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Emergency Pericardiocentesis in Children

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Abstract

Cardiac tamponade is a life-threatening condition characterized by compression of the heart due to pericardial accumulation of different types of fluid and requires prompt diagnosis and immediate therapeutic intervention. Echocardiography is the most useful imaging technique to diagnose the cardiac tamponade and to evaluate the size, location, and hemodynamic impact of the pericardial effusion. Emergency pericardiocentesis is the procedure used for the aspiration of the fluid from the pericardial space in patients with significant pericardial effusion which determines hemodynamic compromise (cardiac tamponade). Emergency pericardiocentesis in children is performed under local anesthesia and is echocardiographic-guided. The first step of echocardiographic-guided pericardiocentesis is to assess the dimension and distribution of the pericardial fluid and the optimal trajectory of the needle in order to efficiently evacuate the pericardial fluid. The transducer is situated 3–5 cm from the parasternal border and the trajectory of the needle is established by the angle of the transducer. The needle is positioned between the xiphoid process and the left costal cartilages and is advanced, while a continuous aspiration is performed. It is important to avoid the neighboring vital organs (heart, liver, lung, internal mammary artery, and the intercostal vascular bundle). Complications which can occur are as follows: dysrhythmias, puncture of coronary artery or mammary artery, hemothorax, pneumothorax, pneumopericardium, and hepatic injury.

Keywords: pericardiocentesis, emergency, children, cardiac tamponade

1. Introduction

Pericardiocentesis is indicated in hemodynamic unstable children with cardiac tamponade. Echocardiography is a useful imaging tool for liquid effusion visualization and for needle trajectory, reducing the risk of complications.

2. Cardiac tamponade

2.1. Definition

Cardiac tamponade is a life-threatening condition characterized by compression of the heart due to pericardial accumulation of different types of fluid in the pericardial space, which determines restriction from normal filling of the cardiac chambers. Other causes that can determine cardiac tamponade are as follows: inflammation, trauma, aortic dissection, and rupture of the heart [1]. This condition requires prompt diagnosis and immediate therapeutic intervention.

2.2. Etiology

Cardiac tamponade can appear in children as a result of the following conditions (**Table 1**).

Accumulation of transudative fluid into pericardial space can occur from obstruction of fluid drainage, while exudative fluid accumulation appears secondary to inflammation, infections, autoimmune, and malignant diseases.

2.3. Physiopathology

Pericardium envelops the heart and consists of two layers (the visceral pericardium and the parietal pericardium), which are separated by a virtual space containing a small amount of fluid (about 20 mL), serving as lubricant. Normally, pericardium has little effect on cardiovascular function as the following: preservation of the interaction between the left and right ventricle during the systole and diastole, limitation of the intrathoracic cardiac movement and acute cardiac dilatation, minimization of the friction between the heart and neighboring structures by the presence of a small amount of fluid in the pericardial space, and anatomic barrier for pulmonary infections by lymphatic structure [1–3].

Abnormal pericardial fluid production will determine an increased intrapericardial pressure, when the normal capacitance volume of the pericardium is exceeded, with hemodynamic

Common causes	Uncommon causes
Infectious pericardial effusion (viral, pyogenic, tuberculous)	Postcardiac percutaneous procedures
Uremia	Radiofrequency ablation
Neoplasia (metastases, leukemia, lymphoma)	Transvenous pacemaker lead implantation
Postcardiac surgery (postpericardiotomy syndrome)	Radiation therapy
Collagen vascular diseases (systemic lupus erythematosus)	Chemotherapy
Trauma (hemopericardium)	Myocardial infarction
	Aortic dissection
	Hypothyroidism
	Kawasaki disease
	Juvenile idiopathic arthritis
	Rheumatic fever

Table 1. Causes of cardiac tamponade [1–8].

consequences, depending on the rate of liquid accumulation in the pericardial sac. Slow accumulation of the fluid cannot produce clinical symptoms, even when a large quantity of fluid is present, while a rapid accumulation of pericardial fluid will determine a sudden increase of the intrapericardial pressure with severe clinical and hemodynamic consequences. Cardiac tamponade can appear in case of sudden increase of the intrapericardial fluid volume or in case of progressive increase of the pericardial fluid beyond the point of possible pericardial distension. In cardiac tamponade, the diastolic filling is severely reduced because of the increased intrapericardial pressure and conversely, the cardiac output will be reduced. During inspiration, the right ventricle is expanded because of the increased inflow, while during expiration, the left ventricle is expanded and causes the diastolic collapse of the right ventricle and right atrium [2, 3, 9, 10].

2.4. Clinical presentation

During the initial stages, ejection fraction and heart rate are increased and consecutively, the cardiac output is preserved. Lately, the compensatory mechanisms are not effective and systemic vascular resistance are increased, in order to maintain systemic blood pressure, with systemic perfusion compromising and finally with decreased myocardial function, reduced cardiac output, and blood pressure. Clinically, the Beck's triad expresses these pathophysiological changes described above and consists of distant heart sounds, hypotension, and jugular venous distension because of elevated central venous pressure. Other clinical signs are diminished peripheral pulses, pulsus paradoxus (a decrease in systolic blood pressure of >10 mmHg during inspiration), hepatomegaly, and Kussmaul's sign (increased jugular venous pressure during inspiration). In late phases, cyanosis and decreased level of consciousness can be present [1–3, 9–11].

2.5. Diagnosis

Cardiac tamponade is diagnosed clinically and on echocardiography, but there are other useful diagnostic investigations.

2.5.1. Chest radiography

Chest radiography can reveal an increased cardiac silhouette ("water-bottle" shape) or a normal-appearing cardiac silhouette.

2.5.2. Electrocardiography

Decreased electrocardiographic voltage and electric alternans (alternating P wave, QRS complex, and T wave voltages because of the swinging motion of the heart) are characteristics of cardiac tamponade.

2.5.3. Echocardiography

Echocardiography is the most useful imaging technique to diagnose the cardiac tamponade and to evaluate the size, location, and hemodynamic impact of the pericardial

effusion. Emergency echocardiographic assessment of tamponade includes two stages: first stage demonstrates the presence of pericardial fluid collection and the second stage assesses the hemodynamic effects of previously detected collection [12]. The first sign of hemodynamic impairment in tamponade is collapse of the right ventricle free wall in early- to mid-diastole because of the increased intrapericardial pressure more than ventricular transmural distending pressure, and is very specific (**Figure 1**). Right atrial collapse appears in late diastole and has high specificity. The absence of the right chamber collapse is present in cases of elevated diastolic pressure in the right chambers, such as pulmonary hypertension, positive pressure ventilation, or severe left ventricle failure [9]. When tamponade progresses, left atrial late-diastolic collapse and left ventricle early-diastolic collapse can appear. Dilatation of inferior vena cava without normal inspiratory variation (less than 50% decrease in diameter during inspiration), known as inferior vena cava plethora, has also high sensitivity for cardiac tamponade. Other signs are swinging heart, respiratory variation in ventricular chamber size, pseudosystolic anterior motion of the mitral valve, fluttering of the ventricular septum, and dilated hepatic veins [1–4, 10, 12–15]. The absence of the heart chamber collapse is considered as a negative predictive sign for cardiac tamponade [9].

Cardiac tamponade occurring after open-heart surgery is suspected in case of signs of low cardiac output, fall in systemic blood pressure associated with tachycardia and increased

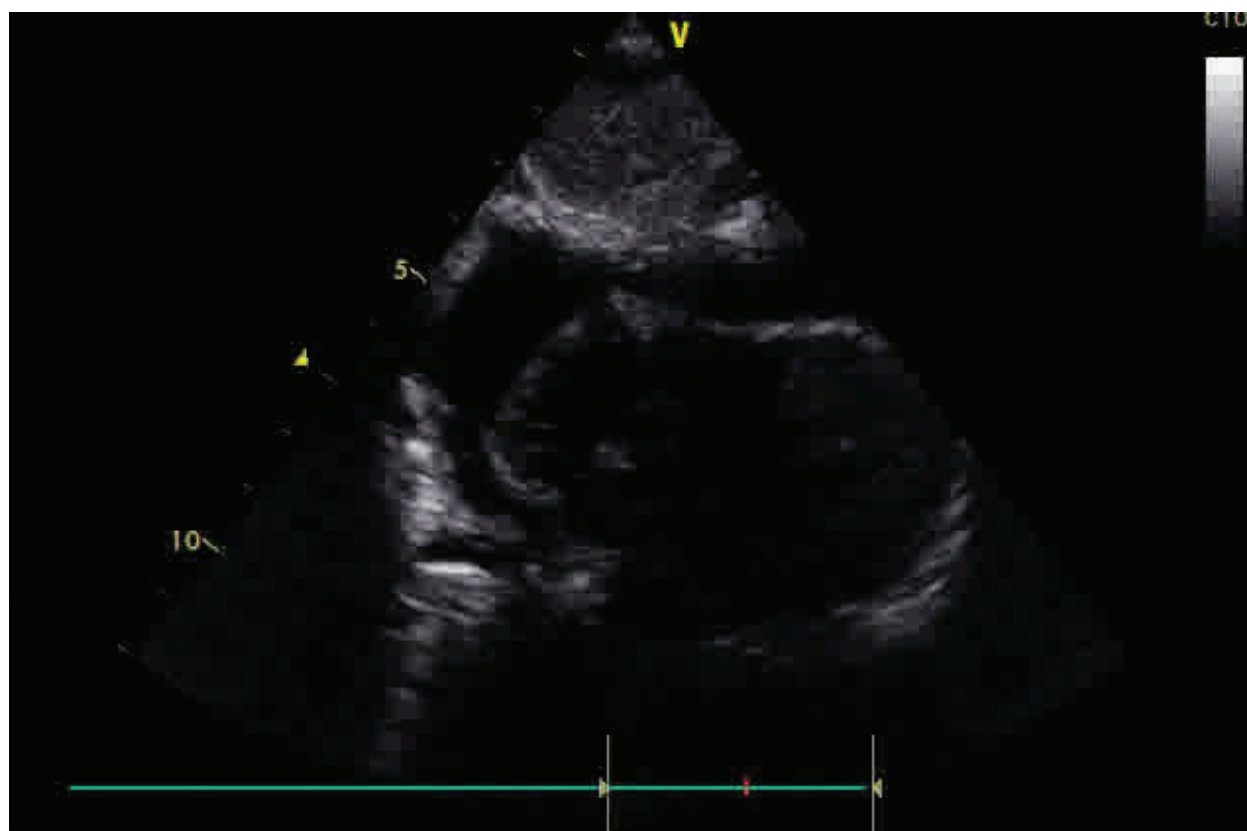


Figure 1. Tamponade, collapse of the right ventricle free wall (echocardiography—subcostal view).

filling pressure, oliguria, decrease of chest drainage, pulsus paradoxus, cardiac arrest, and widen mediastinal shadow on chest radiography [16].

Doppler echocardiography is another useful tool for diagnosis of tamponade, showing large variations with respiration (more than 30%) in the amplitude of inflow and outflow signals, as follows [1–3, 9, 10, 12–15].

- Mitral valve: exaggerated decrease in mitral inflow (E wave velocity) during inspiration and relatively increase of the atrial component (A wave velocity).
- Tricuspid valve: exaggerated increase in tricuspid inflow (E wave velocity) during inspiration.
- Peak velocities in left and right outflow tracts have a large difference with respiratory cycle. During inspiration, there is a drop of peak velocity in the aorta, while in the right ventricular outflow tract, there is an increase of peak velocity.
- Pulmonary veins: decrease of D wave velocity during inspiration.
- Hepatic veins: increased S wave velocity during inspiration; decreased or absence of D wave and high reversal during expiration.

Although there are many echocardiographic signs, none of these findings are entirely diagnostic of cardiac tamponade, so the diagnosis is based on both clinical and ultrasound assessment.

2.5.4. Cardiac CT

Cardiac CT can identify the collapse of the cardiac chambers.

2.5.5. Cardiac MRI

Cardiac MRI can identify the hemodynamic changes of tamponade (collapse of the cardiac chambers).

2.6. Treatment

Emergency pericardiocentesis represents the method used to relieve tamponade. Improvement of the blood pressure and cardiac output can be the result of removal even a small amount of fluid (except of the cases of purulent or malignant pericardial effusions).

3. Pericardiocentesis

3.1. Definition

Emergency pericardiocentesis is the procedure used for the aspiration of the fluid from the pericardial space in patients with significant pericardial effusion, which determines hemodynamic compromise (cardiac tamponade).

Pericardiotomy was first performed in 1815, and the subxiphoid approach was first described in 1911. The ultrasound-guided pericardiocentesis is considered the standard procedure because of lower rate of complications.

3.2. Indications

Pericardiocentesis is indicated in hemodynamic-unstable children with cardiac tamponade and to diagnose the cause of the presence of a pericardial fluid accumulation.

3.3. Contraindications

There are relative contraindications such as uncorrected bleeding disorders, anticoagulation therapy, thrombocytopenia, small pericardial effusion with posterior localization, and aortic dissection.

3.4. Equipment for pericardiocentesis

- Ultrasound machine (**Figure 2**)
- Cardiac monitor
- ECG machine
- Resuscitation equipment including defibrillator
- Antiseptic substances
- Local anesthetic
- Needles
- Syringes
- Catheter guide
- Seldinger wire
- Pigtail catheter
- Alligator clamps
- Drain tubes
- Collection system
- Sterile compressor for transducer
- Sterile fields
- Compresses

3.5.2. Anatomic approach

Three main approaches such as the subxiphoid approach, parasternal approach, and apical approach are used, which are selected based on imaging guidance to find the maximum layer of effusion and avoiding the puncture of other structures [2, 10, 17–19].

Subxiphoid (subcostal) approach was preferred for a long period of time and is the safest approach in cases without ultrasound guidance. The needle is inserted between the xiphoid process and the left costal margin at an angle of 30–45° to the skin, and is directed toward the left shoulder (**Figures 3 and 4**).

Parasternal approach: the needle is placed perpendicular to the skin in the fifth intercostal parasternal space, at 1–3 cm to the sternal border (to avoid the puncture of internal mammary artery). The needle is placed into the intercostal space above the superior edge of the rib (in order to avoid the neurovascular bundle, which is located inferiorly). The risk for pneumothorax is higher than using other approaches.

Apical approach: the needle is introduced 1 cm lateral to the apex beat or at the edge of cardiac dullness and is directed toward the right shoulder.



Figure 3. Echocardiographic-guided pericardiocentesis using the subxiphoid approach.

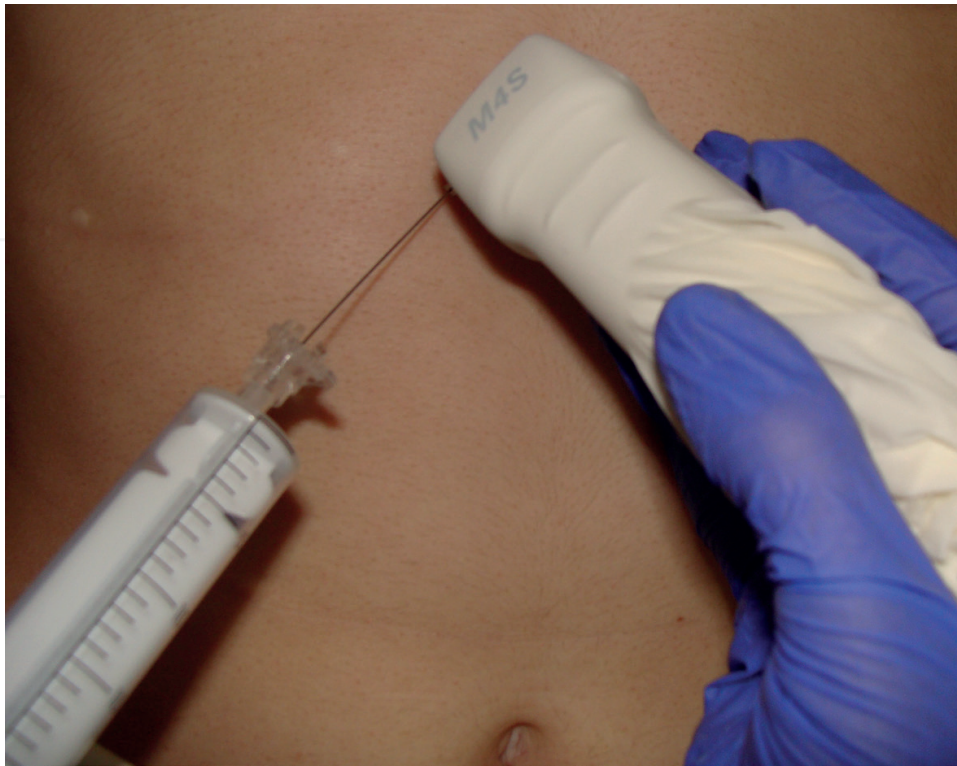


Figure 4. Echocardiographic-guided pericardiocentesis: needle insertion.

In both subxiphoid and sternal approaches, preferable patient's position is sitting at 45° angle, if the clinical condition permits, while supine position is used in patients with severe clinical condition [17, 20].

The advantages and disadvantages of these approaches are presented in **Table 2** [17, 21].

Approach	Advantages	Disadvantages
Subxiphoid	The safest approach in unguided-pericardiocentesis Low risk of pleural injury	High risk for hepatic, gastric, phrenic, and diaphragmatic damage
Parasternal	Echocardiography provides good visualization of the zone of maximum pericardial collection	High risk for pneumothorax and internal thoracic vessels injury
Apical	Lower risk of bleeding because of the paucity of cardiac vascularization near the heart apex Left ventricle has thick walls and protects against puncture No pleura near the apex and low risk of pneumothorax	Avoid in emergency situations

Table 2. Pericardiocentesis approaches.

3.5.3. Procedure

Emergency pericardiocentesis in children is recommended to be performed under echocardiographic guide. Blind pericardiocentesis is performed only in very rare situations, which are immediate life-threatening, because of the major risk for severe complications.

3.5.3.1. *Echocardiographic-guided pericardiocentesis*

The first step of echocardiographic-guided pericardiocentesis is to assess the dimension and distribution of the pericardial fluid and the optimal trajectory of the needle in order to efficiently evacuate the pericardial fluid. The area of maximal fluid accumulation is also determined using the echocardiography. The echocardiographic transducer is covered with a sterile material (sterile glove with ultrasound sterile gel) and is positioned approximately 3–5 cm from the left parasternal border, and the area of maximal fluid accumulation is identified. The direction and trajectory of needle follows the angle of the transducer. The place of puncture is delimited by the angle between the xiphoid process and the left costal cartilages, and 18 mm gauge needles are recommended. The distance between the skin and pericardium is about 5 cm in children. The needle is directed at a 15° posterior angle toward the shoulder and is advanced, while a continuous aspiration is performed with a syringe and the fluid is obtained. The drainage is also assessed using the echocardiography [2, 10, 17–19].

3.5.3.2. *Pericardiocentesis with electrocardiographic assistance*

This procedure can be used when echocardiography guiding is not available. Electrocardiogram monitoring is begun after the pericardial space has been reached, before the needle is advanced. A sterile electrical cord is attached to the needle using an alligator clips and is connected to any precordial lead in order to avoid the ventricular puncture. The electrocardiographic mark of epicardium touching is a wide complex (like a premature ventricular complex, with elevated ST segment), known as current of injury pattern. Atrial arrhythmia or PR segment elevation shows the contact with atrial pericardium, while ventricular arrhythmia is the marker of mechanical stimulation of the ventricular epicardium. The current of injury appears when the needle touches the epicardium and from this point, there is a high risk of myocardium or coronary laceration. Until the current of injury disappears, the needle must be withdrawn few millimeters and then safely placed into the pericardial space [17].

3.5.3.3. *Fluid aspiration*

Aspiration of pericardial fluid can increase the risk of cardiac puncture. Nonclotting aspirated blood and a lower hematocrit level may indicate a pericardial origin [17]. Diagnostic studies are performed on pericardial fluid such as cell count, protein level, glucose, lactate dehydrogenase, bacterial, fungal, and mycobacterial culture, viral PCR, and tumor cytology.

3.5.3.4. *Percutaneous pericardial drainage*

Insertion of a drainage catheter is used to avoid and to reduce the rate of recurrence. The subxiphoid approach is recommended using an 18-mm gauge needle. After the pericardial puncture, the position of the needle in the pericardial sac is assessed using 5–6 mL of agitated saline solution, which is injected and monitored by echocardiography, confirming the position of needle (microbubbles will create contrast into pericardial fluid). A guide wire is inserted into the pericardial space and the needle is removed, and dilatation of the needle tract is performed. Then, a pigtail catheter is inserted over the guide wire via the Seldinger technique and is left in place for few days for drainage of chronic effusions [2, 10, 13, 17, 19].

3.6. Complications

Complications which can occur are as follows: dysrhythmias (atrial fibrillation, ventricular tachycardia, asystole), puncture of coronary artery, hemothorax, pneumothorax, pneumopericardium, cardiac laceration, epicardial or pericardial thrombus, ventricular dysfunction, arterial hypotension because of vasovagal reaction, sudden pulmonary edema due to a sudden increase in pulmonary return, circulatory collapse in patients with an increased rate of drainage, lung laceration, intercostal vessels injury, mammary artery injury, pleuropericardic fistula, infection, diaphragm, phrenic, gastric and hepatic injury, and hemoperitoneum [2, 10, 17–21].

3.7. Follow-up

After pericardiocentesis, an individualized follow-up is required. Daily echocardiographic evaluation is performed in the first few days during hospitalization to evaluate pericardial effusion recurrence and weekly evaluation after patient discharge is required [13].

Tips and tricks:

- Diagnostic of cardiac tamponade is based on both clinical and ultrasound assessment.
- When the needle penetrates the pericardium, the patient who is awake can undergo a sharp chest pain.
- During pericardiocentesis, the needle should not be further advanced after aspiration of pericardial fluid.
- If a large quantity of blood is aspirated, the needle could be in the ventricle.
- Clotting fluid does not reliably indicate the position of needle.
- An increased rate of drainage can determine circulatory collapse.

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