Symposium - ICU & Trauma Procedure Complications

Complications of pericardiocentesis: A clinical synopsis

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ABSTRACT

Pericardiocentesis (PC) is both a diagnostic and a potentially life-saving therapeutic procedure. Currently echocardiography-guided pericardiocentesis is considered the standard clinical practice in the treatment of large pericardial effusions and cardiac tamponade. Although considered relatively safe, this invasive procedure may be associated with certain risks and potentially serious complications. This review provides a summary of pericardiocentesis and a focused overview of the potential complications of this procedure.

Key Words: Bedside procedure, complications, pericardiocentesis, review, ultrasound guidance

INTRODUCTION

Pericardiocentesis (PC) was first described in 1653 by Riolanus, who outlined the trephination of the sternum to relieve fluid surrounding the heart.¹ The “blind” approach to PC used in the past, failed to gain wide support due to high morbidity, with serious or life-threatening complications exceeding 20% and mortality approaching 6%.²⁻⁴ However, with the development of ultrasound-guided techniques in the 1970s, PC has become essential in the diagnosis and management of most hemodynamically significant pericardial effusions.⁵ Ultrasound-guided diagnostic and therapeutic PC is currently considered the standard clinical practice in the treatment of pericardial effusions.⁶ The procedure can be performed safely in an outpatient setting for carefully selected, stable patients.⁷ It is well-tolerated in all age groups, including children,⁸ and can be performed quickly in unstable patients⁹ to relieve symptoms of pericardial tamponade.¹⁰ In significant pericardial effusions, echocardiography-guided PC has high success rates of >95% with relatively little risk [Figure 1]. The morbidity rate is approximately 1–3% and the mortality rate from injuries directly caused by the procedure is less than 1%.²

Despite the standardization of PC, there is no comprehensive literature review summarizing all known complications associated with this procedure. Thus, our group performed a comprehensive search of global medical literature on this topic, including cross-referenced, non-indexed articles. We present a detailed review of the complications of PC, including relevant topics such as procedural indications, anatomic considerations, and preventive strategies.

ETIOLOGIES OF PERICARDIAL EFFUSION

The etiologies of pericardial effusions requiring intervention have changed over time. Historically, the most common causes of pericardial effusions were malignancy and uremia.⁶ Pericardial effusions secondary to tuberculosis were more prevalent among the economically disadvantaged patients, and hospitals caring for underserved populations.¹¹ Recent studies indicate that pericardial effusions occurring as a complication of percutaneous catheter-based procedures are increasing.¹²⁻¹⁶ The incidence of cardiac perforation is 1.5–4.7% for valvuloplasty,¹⁵,¹⁷ 0.2–1% for radiofrequency ablation,¹⁸,¹⁹ 0.1–0.2% for electrophysiological study,²⁰,²¹ 0.03% for coronary angioplasty,²² 0.5% for cardiac biopsy,²³ and 0.01% for diagnostic catheterization.²⁴ Potentially fatal complications such as iatrogenic right and left ventricular perforation have also been reported.²⁵
anticoagulant therapy.[13] This alone may have a significant effect on the overall risk associated with the procedure. Approximately half of patients who underwent PC had taken an anticoagulant or antiplatelet agent the same day.[13] Patients undergoing catheter-based procedures may be at higher risk for presenting acutely with overt tamponade because they are more likely to be receiving antiplatelet and anticoagulant agents for existing cardiovascular disease. Studies show that over 95% of patients requiring PC after a cardiac intervention received at least one anticoagulant or antiplatelet agent on the day of the procedure. A significant proportion of such patients received up to 3 or more of such agents.[13] As expected, anticoagulation is a relative contraindication to performing PC per the European Cardiology Society guidelines and may have an impact on the risk profile and complication rate associated with PC.[13]

Ho et al.,[26] showed that PC performed for pericardial effusion post catheter-based cardiac intervention is associated with higher rates of acute complications when compared to other causes of pericardial effusion. These differences may be explained by variations in the volume of pericardial effusions and the acuity of tamponade development. Large volume effusions have a greater pericardial space available for needle insertion, with suggested effusion size of >20 mm prior to drainage in the absence of an acute tamponade.[27] In addition, acute iatrogenic pericardial effusion and tamponade is hemorrhagic in nature and the fluid is indistinct from blood in cardiac chambers. This would significantly reduce the certainty of positioning of the PC needle tip in the correct location. Thus, there is a lower risk of injuring surrounding structures when draining a large, chronic, serous or serosanguineous pericardial effusions compared to a small, acute hemorrhagic effusions.[26] Larger, malignant chronic effusions tend to be recurrent, and may require repeat intervention.[26]

**PROCEDURAL INDICATIONS**

The primary indication for PC is cardiac tamponade, accounting for >80% of PC procedures.[28,29] Cardiac tamponade is a class I indication for PC according to the European Society of Cardiology guidelines for management of pericardial diseases.[30] A large (>20 mm) pericardial effusion may also be considered for PC (Class IIa recommendation),[30] particularly for diagnostic purposes. Relative indications for drainage based on echocardiography findings include the following: (a) right atrial and/or right ventricular collapse in diastole, or (b) development of a large effusion in less than 1 month.[27] PC is not typically performed when an effusion is noted to be resolving on its own or less invasive methods can be used to make the diagnosis and treat the source of the effusion.

**CONTRAINDICATIONS**

Aortic dissection, myocardial rupture, and traumatic effusion with hemodynamic instability are all contraindications for PC[30] and warrant immediate surgical correction[10] [Figure 2]. PC can only act as a temporizing measure in the event that the patient decompensates en route to the operating room. Other relative contraindications include uncorrected coagulopathy, concurrent or active anticoagulant therapy, and thrombocytopenia (platelet count of <50).[31] Relative contraindications can be reevaluated on a case-by-case basis for special considerations, including acute or symptomatic tamponade and anticipated hemodynamic collapse. Inaccessible (e. g., loculated posterior collections), presence of extensive adhesions, and purulent pericardial effusions are other potential contraindications to PC.

**INFORMED CONSENT**

Universal procedural precautions, patient verification and identification protocols should be used when...
circumstance allows. PC may be performed under implied consent when used in life-saving circumstances. However, a formal informed consent should be obtained in less emergent settings. Despite potentially serious complications, one U. K. study demonstrated that only half of the PCs performed in a series of patients had evidence of written consent in the medical notes.

**ANATOMIC CONSIDERATIONS**

The pericardial sac is a double-walled membrane that surrounds the heart and is located in the middle mediastinum along with the ascending aorta, pulmonary trunk, superior vena cava, azygos vein and main bronchi. It extends from the fifth to the eighth thoracic vertebrae, posterior to the sternum and between the second to sixth costal cartilages. Table 1 describes the three possible approaches for draining pericardial effusions. In general, the anatomic approach to PC is dictated by the location of the largest collection of fluid and the ease of percutaneous access.

**OVERVIEW OF COMPLICATIONS**

Subsequent sections will discuss more frequent complications of PC including rates, severity, and other important procedural and non-procedural considerations. Major complications (incidence 1–2%) include mortality, cardiac arrest, cardiac perforation leading to tamponade, pericardial/epicardial thrombus, cardiac chamber laceration requiring surgery, injury to an intercostal vessel, pneumothorax requiring chest tube placement, ventricular tachycardia, pulmonary edema and local/systemic infection. Minor complications include small pneumothorax, vasovagal response with transient hypotension, non-sustained supraventricular tachycardia, pericardial catheter occlusion, and pleuropericardial fistula. Mortality associated with ultrasound-guided PC is low (<1%) and the overall complication rate may vary between 4% and 20%. These complications will now be discussed, focusing on signs/symptoms, diagnostic considerations, and clinical management. An overview of pericardiocentesis complications is provided in Table 2.

**Cardiac perforation/Iatrogenic tamponade**

The cardiac perforation rate is approximately 1%. In studies evaluating catheter-based pericardial effusion presenting with tamponade, approximately half presented while patients were still at the medical facility where PC was performed, while the remaining half developed after leaving the medical facility. The median presentation time was 5 hours. Because of the very real possibility of late presentation, especially following a catheter-based procedure, clinicians should maintain a high index of suspicion for this complication. Although the optimal duration of such post-procedural monitoring has not been clearly defined, the authors of this report recommend and observation period of 4–6 hours for asymptomatic patients and 6–24 hours for those who exhibit any form of post-procedural symptoms (depending on symptom duration and resolution).

The so-called “rescue pericardiocentesis” for pericardial effusion has also been associated with the development of intrapericardial and subepicardial thrombi in adult and pediatric patients due to cardiac puncture. Several findings suggest an intrapericardial thrombus: (a) failure of symptom improvement following therapeutic PC; (b) detection of a new homogeneous, immobile mass attached to the epicardium with extension into the parietal pericardium; and (c) new crescent-shaped echogenic density on 2-D-echocardiography. Detection of intrapericardial thrombus following PC on non-hemorrhagic effusion suggests cardiac puncture. This can be further supported by: (a) new ST-segment

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**Table 1: Outline of described pericardiocentesis approaches**

| Approach [Reference] | Description | Advantage | Disadvantage |
|----------------------|-------------|-----------|--------------|
| Parasternal [34]     | Needle insertion placement is close to the sternum, usually in the fifth intercostal space The pericardium is exposed at the cardiac notch of the left lung, and the needle is aimed at the area with the most fluid | Echocardiography usually provides adequate/good visualization of target | Risk of pneumothorax generally higher when compared with the sub-xiphoid approach Internal thoracic vessels are at risk due to their proximity to the sternal margin Higher rate of ventricular fibrillation if the left ventricular wall is pierced Avoid in emergency situations |
| Apical [31, 35-37]   | Needle insertion placement is in the intercostal space, 1 cm lateral to the apical beat The needle is directed towards the right shoulder | Smaller sized vessels are near the apex, thus less bleeding risk The thick-walled left ventricle has a protective effect against puncture Left lateral positioning aids pericardial fluid accumulation at the apex Pericardium is superficial at the cardiac apex bare area, where pleura is usually absent, thus facilitating easier targeting | |
| Subxiphoid [2, 31, 36, 38] | Needle insertion is at a 45° angle between the xiphoid process of the sternum and the left costal margin relative to the transverse plane Needle is directed towards the left shoulder | The safest approach in an emergency without access to ultrasound Lower risk of pneumothorax | Highest risk of liver injury, diaphragm and phrenic nerve irritation, and colonic and gastric injury |
right ventricular end-diastolic and end-systolic volumes represented a 76% increase in right ventricular stroke volume, significantly higher than the calculated 64% increase in left ventricular stroke volume. This imbalance may help explain the rapid increase in pulmonary vascular and left atrial volumes as well as an abrupt increase in the pulmonary capillary wedge pressure, contributing to the development of pulmonary edema.\textsuperscript{[64]}

The pericardial decompression syndrome is heterogeneous in presentation and does not seem to be specifically associated with any particular cause of pericardial effusion. It has been associated with both surgical pericardiotomy and pericardiocentesis. Finally, it has been described in various literature sources under different names, including “pulmonary edema,” “ventricular dysfunction or failure,” and “low cardiac output syndrome.” The use of the term “pericardial decompression syndrome” is an attempt to simplify nomenclature and focus on commonalities between the above-listed pathologic states.\textsuperscript{[52,63–66]}

### Pneumopericardium

Another important complication of PC is pneumopericardium, or the presence of air along with fluid in the pericardial sac. This develops when a direct communication between pleura and pericardium forms, air is introduced during the aspiration procedure, or when there is a leak in the drainage system.\textsuperscript{[67–71]} Chest radiograph is the best initial study of choice, demonstrating a wide separation of the pericardium from the heart. Other studies include transthoracic echocardiography, which shows bubbles “swirling” around the heart,\textsuperscript{[72]} and computed tomography, which can confirm air and fluid in the pericardial sac. Close monitoring is typically sufficient for the majority of cases of post-PC pneumopericardium, which is a self-limited phenomenon that tends to resolve spontaneously. However, in patients with hemodynamic instability and accompanying pericardial effusion, repeated PC is the treatment of choice. Careful procedural technique that minimizes air entry into the drainage catheter is crucial to prevent such a complication.\textsuperscript{[67–71,73]}

### Cardiac arrhythmia and vasovagal reaction

Pericardiocentesis has been associated with complications such as vasovagal reaction, transient arrhythmia, sinus node dysfunction, and transient or persistent ST- or PR-segment elevation.\textsuperscript{[74–76]} ST-or PR-segment elevation has been used as a monitoring technique for the detection of inadvertent myocardial injury, but myocardial laceration without associated EKG changes is not uncommon.\textsuperscript{[70]} Persistent ST-elevation post-PC requires special attention as it may reflect subepicardial injury commonly seen in acute coronary occlusion due to thrombosis or vasospasm. Post-PC persistent ST-elevation should warrant additional investigation for myocardial or coronary artery injury.

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**Table 2: Overview of reported complications of pericardiocentesis (alphabetical)**

| Complication                                      |
|--------------------------------------------------|
| Arhythmia                                         |
| Cardiac arrest                                    |
| Cardiac perforation/injury                        |
| Epicardial thrombus                               |
| Hypotension                                       |
| Infection                                         |
| Injury to surrounding structures (including sequelae) |
| Diaphragm, liver, lung; Hemoperitoneum            |
| Intercostal/other vessel injury                   |
| Migratory pulmonary thromboembolism/embolization  |
| Mortality                                         |
| Pericardial tamponade                             |
| Pericardial thrombus                              |
| Pericardiocentesis catheter occlusion             |
| Pleuropерicardial fistula                         |
| Pneumothorax                                      |
| Pulmonary edema                                   |
| Vaso-vagal response                               |
| Ventricular dysfunction                           |

*Does not include incidence for more specific diagnostic or procedural indications.

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Elevation (current of injury) on electrocardiogram; (b) rapid clotting of aspirated fluid; (c) identical dye dilution curves obtained from injection of indocyanine green through a PC needle and via intravenous catheter; and (d) similar values of hematocrit, PCO\textsubscript{2}, PO\textsubscript{2}, pH, and bicarbonate of the aspirated fluid and arterial blood.\textsuperscript{[14,47–49]}

**Hemodynamic derangement**

Hemodynamic derangement can arise from ventricular dysfunction (VD) as a complication of PC. Reported spectrum of clinical manifestations includes cardiogenic shock,\textsuperscript{[50]} cardiogenic pulmonary edema,\textsuperscript{[51]} and non-cardiogenic pulmonary edema,\textsuperscript{[52]} all of which can develop within hours to several days after the procedure.\textsuperscript{[53]} Pericardiocentesis may also contribute to profound hypoxia or right ventricular dilation, with subsequent cardiopulmonary failure.\textsuperscript{[53–62]}

**Pericardial decompression syndrome**

Pulmonary edema following PC for cardiac tamponade can be life threatening.\textsuperscript{[63]} Although infrequent, it is by no means rare. Pulmonary edema occurs primarily as a consequence of paradoxical left ventricular dysfunction post-PC.\textsuperscript{[39]} This is a well-defined clinical entity that mechanistically is yet to be fully explained. Various pathophysiologic mechanisms have been suggested, including considerations discussed in this section and other parts of this review.

Manyari et al.,\textsuperscript{[64]} studied this phenomenon specifically in post-PC patients. The authors used equilibrium gated radionuclide ventriculography immediately before and after PC in 10 patients (of whom 5 had cardiac tamponade). In patients with tamponade, right ventricular end-diastolic volume increased more than left ventricular end-diastolic volume (72% vs. 56%) following PC.\textsuperscript{[64]} Although the study did not evaluate change in right ventricular stroke volume, the measured increase in
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Using either echocardiography or in some cases coronary arteriography before initiating treatment of ischemia, especially in the setting of potential thrombosis.[37,74-77]

Iatrogenic injury to surrounding structures
Erroneous introduction/excursion of the PC drainage catheter can result in superior vena cava perforation, transhepatic perforation of the hepatic veins, as well as IVC and right atrial perforation/injury.[78] The subxiphoid approach can also cause intraprocedural injury to the diaphragm, the phrenic nerve, liver, colon and stomach.[79,80] These complications highlight the very real potential for adverse sequelae associated with PC. It has been recommended that experienced clinicians should perform these procedures with a cardiothoracic unit available in the event of a major complication.[79,80]

MISCELLANEOUS COMPLICATIONS AND TOPICS

Migratory pulmonary thromboembolism/embolization
Extremely rare complications of PC include the potentially fatal migratory pulmonary thromboembolism and shearing and embolization of the outer coat of the guidewire. An abrupt increase in venous return following PC in at-risk patients may result in migration of deep venous thrombus and fatal pulmonary embolism.[81,82]

Hemorrhagic peritonitis/hemoperitoneum
The literature describes hemoperitoneum and hemorrhagic peritonitis following the subxiphoid approach.[83,84] More specifically, perforation of the diaphragm or peritoneum during PC in the setting of anticoagulation can result in clot dislodgment from the diaphragm puncture site, potentially causing subsequent hemorrhagic peritonitis and hemoperitoneum.[83,84]

COMPLICATIONS OF PERICARDIAL ACCESS IN ELECTROPHYSIOLOGY

Recent advances in cardiac electrophysiology include the successful radiofrequency ablation of ventricular tachycardias (VT). While initially all ablations were endocardial, the last decade has seen the rise of epicardial ablations. Originally done to treat VT from Chagas disease this has become a great tool in the treatment of non-ischemic cardiomyopathies, arrhythmogenic right ventricular dysplasias and even in some cases of ischemic cardiomyopathies. It is also useful in ablation of select supra-ventricular arrhythmias.[85-87] Since the procedure involves gaining a dry pericardial access, with no pericardial effusion in between, it is technically demanding and carries its own set of complications. Injury to myocardium, right ventricular puncture and damage to epicardial vessels can occur during access.

Other injuries related to access, catheter manipulation and ablation are also well described and can affect any of the surrounding structures including the phrenic nerve, lungs, or the esophagus.[88-91] As experience with these procedures has increased, practitioners have learned to perform access in various high-risk populations groups – patients who are obese, those with prior coronary artery bypass surgery, those on heparin, and those with history of non-coronary cardiac procedures.[92-95] Another recent development includes the use of various atrial-appendage closure devices many of which require an epicardial access. This carries risks similar to those of epicardial access during ablation.[96]

RECENT PROCEDURAL ADVANCEMENTS

Strategies such as continuous ECG monitoring, fluoroscopy, and echocardiography guidance during PC have greatly reduced complication rates compared to those in blind manipulations. However, the risks and complications of PC described in this paper are still very much real and prevalent. Recent advancements introduced to reduce procedure-related complications are as follows: (a) PC with a visual puncture system; (b) Echocardiography-guided PC with a probe-mounted needle; and (c) administration of agitated saline after needle insertion into the pericardial space to avoid entering a ventricular cavity or other undesired space.[35,97]

In the future, guidelines regarding the rate and volume of pericardial fluid removal could help prevent some of the complications discussed herein, particularly in patients with pre-existing ventricular pathology.

CONCLUSION

Pericardiocentesis can be a potentially life-saving procedure. It has both diagnostic and therapeutic relevance and can be performed at relatively low risk. Complications associated with PC are rare, but can be severe and even life-threatening. The frequency, nature, and severity of complications can vary markedly depending on exact procedural indications and patient-specific risk factors. For smaller, acute pericardial effusions, techniques such as fluoroscopy, a visual puncture system, or other means of image-directed guidance may be necessary. With careful patient selection, taking into consideration the etiology, volume, and location of the pericardial effusion, the risks of PC can be further minimized.

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