 patients. Two had an isolated (lacerated) posterior hemopericardium and could not be reached by the anterior subxiphoid approach. An apical approach can help to achieve aspiration in these cases, especially if the effusion is located laterally.

**Abdominal and Shoulder Pain**

Abdominal pain and referred shoulder pain are caused by irritation of the diaphragm, and occur most commonly with the subxiphoid approach (Duvernoy et al., 1992).
Infection
This is a very rare complication, which can lead to costochondritis, pericarditis, and sepsis (Duvernoy et al., 1992).

Stomach or Colon Penetration
Due to the close proximity of the stomach and the transverse colon in the epigastrium to the subxiphoid placement of the needle, these structures are at risk and may be injured (Abrahams and Webb, 1975).

Liver Injury
The left lobe of the liver is closely related to the subxiphoid region and puncturing the liver may lead to leakage of blood or bile (Clarke and Cosgrove, 1987). Brown et al. (1985) report in an autopsy based study on four liver punctures using the subxiphoid approach aiming at the tip of the left shoulder. The risk of injuring the liver is higher if the needle is inclined below the suggested 45° to the transverse plane of the patient (Abrahams and Webb, 1975).

CONCLUSIONS
Pericardiocentesis, a procedure first conceptualized in the 17th century, is the aspiration of blood or fluid from the pericardial cavity. It can be performed in the emergency setting, for cardiac tamponade, or on an elective basis for recurrent pericardial effusions. By relieving the excessive pressure these fluids impose on the heart, symptomatic patients can find instant relief and life threatening situations can be managed.

The methods and techniques used in pericardiocentesis have changed dramatically since its induction, mostly to minimize the risks involved. While the blind subxiphoid approach was once the gold standard, and it is still indicated in some emergent situations, techniques that bring the needle through the chest wall, either parasternal or apical, are now considered safer and more effective. With echocardiographic guidance, which is now indicated for all elective procedures, these approaches have minimal risk, and physicians are now able to bring the needle in whatever the effusion is largest and closest to the chest wall. Despite these approaches, complications are always a possibility, and the surrounding anatomy requires an acute awareness for avoiding vital structures.

REFERENCES
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