Chapter 10

Role of Echocardiography in the Critically Ill Patients

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/65068

Abstract

Since its inception in 1950s, echocardiography has evolved significantly. Its role has expanded beyond cardiology into operating theaters, intensive care units, and emergency departments. It is an easy, inexpensive, noninvasive, and portable technique, which can be rapidly performed at bedside. It is devoid of complications and, for the most part, universally available. This review focuses on growing importance of echocardiography for critically ill patients in the intensive care and high dependency unit settings including indications, modalities, measurements, and therapeutic impact. Literature review of echocardiography use for the cardiovascular assessment of the critically ill patients was done and various indications are discussed including appropriate use scores. Methods being used include transthoracic and transesophageal echo with various modes. This does include assessment of volume status of the hemodynamically unstable patients, myocardial function, global left ventricular systolic function, regional wall motion abnormalities, cardiac output, cardiac tamponade, valvular function, left ventricular outflow obstruction, and right ventricular function. Other diagnostic assessments include aortic dissection, thromboembolisms, pleural effusions, and septal defects. Echocardiography is now considered as an indispensable tool for diagnosis and management including hemodynamic monitoring in critically ill patients. It provides advantages including noninvasiveness and real-time anatomical and functional assessment of the cardiovascular system.

Keywords: echocardiography, critically ill, ventricular function, hemodynamics

1. Introduction

Echocardiography (echo) is one of the most powerful diagnostic and monitoring tools available to the modern emergency/critical care practitioner. The provision of echo is fundamental to the management of patients with acute cardiovascular disease. Since its inception in 1950s, echocardiography has evolved significantly. Its role has expanded beyond cardiology into operating theaters, intensive care units, and emergency departments [1]. It is an easy, inexpensive, noninvasive, and portable technique, which can be rapidly performed at bedside. It is devoid of complications and, for the most part, universally available. This review focuses on growing importance of echocardiography for critically ill patients in the intensive care and high dependency unit settings including indications, modalities, measurements, and therapeutic impact.

Echocardiography has been included in international guidelines regarding the management of cardiac arrest and in the universal definition of acute myocardial infarction (AMI). In the acutely ill and critical care settings, echocardiography can be used to measure/monitor cardiac output (CO) and to determine abnormalities of cardiac physiology and coronary perfusion, as well as providing more standard anatomical information related to diagnosis.

This chapter is not intended to be a comprehensive review of echocardiographic techniques. Instead, it focuses on the indications, therapeutic impact, and some of the most common scenarios (**Table 1**) where dilemmas can be answered using echocardiography in critically ill patients.

Hypovolemia/hypotension
Hemodynamic instability
Ventricular dysfunction
Evaluation of cardiac thrombus or embolus
Pulmonary embolism infective endocarditis
Acute valvular regurgitations
Pericardial effusions/cardiac tamponade
Complications after cardiac procedures/cardiothoracic surgery
Acute aortic syndromes

Table 1. General indications for echocardiographic examination in the intensive care unit.

2. Types of echo

The challenges of imaging in the acute settings are well studied and may influence echocardiographic findings and interpretation in critically ill patients. These include a number of factors such as filling status, metabolic status, patient habitus and positioning, positive pressure ventilation, intubation/mechanical ventilation, different ventilation modalities, weaning inotropic status, lung injury, the presence of lines/dressings and/or drains, and extracorporeal support. The echocardiographic data should be interpreted in the case scenario of the acutely/critically ill patient, particularly when time-specific factors further challenge the echocardiographer (i.e., cardiac arrest).

2.1. Transthoracic echocardiography

Transthoracic echocardiography (TTE) is a widely available, inexpensive tool, which is generally the initial imaging modality in the assessment of acute cardiac conditions (**Table 2**). It is used in the majority of clinical scenarios associated with cardiac emergencies. Findings can be overlooked if the study is restricted to standard imaging only. The study should be comprehensive and undertaken with a fully equipped echocardiographic machine. The easiest and least invasive way to image cardiac structures is echocardiography using the transthoracic approach [2]. This noninvasive imaging modality is of great value in the critical care settings because of its portability, widespread availability, and rapid diagnostic capability.

Indication	AUS
Assessment of volume status in critically ill patient	U
Hypotension/hemodynamic instability of uncertain or suspected cardiac etiology	A
Suspected complication of MI	A
Acute chest pain with suspected MI, inconclusive ECG during pain	A
Respiratory failure/hypoxemia of uncertain etiology	A
Respiratory failure/hypoxemia when noncardiac etiology is already established	U
To guide therapy of known acute PE	A
To establish diagnosis of suspected PE	I
Reevaluation of known PE change RV function and PAP after therapy	A
Routine surveillance of prior PE, with normal RV function and PAP	I
No chest pain but laboratory and/or other features indicative of MI	A
Severe deceleration injury/chest trauma with suspected or possible pericardial effusion, valvular, or cardiac injury	A
Routine evaluation in mild chest trauma without ECG or biomarker changes	I

Note: I: inappropriate test for that indication (not generally acceptable and not a reasonable approach. Score 1–3 out of 9); U: uncertain for specific indication (may be acceptable and may be a reasonable approach. Also implies that further patient information/research needed to classify indication definitively. Score 4–6 out of 9); A: appropriate test for that indication. (Test is generally acceptable and is a reasonable approach for the indication. Score 7–9 out of 9.) MI: myocardial infarction, PE: pulmonary embolism, RV: right ventricle, PAP: pulmonary arterial pressure.

Table 2. Indications for echocardiography in acute care settings, evaluated using appropriate use scores (AUS).

2.2. Transesophageal echocardiography

A nondiagnostic TTE usually requires a transesophageal echocardiography (TEE). TEE allows better imaging of the posterior structures and heart in general, due to the position of the probe and better acoustic transmission. Certain situations that warrant TEE include acute aortic syndromes, unexplained hypotension, trauma, morbid obesity, prosthetic valve dysfunction, valvular regurgitations/vegetation, and mechanical ventilation with high-level positive end-expiratory pressure and source of cardiac emboli. TEE should be done cautiously in patients with coagulopathy, potential trauma to airway or esophagus, and in patients who are unable to protect their own airways or severely hypoxic without mechanical ventilation. During the study, the airway and hemodynamics should be monitored. In the ICU, transthoracic echocardiography (TTE) may, in certain cases, fail to provide adequate image quality because of different factors that can potentially hinder the quality of the ultrasound signal, be it air, bone, calcium, a foreign body, or any other type of interposed structure.

Other imaging modalities include contrast echocardiography, 3D-echo, lung ultrasound examination, focused cardiac ultrasound, and pocket imaging devices.

3. Hemodynamic evaluation

3.1. Ventricular function

3.1.1. Left ventricular systolic function

Patients may present with a spectrum of conditions ranging from cardiogenic shock, acute pulmonary edema, isolated RV dysfunction, or heart failure (HF) complicating an ACS. Since HF is not a diagnosis *per se*, but rather a syndrome, additional investigations are required to determine the underlying cause. Rapid diagnosis of the underlying cause, and distinction between HF due to systolic versus isolated diastolic dysfunction, should be obtained since identification of these features determines immediate treatment in the acute settings.

Assessment of the left ventricular (LV) systolic function is an integral part of the medical management of hemodynamically unstable critically ill patients. Assessment of the global LV function can be quickly obtained by "eyeballing" from the parasternal long- and short-axis, apical two- and four-chamber, and subcostal views and real-time visualization of the kinetics and size of the cardiac cavities, a combination of ejection fraction/fractional shortening, Doppler patterns of ventricular filling and tissue. Doppler imaging supplements to the information from the echocardiogram. Assessment of the chamber size and LV wall thickness is also done. Findings may include increase in the left ventricular end-systolic and diastolic volume, increase in end-systolic and diastolic diameter and abnormal wall motion. Two other modes of imaging that are relatively easy to obtain for the assessment of the LV function are the atrioventricular plane displacement (AVPD) and systolic tissue Doppler velocities (sTD) [3].

TTE was shown to be an excellent diagnostic tool for assessment of the LV function in the ICU, even when positive end expiratory pressure was present [4]. However, if the TTE provides suboptimal imaging for evaluation of ventricular function, TEE can be obtained for better assessment. It is important to remember that significant LV dysfunction is common in critically ill patients and the "normal" values quoted from noncritical care studies may not be valid.

http://dx.doi.org/10.5772/65068

3.1.1.1. Sepsis-related cardiomyopathy

Bedside echocardiography is an important tool for identification of the cause of hemodynamic instability (which may be of cardiogenic, hypovolemic, or distributive origin) and for the further management (i.e., administration of fluid, vasoactive, or inotropic agent infusion). Classically, septic shock has been considered to be a hyperdynamic state characterized by normal or high cardiac output (CO). But echocardiographic studies indicate that ventricular performance is often diminished in those patients. LVEF might not be a reliable index of LV systolic function in patients with early septic shock.

3.1.1.2. Stress-induced cardiomyopathy (Takotsubo syndrome)

Defined as a transient, stress-induced dysfunction of the LV apex, it predominantly affects female patients (90%). Takotsubo cardiomyopathy mimics an ACS, echo findings show a reversible LV dysfunction with regional wall motion abnormalities, but these patients have no angiographic evidence of ACS. Akinesia has also been demonstrated in the LV mid-cavity, LV base, and RV, with or without sparing of the other LV segments (**Figure 1**). Echo is a useful tool for the follow-up as the LV function must completely recover over time to confirm the diagnosis.

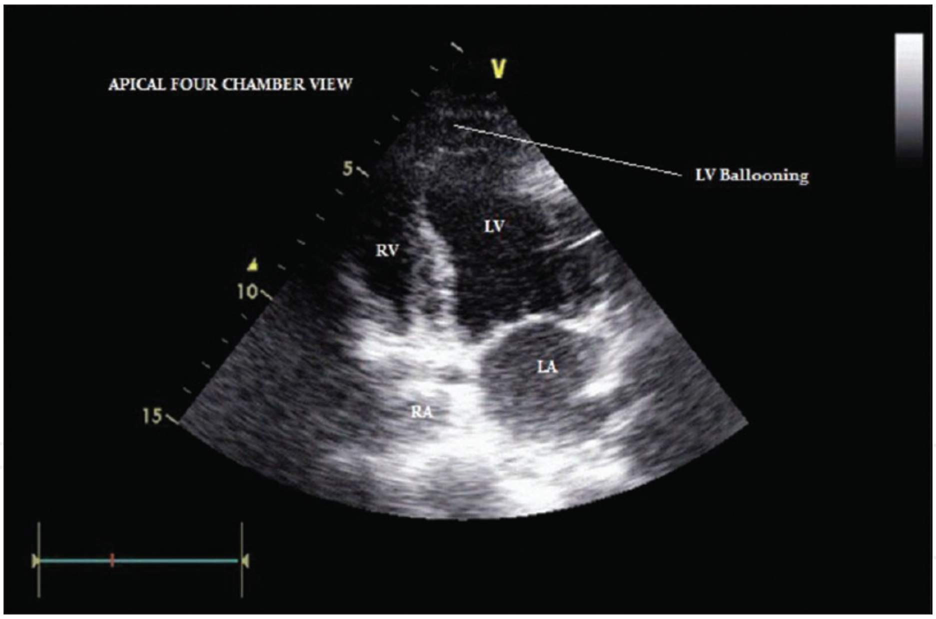

Figure 1. Takotsubo's cardiomyopathy.

LV measurements also provide data on myocardial injury, cardiomyopathies, and fluid status. The left atrial size is evaluated as an enlarged Left atrium (LA) may indicate significant valvular disease, intra-atrial shunting and atrial fibrillation, all of which may in turn cause hemodynamic instability. Finally, the aortic and mitral valves are assessed to complete the examination of left ventricular function. Two-dimensional speckle tracking echocardiography (STE) offers potentially useful information in acute HF patients with underlying cardiomyopathies.

3.1.2. LV diastolic function

In the ICU, when EF is normal or supernormal and ventricular filling pressure (pulmonary artery occlusion pressure) is elevated, diastolic dysfunction should be suspected. The filling patterns related to the diastolic function can be influenced by different factors such as heart rate, ischemia, left atrial pressure, ventricular hypertrophy, and valvular pathologies. In patients with an abnormal relaxation pattern ($E/A < 1$), and peak E velocity <50 cm/s, LV filling pressures are usually normal [5]. With restrictive filling ($E/A \geq 2$, mitral E deceleration time <150 ms), mean LA pressure is often increased. Patients with heart failure with preserved LV ejection fraction (HFpEF) present with signs and/or symptoms of HF and several echocardiographic findings.

In both acute systolic and diastolic HF, interstitial edema may be diagnosed at the bedside by the demonstration of an abnormally high number of bilateral sonographic B-lines (also called ultrasound lung comets). Two-dimensional speckle tracking echocardiography offers diagnostic data in acute heart failure associated with cardiomyopathies, specifically when ejection fraction appears preserved [5].

3.1.3. Cardiac arrest

Echo is a very useful tool in the management of critically ill patients with cardiac arrest. The use of echo in an advanced cardiac life support (ACLS) is supported by international evidence-based recommendations. Peri-resuscitation echocardiography does not impact upon high-quality cardiopulmonary resuscitation (CPR) when appropriately applied and requires special training in advanced cardiac life support (ACLS) compliant manner. Images should be obtained only during the pulse/rhythm check. It can provide data to diagnose or exclude certain potential reversible causes of cardiac arrest (including severe LV/RV dysfunction, myocardial infarction, hypovolemia, pulmonary embolism (PE), tension pneumothorax, or tamponade). Echo is particularly useful in situations of pulseless electrical activity (electromechanical dissociation—EMD) to differentiate between pseudo-EMD and true EMD. Though there is extensive data, we need further recommendations regarding how to use echo during a code situation and specific guidelines for termination of resuscitation.

3.2. Right ventricular function

Right ventricular (RV) function can be altered by massive pulmonary embolism and acute respiratory distress syndrome (ARDS), the two main causes of acute cor pulmonale, in the critical care settings [6]. Other causes of acute RV dysfunction include RV infarction associated with inferior myocardial infarction, myocardial contusion, fat or air embolism, acute sickle-cell crisis, and sepsis. In unstable critically ill patients, specifically those with massive PE and acute respiratory distress syndrome, a diagnosis of RV dysfunction may guide therapy (e.g., use of thrombolytics, vasopressors, volume resuscitation, and catheter-directed interventional therapy). RV size and function are frequently evaluated by visual comparison with the left ventricle. RV kinetics of the cavity and septum, and diastolic dimensions are also measured, using either TTE or TEE. Measuring the ratio between the RV and LV end diastolic areas from apical four-chamber view is one of the best ways to evaluate RV dilation [7]. The diastolic ventricular ratio of 0.6–1.0 is consistent with moderate RV dilation and a ratio of 1 is consistent with severe RV dilation. Tricuspid regurgitation, right atrial dilation, and inferior vena caval dilation are commonly associated with RV diastolic enlargement.

3.2.1. Pulmonary embolism

Though pulmonary angiography remains the gold standard for diagnosis of pulmonary embolism (PE), other available imaging modalities include ventilation-perfusion scanning, spiral computed tomography (CT), and magnetic resonance imaging (MRI) angiography. TTE can help to establish a prompt diagnosis to identify patients with high-risk features, especially if the patient is hemodynamically unstable. Overall, the sensitivity of TTE for the diagnosis of pulmonary embolism is about 50–60% while the specificity is around 80–90%. In some situations, that is, in critically ill patients, TEE may improve the sensitivity.

The main indirect findings for pulmonary embolism (**Table 3**) are the consequences of acutely increased pulmonary artery/right heart pressures [5]. In pulmonary embolism, RV hypokinesia is not necessarily global but can be limited to the mid-RV free wall while the contraction of the RV apex may be normal or hyperdynamic (McConnell sign) (**Figure 2**).

Thrombus into right chambers
RV systolic dysfunction/global RV hypokinesia
Dilatation RA, RV (end-diastolic RV/LV diameter.0.6 or area.1.0)
Mild to severe TR
Pulmonary arterial dilatation
Abnormal septal motion toward LV
McConnell sign—mid-RV wall hypokinesia with apical sparing
Pulmonary hypertension around 40–50 mm Hg (60 mm Hg in the case of pre-existing pulmonary hypertension)
Lack of respiratory variation of the inferior vena cava

Table 3. Echocardiographic finding in pulmonary embolism.

As other clinical conditions can produce acute cor pulmonale in the ICU, better visualization of the pulmonary arteries is needed to achieve high accuracy for the diagnosis of PE. This goal can be achieved by using TEE. TEE helps to achieve a better visualization of the pulmonary arteries and detecting emboli that are lodged in the main and right pulmonary arteries. The diagnosis is made when an embolus is visualized. When the index of suspicion for PE is high and TEE is negative, then pulmonary angiography or helical computed tomography should be considered as the next step. The demonstration of acute cor pulmonale with echocardiography has important prognostic and therapeutic implications. The presence of cor pulmonale with massive PE is associated with increased mortality, whereas the absence of RV dysfunction is associated with a better prognosis.

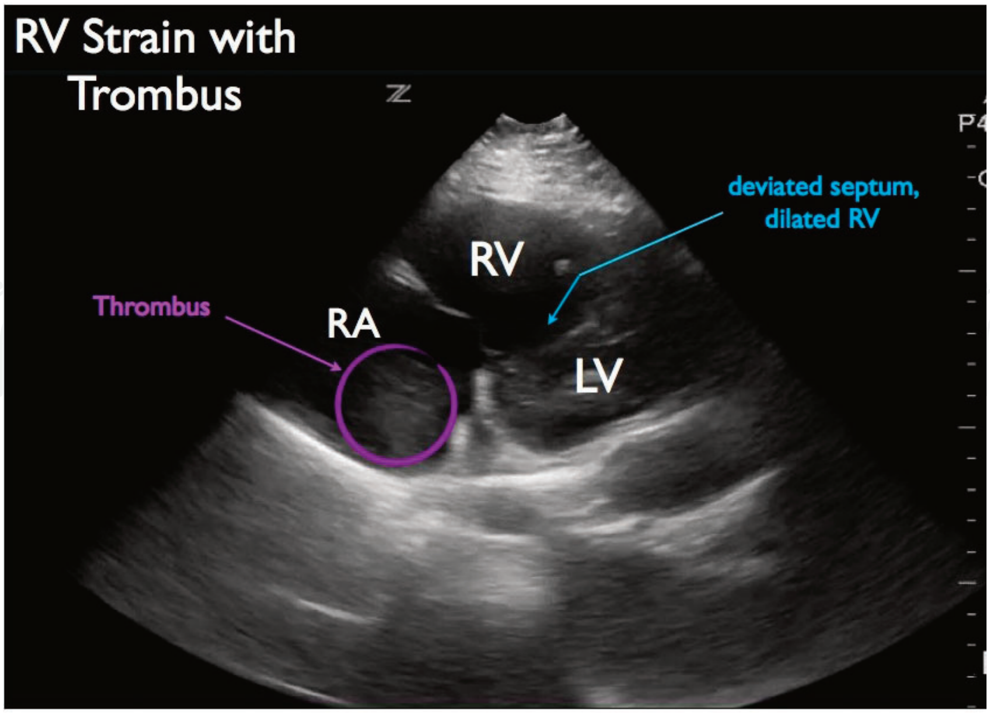

Figure 2. Thrombus in the right ventricle.

3.3. Assessment of cardiac output (CO)

Measurement of CO is an important data in the assessment of critically ill patients with unstable hemodynamics. Cardiac output and stroke volume can be established by combining Doppler data derived from blood flow velocity through a conduit and the cross-sectional area of the conduit. The most common and most reliable technique is using the left ventricular outflow tract and aortic valve. Another method using an esophageal probe inserted in sedated patients, to measure blood flow velocity waveforms in the descending aorta combined with a nomogram, is particularly useful in adult patients to provide continuous monitoring of cardiac function.

3.4. Assessment of filling pressures and volume status

Accurate measurement of volume status and LV preload is important for management of critically ill patients. Besides, invasive pressure measurements to assess LV filling may not correlate well with LV volume. Echo can be very useful in adequately evaluating preload. Measurements from two-dimensional and Doppler echo include LV end-diastolic volume (EDV), LV end-diastolic area (EDA), transmitral diastolic filling pattern, and mitral and pulmonary venous flow.

"Eyeballing" LV end-diastolic (LVED) and end-systolic (LVES) areas provide a quick assessment of intracardiac volume status. Findings in hypovolemic patients include hyperdynamic LV with a reduced end-diastolic volume and "kissing" papillary muscles in systole, suggesting an increased ejection fraction with an empty ventricle at end-systole. Septic patients tend to have a reduced afterload, which is usually demonstrated by a normal LVED area, but a reduced LVES area. Patients with chronic cardiac failure have a dilated LV and may be hypovolemic even with a higher LVED area.

Right atrial pressure measurement is also helpful in the evaluation of the circulating volume status and often measured by the diameter and change in caliber with inspiration of the inferior vena cava. A dilated vena cava (diameter of 20 mm) without a normal inspiratory decrease in caliber (50% with gentle sniffing) usually indicates elevated right atrial pressure. Available data suggest inferior vena cava diameter variation with inspiration can be used a guide to fluid therapy [8]. A small vena cava in mechanically ventilated patient excludes the presence of elevated right atrial pressure, as these patients usually have dilation of the inferior vena cava [9].

3.5. Assessment of pulmonary artery pressure

Pulmonary hypertension is usually diagnosed when systolic pulmonary pressure is ~35 mm Hg, diastolic pulmonary pressure is ~15 mm Hg, and mean pulmonary pressure is ~25 mm Hg. Critically ill patients commonly have pulmonary arterial hypertension, possibly from various cardiac, pulmonary, and systemic processes. Several echocardiographic methods have been validated for noninvasive estimation of pulmonary artery pressure [10], which are useful in critically ill patients. A large number of ICU patients have some degree of tricuspid and pulmonary regurgitation, which are needed to measure pulmonary arterial pressure. The tricuspid and pulmonary regurgitation velocities determine systolic and diastolic pulmonary artery pressures.

3.6. Assessment of valvular function

Significant valvular abnormalities can be present in the critically ill patient without being clinically recognized. In the ICU, TTE can provide valuable information concerning valvular integrity and function [11] but may be suboptimal and TEE may be indicated. Adequate and accurate evaluation of the valvular structures may often be required in the critically ill patients. The most common indications for bedside echocardiography for evaluation of the valvular apparatus in this population are for suspected endocarditis, acute valvular stenosis or regurgitation, critical aortic stenosis, significant mitral stenosis, or prosthetic valve dysfunction including regurgitation and obstruction. Information regarding etiology, pathogenesis, and severity of the valvular lesions, valvular anatomy and function, chamber size, function, and wall thickness of the ventricles can be readily obtained by echo. Abnormalities such as vegetation, thrombus, fibrosis, calcification, immobile, or prolapsing leaflets or prosthetic valve dehiscence can be detected by echo [5].

3.7. Evaluation of the pericardial space

Suspected tamponade is the most common indication for assessment of the pericardium in the critically ill patient. The pericardial space can be filled with a variety of substances including fluid, pus, blood, or air. Presence of fluid in this space is detected as an echo-free space. TTE easily detects pericardial effusion (**Figure 3**), usually in the parasternal long and short-axis and the apical views. But, given higher chances of suboptimal TTE in critically ill patients, TEE may be warranted, particularly in patients with poor acoustic windows or post cardiothoracic surgical patients.

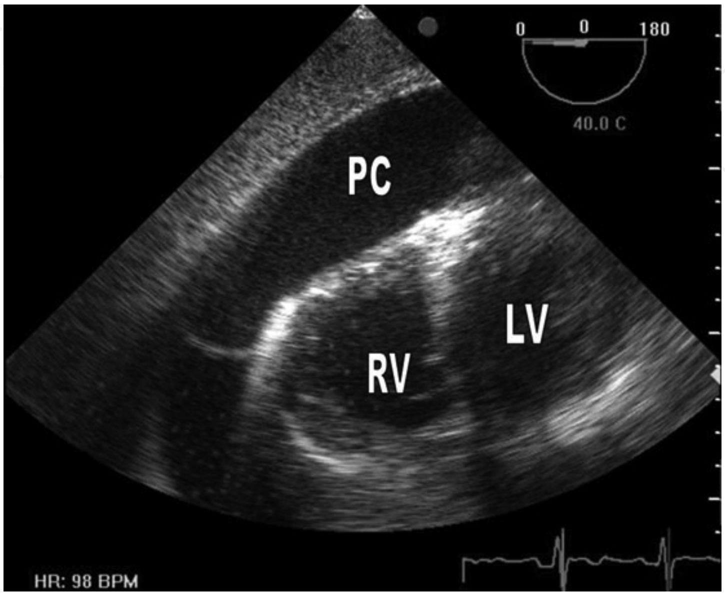

Figure 3. Pericardial effusion.

Echocardiography is also useful in the management of pericardial effusion, as pericardiocentesis can be performed safely under echocardiographic guidance [12]. Echocardiography also can be used to accurately place the needle during the drainage, immediately monitor the results of the pericardiocentesis, and serially monitor to evaluate the reaccumulation of the effusion.

3.7.1. Cardiac tamponade in the ICU

The most common causes of cardiac tamponade in the ICU are listed in **Table 4**.

Complication of myocardial infarction (e.g., ventricular rupture)
Blunt or penetrating chest trauma
Proximal ascending aortic dissection
Myocardial or coronary perforation secondary to catheter-based interventions (i.e., after
intravenous pacemaker lead insertion, central catheter placement, or percutaneous coronary interventions)
Uremic or infectious pericarditis
Compressive hematoma after cardiac surgery
Pericardial involvement by metastatic disease or other systemic processes

Table 4. Common causes of cardiac tamponade in intensive care unit.

http://dx.doi.org/10.5772/65068

There are several 2D-echo findings that suggest a hemodynamically significant pericardial fluid collection (**Table 5**). The rate of accumulation of the pericardial fluid, and collection and size of the collection determine the intrapericardial pressure. Although diastolic RV collapse (inward diastolic motion of the RV free wall) occurs later, it is a more specific sign and is best appreciated from the parasternal or subcostal long-axis views [13] (**Figure 4**).

Usually large pericardial effusion
Swinging heart
RA collapse (rarely LA)
Diastolic collapse of the anterior RV-free wall (rarely LV)
IVC dilatation (no collapse with inspiration)
TV flow increases and MV flow decreases during inspiration (reverse in expiration)
Systolic and diastolic flows are reduced in systemic veins in expiration and reverse flow with atrial contraction is increased

Table 5. Echo findings of hemodynamically significant pericardial effusion.

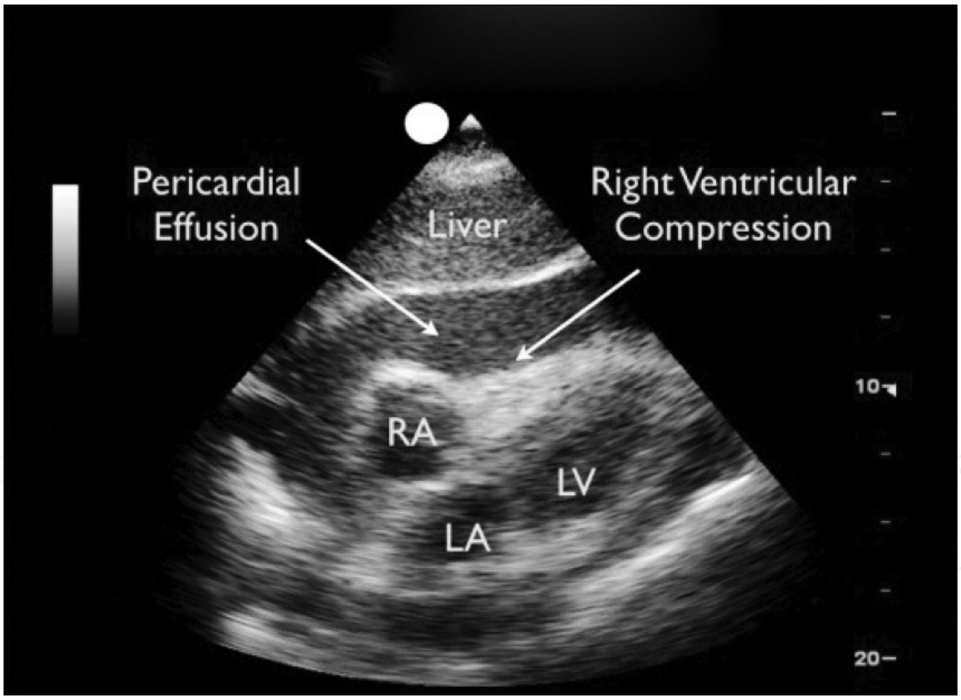

Figure 4. Cardiac tamponade.

If the patient's condition requires urgent pericardiocentesis, the procedure may be echocardiographically guided, as this has been shown to reduce complications. Echocardiography can additionally be used to verify whether the collection has been completely drained. TEE is rarely indicated in this setting.

4. Some other common conditions/scenarios

4.1. LVOT obstruction

In patients who develop dynamic Left Ventricular Outflow Tract (LVOT) obstruction with resultant decrease in cardiac output, particularly the ones who fail to respond to inotropic support, echo is a valuable diagnostic tool. In these patients, right heart catheterization can often be misleading, resulting in inappropriate management.

4.2. Cardiogenic shock

The commonest cause of cardiogenic shock is severe systolic dysfunction from acute myocardial infarction and echo remains an excellent initial diagnostic tool. Shock due to LV dysfunction remains the leading cause of mortality in AMI (50–70%) [14]. Other etiologies include mechanical complications of AMI, myocarditis, cardiomyopathy, valvular heart disease, RV dysfunction, myocardial contusion, and acute aortic dissection. TTE should be obtained first in this set of patients and TEE may be warranted when TTE is suboptimal. Common findings of cardiogenic shock complicating acute myocardial infarction are shown in **Table 6**.

LV dysfunction	Depressed EF, regional wall motion abnormalities, decrease in stroke volume, CO, elevated LV pressures, mitral regurgitation infarction
RV infarction	RV dilatation, dyssynergy, paradoxical septal motion, and McConnell sign, decrease of tricuspid annulus systolic excursion (TAPSE)
Free ventricular wall rupture	Obvious cardiac tamponade or only pericardial collection in subacute free wall rupture (30% of rupture)
Acute mitral regurgitation	Complete or partial rupture of the posterior papillary muscle with partial or complete flail of the mitral valve. Also from acute systolic anterior motion of the mitral valve secondary to dynamic LVOT obstruction

Table 6. Echo findings in cardiogenic shock complicating acute myocardial infarction.

4.3. Complications after cardiac surgery/procedures

In patients with hemodynamic instability after cardiothoracic operations, bedside echocardiography has been shown as a valuable tool in the critical care management [15]. TTE is often suboptimal and TEE is warranted as it obtains information that can help determine the etiology of hypotension in this set of patients. Most frequently encountered echocardiographic findings of LV dysfunction, cardiac tamponade, RV failure, hypovolemia, and valvular dysfunction have been described in earlier sections of this chapter.

Echo is useful in other situations such as evaluation of coronary arteries in suspected coronary disruption, RV dysfunction, and TAPSE (pre-, intra-, and postoperative TAPSE) evaluation, immediately after heart transplant (to rule out early rejection, early RV dysfunction, tamponade, or other causes of instability). Echo is an initial modality of imaging in patients who underwent catheterization/electrophysiology procedures presenting with potential acute complications include ventricular failure, cardiogenic shock, tamponade, displacement of implanted devices, and occlusion of coronary stents.

4.4. Extracorporeal support

Extracorporeal support is increasingly used to support critically ill patients with severe cardiac and/or respiratory failure. Echocardiography for extracorporeal support is highly specialized. Thus echocardiography has a vital role in excluding any potentially treatable underlying cause for cardiorespiratory failure, essential to determine the requirement for the RV and/or LV support and level of support required, mandatory to exclude cardiovascular contraindications for initiation of the support. Echocardiography subsequently has a vital role in its successful implementation, including confirming/guiding correct cannula placement, ensuring the goals of support are met, detecting complications, and assessing tolerance to assistance. Finally, in patients requiring extracorporeal cardiac support, various echocardiographic parameters have been proposed to be used in conjunction with clinical and hemodynamic assessment in order to attempt to predict those patients who can be successfully weaned.

4.5. Cardiac arrhythmias

In the critically ill patient population, heart rates of 100–120/min may be required to maintain adequate cardiac output.

4.5.1. Atrial arrhythmias

Atrial arrhythmias, common in the acute settings, present challenging conditions for assessing cardiac function and hemodynamics, especially when irregular (as in atrial fibrillation). Use of echo in critically ill patients is done with caution. In atrial fibrillation, measurements are obtained from an average of about 10 consecutive heartbeats, to permit the use of echocardiographic parameters usually used in sinus rhythm, to predict elevated filling pressures. The "index beat" method using the measurement performed on the cardiac cycle following a pair of equal preceding cardiac cycles, is also being used in practice.

4.5.2. Ventricular arrhythmias

Echocardiography is one of the first investigations to be performed as soon as the arrhythmia is successfully terminated. Etiologies include ischemic and nonischemic causes that require echocardiographic evaluation.

4.6. Assessment of the aorta

TTE is a good initial investigation tool for evaluation of the proximal aorta (ascending aorta and arch). Because of the close anatomic relationship between the thoracic aorta and the esophagus, TEE allows optimal visualization of the entire thoracic aorta.

4.6.1. Aortic dissection and rupture

Diagnosis and management of aortic dissection is an emergency and these patients are often critically ill. Of the various available imaging modalities, echo, particularly TEE has been recommended for evaluation of suspected aortic dissection (**Figure 5**). TEE has the ability to assess the following, including extension of dissection into the proximal coronary arteries, the point of entry and exit between the true and false lumens, the presence of thrombus in the false lumen, the presence of pericardial or mediastinal hematoma or effusion, severity, and mechanism of associated aortic valve regurgitation, and ventricular function.

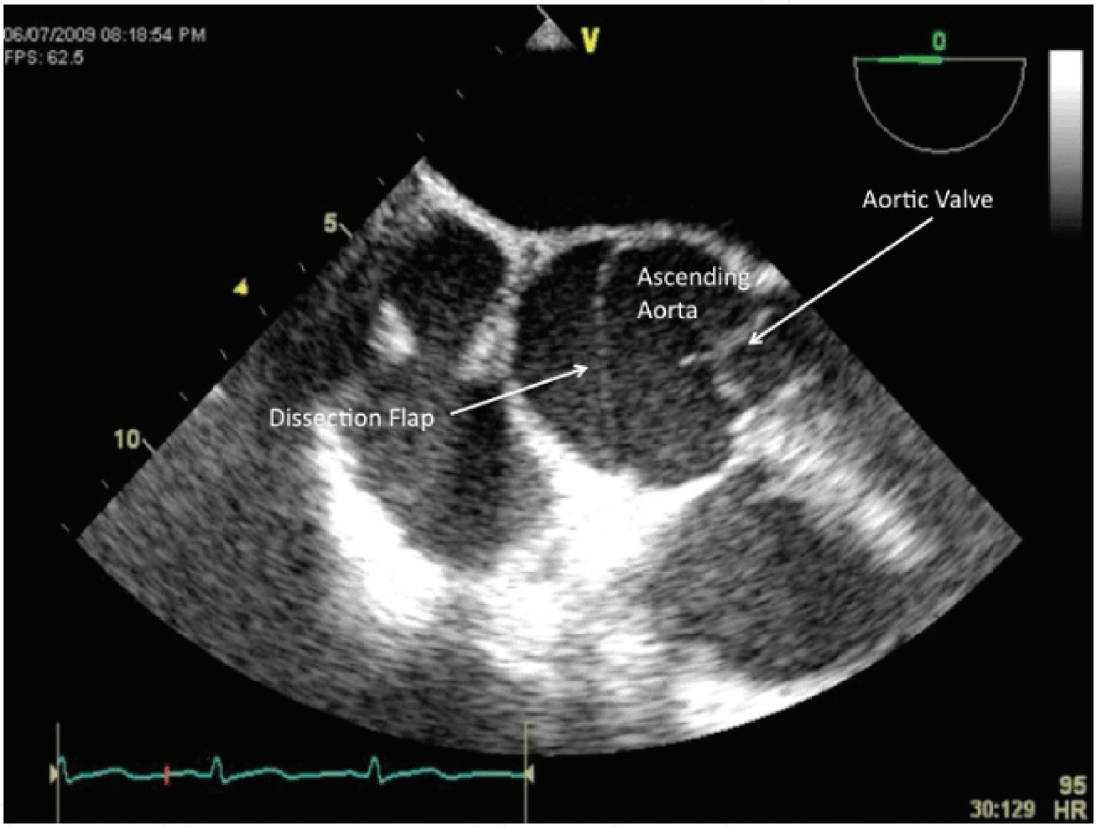

Figure 5. Ascending aortic dissection on TEE.

4.6.2. Intraaortic balloon pump

TEE is useful in various phases of management including evaluation of aortic regurgitation as a contraindication prior to insertion, to confirm the position of the catheter, to ensure correct functioning of the balloon, and to rule out complications such as aortic dissection.

4.6.3. Traumatic injuries of the heart and aorta

Blunt or penetrating chest trauma may cause severe injury to the heart and great vessels. A rapid, focused assessment with echocardiography can detect pericardial collection, myocardial contusion, mediastinal hematomas, aortic intramural hematomas, aortic dissection or transection, and pleural collections. Both TTE and TEE play an important role in the assessment of patients with chest trauma, and TEE may be indicated in patients with polytrauma and/or on mechanical ventilation or when a traumatic, acute aortic syndrome is suspected. It is important to distinguish aortic from cardiac injuries. Also, traumatic pseudoaneurysms must be differentiated from true aneurysms. Trauma may cause aortic rupture, dissection, or intramural hematoma. Partial disruption of the aortic wall may lead to pseudoaneurysm. Once pericardial tamponade is excluded, a standard echocardiogram is useful in other conditions, like cardiac contusion/dysfunction, myocardial rupture, septal and valvular injury. Acute MI from coronary artery dissection and arrhythmias in acute trauma patients warrant echocardiographic evaluation.

4.7. Infective endocarditis

Febrile illness in critically ill patients warrants evaluation including infective endocarditis. See section on valvular lesions evaluations. Echocardiography is the test of choice for the noninvasive diagnosis of endocarditis. The echocardiographic findings may include new valvular regurgitation, an oscillating intracardiac mass on a valve or supporting structure or in the path of a regurgitant jet or an iatrogenic device, valve abscesses and new partial dehiscence or vegetation of a prosthetic valve. TEE has also been clearly shown to be superior to TTE for diagnosing complications of endocarditis, such as aortic root abscess, fistulas, and ruptured chordae tendineae of the mitral valve.

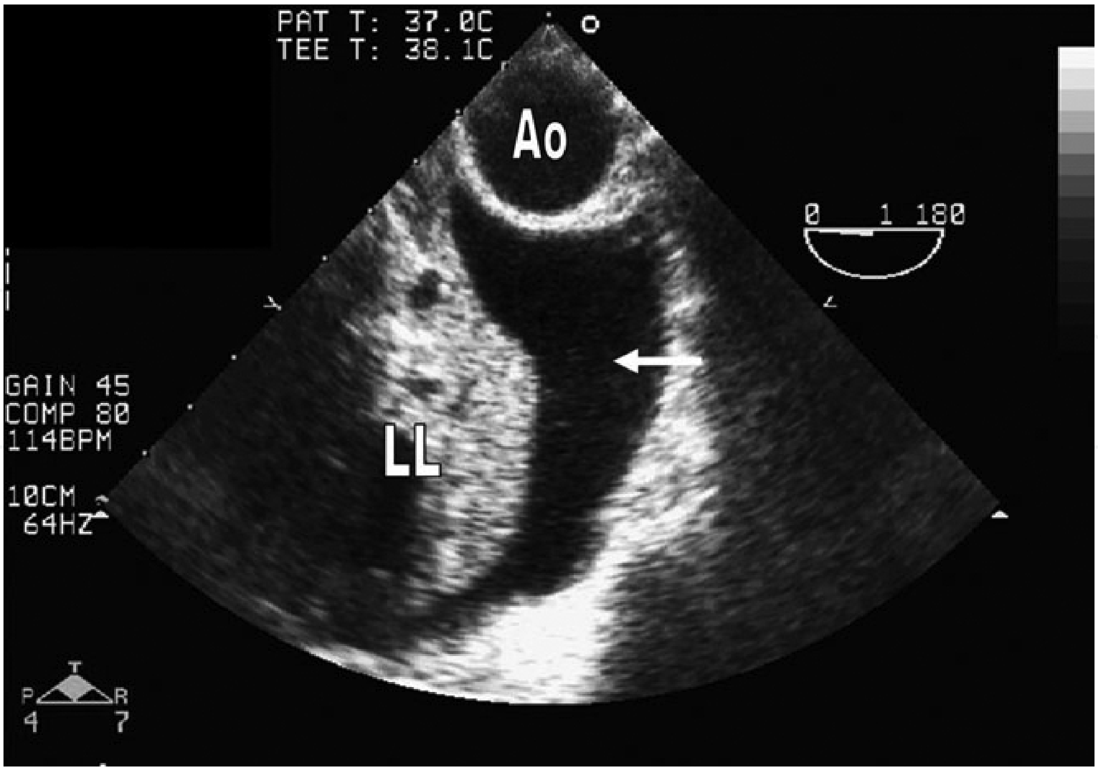

Figure 6. Pleural effusion on echo.

4.8. Pleural effusions

Echocardiogram often finds the presence of pleural effusions (**Figure 6**) and can be used as a diagnostic tool while evaluating the cardiovascular system, especially in patients with acute dyspnea and decompensated heart failure.

4.9. Assessment for intracardiac and intrapulmonary shunts

In critically ill patients with unexplained embolic stroke or refractory hypoxemia, the presence of a right-to-left shunt needs to be excluded. Common positions of right-to-left shunt are atrial septal defect or patent foramen ovale at the cardiac level, arteriovenous fistula at the pulmonary level and pulmonary arteriovenous fistulas. Bubble study, color Doppler studies, and contrast-enhanced studies are done to increase the detection rate of intracardiac shunt.

4.10. Source of embolus

Patients presenting with acute unexplained embolic stroke and arterial occlusions, echocardiography should be obtained to investigate a potential embolic source of cardiac origin. In this situation, TEE is the preferred imaging of choice. Possible cardiac sources of emboli include thrombus in the left atrial or appendage, LV thrombus, valvular vegetation, right-sided clots (right atrium, right ventricle, vena cava) combined with a right-to-left intracardiac shunt (leading to a paradoxical embolus), thoracic atheromatosis, and cardiac tumors. TEE is a valuable tool in evaluating the left atrium and appendage for the presence of thrombus, for patients with atrial fibrillation or flutter in whom cardioversion is considered.

5. Conclusion

Echocardiography is now considered as an indispensable tool and primary imaging modality for diagnosis and management of hemodynamic monitoring in critically ill patients. However, echocardiography is subject to variations in interpretation, which can potentially lead to errors, as with any diagnostic and monitoring tool and caution need to be undertaken during interpretation. Nevertheless, it provides advantages including noninvasiveness and rapid and accurate real-time anatomical and functional assessment of the cardiovascular system under stressful situations and is very useful in assisting therapeutic procedures.

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