Chapter

Percutaneous Approach to Pericardial Disease Management

Jack Hartnett, Richard Armstrong, Lisa Brandon, Hani Jneid, Igor F. Palacios and Andrew O. Maree

Abstract

Percutaneous access of the pericardial space is increasingly sought. This is not only due to growing prevalence of pericardial effusions and cardiac tamponade, but also the emerging diagnostic and therapeutic potential of the pericardial space for mapping and ablation of arrhythmogenic circuits, biopsy, and drug delivery. Although increasingly performed, percutaneous pericardiocentesis remains a technically challenging procedure with potentially life-threatening complications. Consequently, management of patients with pericardial disease is highly complex. In this chapter we outline a step-by-step approach to percutaneous pericardiocentesis and the required specialised management of pericardial disease patients. Procedural complications are discussed along with their alleviating therapeutic strategies. Furthermore, we describe approaches to the prevention and management of recurrent pericardial effusion including diagnostic and therapeutic procedures such as percutaneous balloon pericardiotomy and intra-pericardial delivery of chemotherapeutics and sclerosing agents.

Keywords: pericardial effusion, cardiac tamponade, pericardiocentesis, percutaneous balloon pericardiotomy

1. Introduction

The pericardial space is a potential space contained between the inner visceral pericardium and the outer fibrous pericardium. In normal physiological states it contains up to 50 mL of serous fluid, which acts as a lubricant for the enclosed heart [1]. Similar to the pleural space, the pressure within the pericardial space varies with respiration driven changes in intra-thoracic pressure – ranging from – 5 cm of water during inspiration to +5 cm water during expiration. However, in certain pathological states, both the volume and pressure within the pericardial space can increase giving rise to haemodynamic compromise.

An increase in intra-pericardial volume and pressure is initially compensated for by the compliance of the pericardium [2]. However, when intra-pericardial pressure rises to equilibrate with or surpass intra-cardiac pressures (at approximately 15–20 mm Hg), right heart haemodynamic function is compromised. The underlying pathophysiology centres on excessive intra-pericardial pressures that cause compression of right heart chambers. Consequently, right ventricular filling is restricted and results in a reduction in cardiac output, increased systemic venous pressures and ultimately cardiac tamponade.

Cardiac tamponade is a clinical diagnosis characterised by the concurrent presence of three non-specific clinical signs known as Beck's Triad. This comprises hypotension, distended neck veins and 'distant muffled' heart sounds on auscultation [3]. Although cardiac tamponade is classically taught as a potentially fatal medical emergency requiring immediate intervention, in practice, the presentation is a spectrum ranging from more subtle asymptomatic persistent hypotension (often refractory to intravenous fluid resuscitation) to life-threatening circulatory collapse.

Clinical severity is not only determined by the volume of fluid within the pericardial space, but also the rate at which it accumulates. Rapidly developing pericardial effusions are more likely to cause cardiac tamponade at smaller fluid volumes than slowly accumulating effusions [2]. In rapidly accumulating pericardial effusions, the pericardium remains relatively stiff resulting in a rapid rise in intra-pericardial pressure. In comparison, slow progressive effusions allow for adaptive stretching of the pericardium over time and thus result in lower intra-pericardial pressures for longer.

Echocardiography is crucial to the assessment of any patient with suspected pericardial effusion and/or cardiac tamponade [4]. It can be performed quickly at the bedside to confirm cardiac tamponade in an emergency setting. Although less convenient, haemodynamic assessment during invasive catheterisation can also provide important diagnostic information. **Boxes 1** and **2** outline key echocardiographic and haemodynamic findings in cardiac tamponade.

Definitive management is drainage of the excess pericardial fluid. This is most commonly performed via percutaneous pericardiocentesis which involves insertion of a needle through the skin into the pericardial sac to drain the effusion and relieve haemodynamic compromise on the heart. In this chapter we outline a step-by-step guide to percutaneous pericardiocentesis along with the peri-procedural management of pericardial patients. Novel techniques to prevent and alleviate recurrent pericardial effusions – such as percutaneous balloon pericardiotomy and intra-pericardial chemotherapeutics – are also discussed.

- Presence of a pericardial effusion
- Right atrial collapse in late diastole
- Right ventricular free wall collapse in early diastole
- Increase in E-wave velocity across tricuspid valve during inspiration
- Decrease in E-wave velocity across mitral valve during inspiration
- Inspiratory decrease and expiratory increase in diastolic pulmonary venous forward flow
- Dilated inferior vena cava without inspiratory collapse

Box 1.
Key echocardiographic findings in cardiac tamponade.

- Elevated right atrial pressure
- Elevated intra-pericardial pressure (very similar to right atrial pressure)
- Elevation and equalisation of left–right ventricular filling pressure
- Loss of y descent of the right atrial pressure waveform
- Arterial pulsus paradoxus (i.e., an inspiratory decrease in excess of 10 mmHg in systolic blood pressure)

Box 2.
Key haemodynamic findings in cardiac tamponade.

2. Percutaneous pericardiocentesis

2.1 Indications

The clinical utility of percutaneous pericardiocentesis cannot be understated. It is both diagnostic – providing pericardial fluid for analysis of cell counts, cytology, culture etc. – as well as therapeutic – reducing intra-pericardial pressures and improving right ventricular filling and cardiac output. However, as subsequently outlined, it is a technically challenging procedure with potential life-threatening complications. As such, there are a narrow range of indications for percutaneous pericardiocentesis (**Box 3**) [5].

Timing of percutaneous pericardiocentesis depends on the degree of haemodynamic deterioration and the rapidity with which compromise has developed. Echocardiographic features, aetiology of the underlying effusion and risk–benefit ratio of the procedure (e.g. presence of concurrent coagulopathy) must be considered.

Among patients with life-threatening circulatory collapse, immediate intervention is required. However, the clinical scenario is more complex when haemodynamic compromise is progressive. Percutaneous pericardiocentesis may be deferred to facilitate appropriate planning but these patients remain at high risk of clinical deterioration. Numerous scoring systems have been developed to aid clinicians in determining the timing of intervention. *Halpern et al.,* developed a pericardial effusion scoring

- Cardiac tamponade
- Suspected bacterial pericarditis (including tuberculous pericarditis)
- Suspected neoplastic pericarditis
- Moderate to large pericardial effusions not responsive to medical therapy
- Chronic (persisting longer than 3 months) large pericardial effusion (> 20 mm on echocardiography in diastole)

Box 3.
Indications for percutaneous pericardiocentesis.

index to predict need for pericardiocentesis among patients with haemodynamically stable moderate-to-large pericardial effusions [6]. More recently, the ESC Working Group on Myocardial and Pericardial Diseases published a novel triage system based on aetiology, clinical presentation and diagnostic imaging findings [7]. A combined score of six or greater requires urgent pericardiocentesis. In cases of a score less than six, intervention can be delayed for up to 12–24 hours to facilitate planning. Of note, these recommendations are not based on a body of published data but rather on expert opinion. As such randomised studies are required to validate this triage system.

In the absence of clinical haemodynamic compromise, echocardiographic evidence of cardiac tamponade is not a clear indication for intervention as recent evidence suggests echocardiographic findings of 'pre-tamponade physiology' may be over-sensitive [4]. Consequently, despite near ubiquity of echocardiographic assessment, the decision to proceed with pericardiocentesis is primarily a clinical one.

2.2 Contraindications

Percutaneous pericardiocentesis is potentially life-saving and as such there are no absolute contraindications. It is, however, a technically challenging procedure with potential complications. The decision to intervene mandates risk–benefit analysis. Furthermore, surgery may offer a superior alternative to percutaneous intervention in some clinical scenarios (**Box 4**).

Haemopericardium secondary to aortic dissection, trauma (iatrogenic or otherwise) or ventricular free wall rupture post myocardial infarction are clear indications for emergency cardiothoracic surgery [8]. Furthermore surgical repair should not be

- Haemopericardium secondary to type A aortic dissection
- Traumatic haemopericardium
- Haemopericardium secondary to post-myocardial infarct ventricular free wall rupture
- Bleeding diathesis
    - Use of anticoagulants
    - Raised INR/APTT/PT
    - Platelet count <50,000
- Recurrent pericardial effusions
- Purulent pericardial effusions
- Small pericardial effusions that warrant drainage
- Loculated pericardial effusions
- Posteriorly located pericardial effusions difficult to access percutaneously

Box 4.
Situations warranting special consideration before performing pericardiocentesis.

delayed by attempted percutaneous pericardiocentesis. Only in cases where surgery is delayed or the patient is too unstable for transfer to theatre should percutaneous intervention for controlled drainage of small amounts of haemopericardium be considered [9]. Surgery is also preferred for unstable septic patients with purulent pericardial effusions and in cases of loculated effusions [5].

Surgery offers numerous advantages that include access to large pericardial tissue samples for histopathological analysis, the ability to insert large bore drains (particularly important in purulent pericardial effusions) and the ability to drain complex loculated effusions. However, outside of the scenarios outlined above, surgical risk may outweigh benefit. In particular, general anaesthesia may cause hypotension and circulatory collapse in patients with restrictive cardiac physiology [10].

Percutaneous pericardiocentesis for diagnostic purposes alone is generally not recommended. Aetiology of an effusion can usually be determined based on clinical presentation, laboratory results and imaging without requiring pericardial fluid samples for analysis. Evidence suggests that in approximately 60% of pericardial effusions there is an identifiable underlying cause [11]. In the case of small effusions that do not meet criteria for therapeutic drainage, procedural risk is high.

Similarly percutaneous drainage is not recommended for idiopathic pericardial effusions without haemodynamic compromise. Published data indicate that such effusions respond well to anti inflammatory therapy or resolve spontaneously [5].

3. Performing a percutaneous pericardiocentesis

3.1 Preparation

Informed consent must be obtained from the patient with capacity. The procedure itself must be explained along with the indication and potential complications (**Box 5**) [12–14].

- Monitor ECG signal from aspiration needle
    - ST segment elevation/premature ventricular contractions (PVCs) suggest epicardial irritation or puncture
    - PR segment elevation/premature atrial contractions (PACs) suggest entry into right atrium
- Monitor pressure
    - Intrapericardial pressure tracing observed (right ventricular pressure waveform suggests entry into right ventricle)
- Inject agitated saline and observe for bubbles arriving in pericardial space with echocardiography
- Inject contrast under fluoroscopic screening
- Advance an 0.035-inch J wire and observe it wrapping around heart using fluoroscopy

Box 5.
Techniques for confirming needle/catheter placement in the pericardial space.

The procedure should be performed in the catheterisation laboratory either under echocardiographic [15] or fluoroscopic guidance [16]. In emergency settings percutaneous pericardiocentesis in a controlled planned environment may not be possible and the procedure may have to be performed at the bedside under echocardiographic guidance alone.

Monitoring of heart rate, blood pressure and oxygen saturations along with continuous electrocardiographic (ECG) monitoring is required. Echocardiography facilitates needle tip visualisation and confirms entry into the pericardial space. A resuscitation trolley should be available at the bedside to pre-empt life-threatening complications. Furthermore, a sonographer and nurse should be present during the procedure to provide assistance.

3.2 Patient positioning

The patient should be positioned head-up at a 30–45° angle to allow pooling of the fluid to the inferior surface of the pericardial sac. The objective of patient positioning is to minimise the distance between the skin surface and the target fluid contained within the pericardial space.

3.3 Selecting an entry site

Prior to creation of a sterile field with a drape, the most appropriate entry site should be determined using echocardiography. The entry site should be the shortest distance from the skin to the pericardial fluid – thus minimising the risk of damage to intervening structures. Once the optimal entry site has been selected, the proceduralist should note the distance in centimetres from the probe to the pericardial fluid. This acts as an approximate guide for the distance in which the needle tip should be inserted to achieve access to the pericardial fluid.

The classical entry site is sub-xiphoid as usually the fluid accumulates along the inferior surface of the pericardial sac under gravity. However, the rise in the use of echocardiographic visualisation has enabled alternative access sites (e.g. apical, parasternal) to be used safely depending on the clinical scenario. Distance to the pericardial space is greater with the sub-xiphoid approach compared to other entry sites and risk of damage to adjacent structures (e.g. liver, peritoneal cavity) is higher, likelihood of iatrogenic pneumothorax is lower compared to an apical or parasternal approach. Recent evidence supports echocardiography-guided entry site selection with numerous observational studies reporting fewer peri-procedural complications compared to a traditional sub-xiphoid approach [12, 13, 15, 17].

3.4 Aseptic technique

A strict aseptic technique must be adhered to such that introduction of iatrogenic infection into the pericardial space is avoided. The skin around the proposed entry site is first cleaned with aseptic solution prior to the application of a drape to create the sterile field. Additional sterile drapes placed over the lower abdomen and lower limbs reduce risk of inadvertent contamination.

3.5 Local anaesthetic

One percent lignocaine is infiltrated into the skin at entry site. Local anaesthetic should also be injected into the deeper subcutaneous tissues along the proposed route to minimise intra-procedural pain. Care must be taken when applying lignocaine to ensure it is not infiltrated into small intervening blood vessels.

3.6 Access to the pericardial space

A needle is inserted at a 90° angle to the skin along the planned trajectory. As outlined above, the most common entry point is sub-xiphoid. However, with the advent of more advanced imaging techniques, alternative entry points are increasingly common – particularly in instances of loculated pericardial effusions [18]. The needle is advanced at an angle of 15–30° toward the left shoulder such that it passes beneath the inferior costal margin.

Continuous aspiration should be attempted during insertion to avoid inadvertent entry into vasculature and to confirm entry into the pericardial space. Further local anaesthetic can be infiltrated into the subcutaneous tissues intermittently during entry as additional intra-procedural analgesia.

3.7 Approaches for confirming entry into pericardial space

3.7.1 'Blind'

In emergency situations at high risk of immediate patient demise, percutaneous pericardiocentesis may need to be performed 'blind'. In such cases, ECG monitoring and continuous needle aspiration during insertion should be utilised to confirm pericardial space entry. The commencement of fluid drainage from the inserted needle is suggestive of entry. However, a sanguineous aspirate may pose a dilemma for the clinician as it may be unclear whether this is due to a haemorrhagic pericardial effusion or myocardial puncture. The development of ST segment elevation on continuous ECG monitoring is suggestive of needle over-advancement leading to myocardial injury [19].

3.8 Echocardiography

Since the development of echocardiography-guided pericardiocentesis in 1979, the technique has rapidly become standard of care [17]. The approach can either be performed under continuous echocardiographic surveillance, in which the needle tip is visualised throughout its trajectory from skin to pericardial space [20], or via the echocardiography assisted technique, in which the probe is used only to confirm entry into the space post insertion [17].

Regardless of approach subtype, correct position can be determined by injecting 5–10 mL of agitated saline through the needle and visualising bubbles arriving into the pericardial space. The presence of bubbles within the cardiac chambers is suggestive of needle over-advancement into the myocardium and should alert the clinician to withdraw. Inability to visualise bubbles can either be due to extra-cardiac position of the needle tip or presence of a very large pericardial effusion which hampers visualisation. To distinguish between the two potential aetiologies more agitated saline should be injected and the pericardial space visualised from an alternative echocardiographic window.

3.9 Fluoroscopy

Fluoroscopy guided pericardiocentesis is performed in the catheterisation laboratory - most commonly for iatrogenic pericardial effusions that occur during interventional procedures or cardiac surgery [21, 22]. Injection of contrast through the needle tip followed by radiographic imaging can be used to assess needle tip position relative to the pericardial space. Should the position be correct, contrast will pool in the dependent portion of the pericardial space. Alternatively, a 0.035-inch J-wire can be inserted through the needle. It should be seen to curl around the heart silhouette on radiographic imaging if the needle tip is in the pericardial space. Guidewire position should be confirmed in two orthogonal planes (e.g., lateral and antero-posterior). Passage outside of this silhouette indicates an extra-pericardial location.

Fluoroscopy guidance is limited by radiation exposure to both patient and clinician along with the requirement to be performed in the catheterisation laboratory.

3.10 Computed tomography (CT)

In recent years computed tomography (CT) guided pericardiocentesis has emerged as a viable alternative technique for select indications such as cardiac effusions which are often posteriorly located and difficult to visualise with echocardiography [23]. The procedure involves a planning CT scan to delineate pericardial anatomy, subsequent needle insertion through the marked trajectory followed by a single CT scan post procedure to confirm needle entry. This technique is not performed under continuous CT imaging.

There are clear drawbacks to CT guided pericardiocentesis – lack of continuous imaging during insertion, radiation exposure and prolonged procedure time (median time is 65 minutes per procedure in one study [24]). However, despite these shortcomings, CT guidance does have clinical utility. It is particularly useful for cases of difficult-to-access loculated pericardial effusions or for access to 'dry' pericardial spaces (i.e., do not contain an effusion) for interventional procedures.

3.10.1 Drainage catheter placement

The drainage catheter is inserted via Seldinger-technique. A 0.035-inch J wire is inserted through the needle into the pericardial space. If resistance to insertion is encountered, the J-wire should not be forced. Instead troubleshooting should begin to identify the source of resistance. Once the J-wire is correctly and securely positioned, the insertion needle can be removed. A 6–8 Fr dilator is then inserted over the wire to dilate the entry tract for subsequent placement of the 6–8 Fr pigtail drainage catheter. Appropriate positioning of the drainage catheter can be proven via the various techniques outlined above.

The end of the 6–8 Fr pigtail drainage catheter is connected to a three-way tap so that pericardial fluid can be initially drained into a 50 mL Leur-lock syringe and subsequently transferred into the drainage bag. The drain is usually sutured to the skin to prevent dislodgement – particularly in cases of likely prolonged drainage time.

4. Post pericardiocentesis management

Management of patients post percutaneous pericardiocentesis should occur in a specialised cardiac care unit (CCU) at a tertiary level medical centre where possible (**Box 6**). It is a technically challenging life-saving procedure with potential complications.

A chest X-ray (CXR) should be obtained immediately post procedure to exclude an iatrogenic pneumothorax. Regular vital sign recording along with clinical observation should be undertaken to ensure early detection of complications such as haemodynamic collapse, pericardial decompression syndrome or iatrogenic introduction of infection.

Appropriate care of the drainage catheter is essential. The catheter can either be left on continuous free drainage or intermittent aspiration. Intermittent aspiration every 4–6 hours via the three-way valve system is often preferred in clinical practice due to the lower risk of luminal occlusion [25]. The drainage system should be flushed with sterile heparinised saline between aspirations to preserve patency.

The volume of pericardial fluid drained should be recorded at regular intervals. Drainage of greater than 450 mL in the immediate post insertion setting should be avoided due to the higher risk of pericardial decompression syndrome [26].

The drain should be removed when less than 25 mL of fluid is drained in a 24-hour period [25]. Prior to removal an echocardiogram should be performed to ensure

- Close vital sign monitoring and clinical observation for development of complications
- Post-procedure chest x-ray (CXR) to exclude pneumothorax
- Analgesia (usually with non-steroidal anti-inflammatory agents) as required for pericardial pain
- Catheter drainage can be either free drainage or intermittent aspiration
- Record volume draining at regular intervals
- Strict aseptic technique for catheter manipulation
- Flush drainage catheter with heparinised saline every 6–8 hours
- Minimise duration of catheter stay to reduce risk of infection
- Remove catheter as soon as appropriate or when volume draining is less than 25 mL in 24 hour period
- Remove drainage catheter in event of fever or septic clinical deterioration
- Perform echocardiogram to determine residual pericardial effusion size prior to removing drainage catheter
- Surveillance echocardiogram at appropriate intervals following catheter removal
- Immediate echocardiogram in event of haemodynamic deterioration

Box 6.
Post-pericardiocentesis management.*

adequate interval echocardiographic improvement. In the event of haemodynamic instability post pericardial drain removal an immediate echocardiogram should be performed to assess for evidence of cardiac tamponade [25].

5. Complications of percutaneous pericardiocentesis

Although considered a high-risk procedure, complication rates for echocardiography guided or fluoroscopy guided percutaneous pericardiocentesis are low. Multiple large scale retrospective observational studies report total complication rates of up to 4.7–6.2% [12, 27]. Importantly, procedural success rates are high. In one study involving 1127 echocardiography guided pericardiocentesis procedures over 21 years, procedural success rate was 97% and did not change over the study period [12]. However, it must be noted, these analyses were performed from patient cohorts across a timespan of decades in large tertiary level institutions with considerable expertise. As such real-life complication rates may be higher when performed for emergency indications in lower volume centres by less experienced clinicians.

In comparison, 'blind' percutaneous pericardiocentesis is associated with a life-threatening complication rate of 20% and a mortality risk of up to 6% [19]. Consequently, imaging guided pericardiocentesis is the gold standard and a 'blind' procedure should only be performed in life-threatening emergency settings when no alternative is readily available.

Complications of percutaneous pericardiocentesis include death due to iatrogenic damage to the myocardium or adjacent structures. Myocardial or coronary artery puncture can result in haemopericardium and worsening tamponade. Haemopericardium can initially be clinically silent or present as either a tamponade refractory to drainage or worsening bloody pericardial drain output. Iatrogenic peri-procedural haemopericardium occurs in less than 1% of cases and is an indication for emergent cardiothoracic surgery [19].

Accidental puncture of surrounding structures can also have deleterious consequences. Vascular damage (including puncture of the intercostal vessels or internal mammary vessels) can lead to significant blood loss. Piercing of the lung parenchyma can result in a pneumothorax while accidental intra-peritoneal puncture (most likely with a sub-xiphoid approach) can lead to intra-abdominal organ damage. The most commonly involved intra-abdominal structure is the liver, however, cases of hollow viscus perforation and inferior vena cava perforation have been reported [28, 29].

Incidence of bacterial infection introduction into the pericardial space is low. As such there is no consensus on use of prophylactic antibiotics in the peri-procedural setting.

Arrhythmias in the peri-procedural setting is also a concern. All patients should be on continuous electrocardiographic monitoring during the procedure and during post-procedural observation in the cardiac care unit [30]. ST segment elevation during pericardiocentesis is an indicator of possible myocardial needle puncture while persistent ST segment elevation post procedure is suggestive of potential coronary artery injury leading to myocardial injury [19, 31]. Vasovagal bradycardia is common post pericardiocentesis. Although generally self-limiting, there have been documented fatalities secondary to vasovagal hypotension [32].

Pericardial decompression syndrome, although it has multiple aliases, it is broadly defined as an acute deterioration in haemodynamics that results in hypotension and pulmonary oedema post an uncomplicated pericardiocentesis procedure [33–35]. It is estimated to occur in 5% of cases [36]. Although there is some limited data to suggest it occurs more frequently in malignant effusions, there is no strong predisposition for any particular effusion aetiology [36]. The underlying pathophysiology has not been fully elucidated, however, there are multiple proposed mechanisms. One theory suggests increased right ventricular venous return post decompression results in septal bowing and a consequent drop-off in left ventricular stroke volume leading to pulmonary oedema [34, 37, 38]. Another proposed mechanism involves left ventricular myocardial stunning secondary to pericardial compression induced coronary ischaemia [36, 39]. Judicious drainage of the pericardial effusion to allow haemodynamic re-equilibration is recommended to avoid the development of pericardial decompression syndrome. The European Society of Cardiology recommends rapid drainage of the fluid volume required to clinically alleviate tamponade but that subsequent fluid drainage should be no more than 1 L in 24 hours to allow haemodynamic re-equilibration [5].

6. Recurrent pericardial effusions

The natural course of a pericardial effusion can be unpredictable. To prevent fluid re-accumulation and to promote adherence of the pericardial layers, the drain should not be removed until output is <30 mL in a 24-hour period. In cases at high risk of effusion recurrence, prolonged drainage is a Class IB recommendation from the European Society of Cardiology as it has been shown to reduce recurrence rates [5]. Despite this, recurrent pericardial effusion post-pericardiocentesis is common. It is particularly frequent among malignant pericardial effusions which have a recurrence rate as high as 31–62% [40, 41].

There are multiple therapeutic options for the management of recurrent pericardial effusions including repeated percutaneous pericardiocentesis, intra-pericardial administration of sclerosing agents or chemotherapeutics or creation of a pericardial 'window' - either through open cardiothoracic surgery, a video assisted thorascopic approach (VATS) approach or percutaneous balloon pericardiotomy.

There is no guideline or consensus on the approach for interventional management of recurrent effusions as there is a paucity of evidence directly comparing management strategies.

6.1 Surgical pericardial window

Although not the scope of this chapter, surgical intervention for recurrent pericardial effusion is common – either via drainage through a pericardial window or surgical pericardiectomy. Access to the pericardium can be obtained either via an open thoracotomy, an open sub-xiphoid incision or VATS approach [42].

Multiple small retrospective single institution analyses have reported that while initial success and diagnostic yield is similar between surgical and percutaneous pericardiocentesis, the complication rate and re-accumulation rates are lower with surgical intervention [43, 44]. It must be noted that these studies included first presentation and recurrent pericardial effusions and both malignant and non-malignant aetiologies. In some studies, there may be a selection bias toward surgical intervention as the cohort also included post-operative pericardial effusions following cardiothoracic surgery. A recent published analysis of 44,637 non-surgically related pericardial effusion cases managed either surgically or percutaneously has reported higher mortality and re-intervention rates with percutaneous intervention but increased risk of post-procedural complications and longer hospital admissions with surgery [45].

6.2 Percutaneous balloon pericardiotomy

Percutaneous balloon pericardiotomy is a less-invasive alternative for the management of recurrent pericardial effusion. It is usually reserved for patients with recurrent malignant effusions who are unfit for surgical intervention or in whom the in-hospital post-operative period would significantly impact their remaining limited quality of life.

First described by *Palacios et al.*, in 1991, percutaneous balloon pericardiotomy is similar to a conventional percutaneous pericardiocentesis procedure [46]. It is performed in a cardiac catheterisation laboratory under either fluoroscopic or echocardiographic guidance. A sub-xiphoid approach is used and the area pre-infiltrated with local anaesthetic prior to incision. A stiff 0.038-inch wire with a pre-shaped broad curved tip is advanced into the pericardial space via a needle or through a pre-existing pericardial drain catheter. Position is confirmed via either echocardiography or fluoroscopy. A 10French dilator is advanced over the wire to pre-dilate the skin and subcutaneous tissues and then removed. A balloon-dilating catheter is then advanced over the wire under fluoroscopic guidance until it straddles the parietal pericardium. A 30×20 mm diameter balloon is used, but use of the Inoue balloon (Torray International America Inc., Houston, TX, USA) has also been described. It is essential the proximal end of the balloon is beyond the skin to prevent pericardio-cutaneous fistula formation. The position of the balloon is confirmed via insufflation with a contrast – saline mix. Insufflation is repeated until the waist formed by the parietal pericardium on the balloon visually disappears. The balloon-dilating catheter is then replaced with a pericardial drain catheter.

Post-procedural management is similar to percutaneous pericardiocentesis described above. However, intra-operative and post-operative pain is greater with balloon pericardiotomy – primarily due to purposeful stretching of the nociceptive fibre rich parietal pericardium [47]. Consequently, pre-medication with analgesics and regular pain scores is essential to the care of a balloon pericardiotomy patient.

The previously listed complications of percutaneous pericardiocentesis can also be seen with percutaneous balloon pericardiotomy. However, post-procedural left sided pleural effusion is more common following balloon pericardiotomy. This is believed to be due to balloon insufflation induced creation of a pericardiopleural window which allows the recurrent effusion to drain into the more resorptive pleural space. In one retrospective analysis by *Ziskind et al.* involving 50 cases of balloon pericardiotomy, a post-procedural pleural effusion was seen in all cases and eight required thoracocentesis mediated drainage [47]. Post-operative pneumothorax also appears to occur more commonly with balloon pericardiotomy.

Although usually reserved for oncology patients with poor operative fitness, percutaneous balloon pericardiotomy is an effective alternative to surgical intervention with procedural success rates of 85–100% documented in retrospective studies [48, 49]. However, patient prognosis is poor. Median survival post procedure in these patients is reported up to 3.3 months [47]. The poor survival was primarily driven by underlying malignancy since peri-procedural mortality rates were low (approximately 0–1%) [48].

Overall, there remains a paucity of evidence surrounding percutaneous balloon pericardiotomy. The 2015 ESC guidelines for the diagnosis and management of pericardial diseases do not recommend balloon pericardiotomy for neoplastic effusions but rather "in rare cases of recurrent effusion" [5].

6.3 Intra-pericardial delivery of therapeutics

Intra-pericardial administration of therapeutics is a potential percutaneous intervention which can be performed once percutaneous access has been obtained and the effusion has been drained.

The most common indication is for delivery of sclerosing agents, which drive inflammation and fibrosis of the visceral and parietal layers – thus eliminating the potential space for fluid to re-accumulate. A variety of chemotherapeutic or sclerosing agents have been employed in the past. These include tetracyclines [50], bleomycin [51], cisplatin [52, 53] and thiotepa [54, 55].

Intra-pericardial instillation of sclerosing agents such as talc has no proven recurrence reduction benefit over other approaches including balloon pericardiotomy and surgical intervention. Although it has lower peri-procedural risks, specific complications include severe retrosternal chest pain (likely due to the induction of constrictive pericarditis), atrial arrhythmias or electrocardiographic changes on monitoring suggestive of sub-pericardial or epicardial injury [56, 57].

The 2015 ESC guidelines on the diagnosis and management of pericardial disease recommend intra-pericardial instillation of chemotherapeutics as part of the management of large neoplastic pericardial effusions [5]. It has been shown to reduce recurrence for lung and breast malignancy associated pericardial effusions [52–54]. Chemotherapy choice should be tailored to the specific malignancy – cisplatin is more effective for lung malignancy [52, 53] and thiotepa more beneficial in breast cancer [54].

7. Pericardial complications of Catheter Ablation

Catheter ablation of atrial fibrillation is an established therapy however pericardial effusion is a common complication that occurs in up to 14% of cases [58]. The majority of effusions are mild and asymptomatic and resolve spontaneously within a month. However pericardial tamponade may occur in up to 1% of cases and is usually related to traumatic transseptal puncture [59].

Ischaemic and non-ischaemic cardiomyopathy and infiltrative myocardial disease may be complicated by ventricular tachycardia. Treatment with catheter ablation is increasingly employed with improved outcome. While an endocardial approach is most common, presence of epicardial re-entrant circuits can result in treatment failure and necessitate an epicardial approach. This approach can be percutaneous or surgical and improves procedural success but major complication rates in certain sub-groups, such as post infarct patients, may be as high as 14%. Complications include haemopericardium, right ventricular puncture and may necessitate emergent cardiac surgery [60].

8. Conclusions

Incidence of cardiac tamponade is rising due to the increasing prevalence of pericardial access for electrophysiological intervention and cardiothoracic surgery.

Fortunately, percutaneous pericardiocentesis is a safe and effective intervention for the management of this potentially life-threatening clinical syndrome. However, the field of percutaneous pericardial intervention has significantly expanded beyond pericardiocentesis alone. More complex interventional techniques including balloon pericardiotomy and intra-pericardial instillation of chemotherapeutic agents have emerged, particularly in the management of recurrent malignant pericardial effusions.

Conflict of interest and funding

None.

Author details

Jack Hartnett[1], Richard Armstrong[1], Lisa Brandon[1], Hani Jneid[2], Igor F. Palacios[3] and Andrew O. Maree[1*]

1 Department of Cardiology, St James's Hospital, Dublin, Ireland

2 Division of Cardiology, Department of Internal Medicine, University of Texas Medical Branch (UTMB), Galveston, United States

3 Division of Cardiology, Massachusetts General Hospital, Harvard Medical School, Boston, United States

*Address all correspondence to: amaree@tcd.ie

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