Chapter 14
Transthoracic Echocardiography: The Basic Views

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Abstract Bedside transthoracic echocardiography (TTE) is a valuable, noninvasive, point-of-care diagnostic tool that can be used for cardiac evaluation of symptomatic or hemodynamically unstable patients. Use of TTE in the perioperative setting, emergency medicine or critical care patient population can provide new objective data and guide clinical management. The increasing availability of TTE and minimal training required to become competent makes the bedside TTE examination complementary to TEE.

Keywords Transthoracic echocardiography · Cardiac ultrasound · Basic views · Bedside transthoracic echocardiography (TTE) · Noninvasive

Abbreviations

TTE	Transthoracic echocardiography
TEE	Transesophageal echocardiography
LV	Left ventricle
FOCUS	Focused cardiac ultrasound
ASE	American Society of Echocardiography
ACEP	American College of Emergency Physicians
PEA	Pulseless electrical activity
LAX	Long axis
LA	Left atrium

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LVOT	Left ventricular outflow tract
RV	Right ventricle
SAX	Short axis
IVC	Inferior vena cava

Bedside transthoracic echocardiography (TTE) is an increasingly used, noninvasive diagnostic tool for cardiac evaluation of symptomatic and hemodynamically unstable patients. With minimal training in image acquisition and interpretation, intensivists can use bedside TTE to estimate global left ventricular (LV) function with reasonable accuracy [1]. In addition, the information obtained from a focused cardiac ultrasound (FOCUS) examination can guide management in the critically ill patient until a formal echocardiographic examination can be completed. The American Society of Echocardiography (ASE) and American College of Emergency Physicians (ACEP) emphasize the important role of FOCUS in patient care and its complementary role to comprehensive echocardiography [2].

For patients with undifferentiated hypotension, the primary advantage of bedside TTE is to distinguish cardiogenic shock from shock of other causes [2]. Hand-held echocardiography may also be used in the management of cardiac arrest for the evaluation of reversible causes [3]. Furthermore, using bedside echocardiography to distinguish between true pulseless electrical activity (PEA) and "pseudo-PEA," in which the patients have echocardiographic evidence of cardiac motion without palpable pulses, can change outcomes [2, 3]. Patients with "pseudo-PEA" arrest had better prognoses as they had potentially treatable causes that could be identified by TTE [4]. Other time-sensitive evaluations that can be completed with bedside TTE include assessment for pericardial effusion, relative chamber size, global cardiac systolic function, and volume status.

This chapter is not intended to be a comprehensive review of TTE. Instead, the goal of this chapter is to provide a brief overview of how to acquire the basic TTE views and recognize abnormalities that may cause hemodynamic instability. As discussed in Chap. 11, evaluating the hemodynamically unstable patient focuses on identifying gross abnormalities on echocardiography and implementing correctional action. Noting small minutiae of findings is typically not the cause of significant hemodynamic disturbances. A formal echocardiographic evaluation may be indicated to follow up and/or confirm preliminary findings.

Basic TTE Views

When introducing TTE imaging into a practice, many practitioners have the sense that this modality is a difficult endeavor to learn. However, when transitioning to TTE imaging from a knowledge base of transesophageal echocardiography (TEE), the echocardiographer can envision that the ultrasound physics, cardiac structures, and cardiac physiology are unchanged. Although the approach to the heart, “the windows,” is different, the views are often very similar. For example, the parasternal long-axis view images the same structures as the midesophageal (ME) long-axis view; the image is simply “turned” on its side. Once the echocardiographer gathers confidence in the image acquisition, the interpretation of the images is essentially unchanged.

Unlike transesophageal imaging where the esophagus remains in close position to the heart despite patient position or respiration, transthoracic imaging requires interaction of the patient for optimal views. The optimal patient position for transthoracic imaging depends upon the specific imaging window and desired view. Parasternal and apically located views often utilize the left lateral decubitus (LLD) position with the patient’s left arm extended above the head. The purpose of this position is to allow the heart to be located nearest the chest wall due to gravity. Raising the left arm also increases the intercostal distance, decreasing shadowing from the ribs. However, this is not always possible in critically ill or perioperative patients and compromises may be necessary. Subcostal views often benefit from the patient remaining supine and therefore offer an alternative window in patients who are unable to be optimally positioned. In addition, image clarity will vary with respirations as the probe on the chest wall moves toward and away from the heart. The addition of air-filled lungs between the probe and cardiac structures will often obscure the image appearance. Therefore, timing of ventilation through patient breath holding can aid in obtaining improved images.

Parasternal Long-Axis (LAX) View

The basic TTE examination begins with the parasternal LAX view and proceeds in a clockwise fashion (Fig. 14.1). With the ultrasound indicator (notch or light

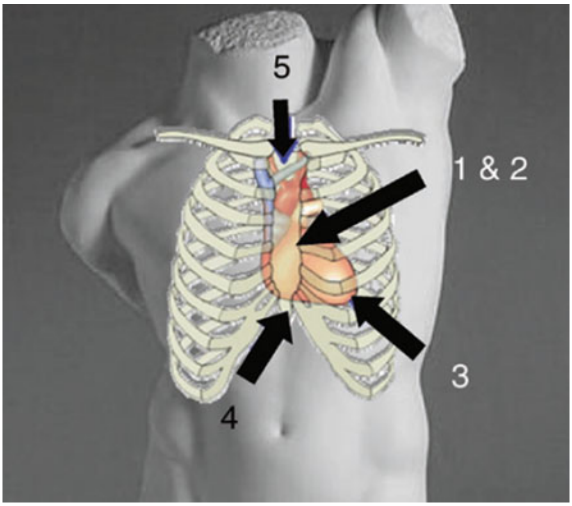

Fig. 14.1 Probe placement on chest wall for windows to basic transthoracic views. *1* parasternal long-axis view; *2* parasternal short-axis view; *3* apical four-chamber view; *4* subcostal view; *5* suprasternal view (not discussed in this chapter) (with permission from Springer Science+Business Media: Price [8])

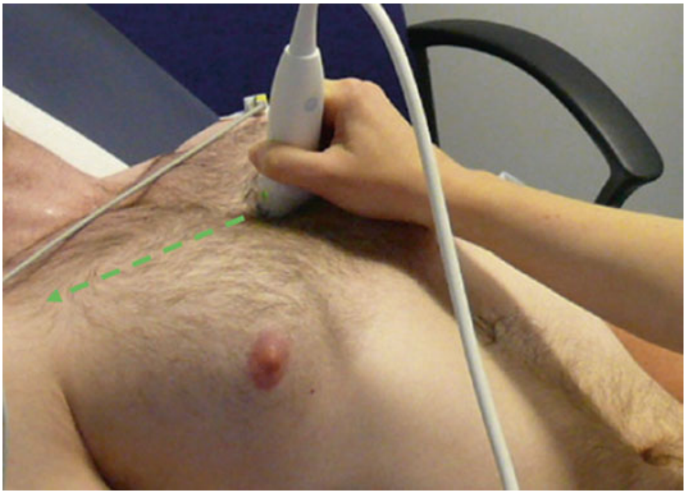

Fig. 14.2 Parasternal LAX probe position shown for a supine patient. The probe is placed in the second intercostal space lateral to the sternum with the indicator (direction noted by *green dashed arrow*) pointed toward the patient's right shoulder (with permission from Springer Science +Business Media: Price [8])

indicating the right side of the ultrasound image) pointing toward the patient's right shoulder, the transducer probe is placed in the second or third intercostal space just lateral to the left sternal border (Fig. 14.2). This view is often one of the easiest to obtain and simultaneously provides a significant amount of information. Structures that are seen and evaluated include the left atrium (LA), left ventricle (LV), left ventricular outflow tract (LVOT), right ventricular outflow tract (RVOT), left-sided valves inclusive of the mitral valve and aortic valve, and the proximal ascending aorta (Fig. 14.3; Video 14.1). When comparing to a similar TEE view, the parasternal long axis is nearly identical to a ME long axis displayed on its side. By increasing the depth of the image, a short-axis view of the descending aorta can be visualized in the far field of the image (Fig. 14.4).

In this echocardiographic window, RV size and systolic function, LV size and systolic function, regional wall motion of the anteroseptal and inferolateral walls, and stenosis or regurgitation of the mitral and aortic valves can be assessed. The parasternal LAX can also be used to identify an anterior or a posterior pericardial effusion as a cause of hemodynamic instability. The utility of this single view cannot be overstated.

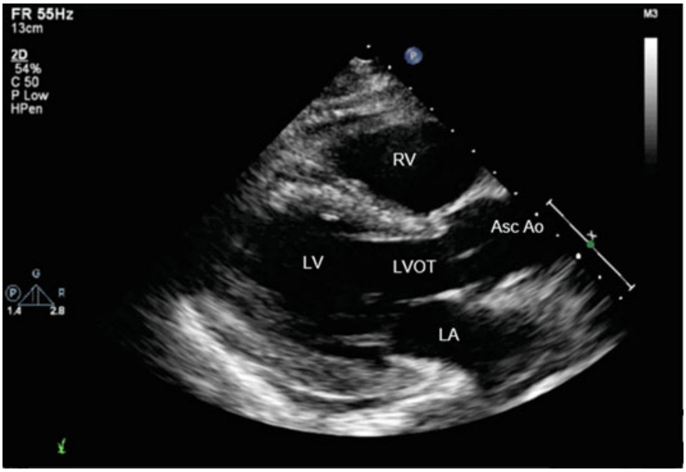

Fig. 14.3 Parasternal LAX view. *LA* left atrium; *LV* left ventricle; *LVOT* left ventricular outflow tract; *RV* right ventricle; *Asc Ao* ascending aorta

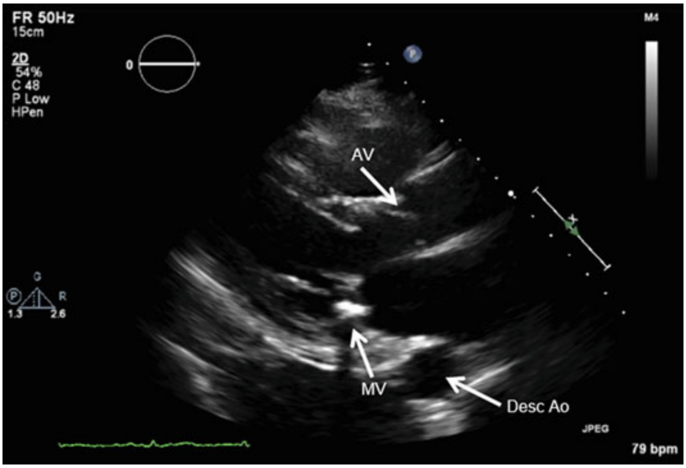

Fig. 14.4 Parasternal LAX view (increased depth). *AV* aortic valve; *MV* mitral valve; *Desc Ao* descending aorta

Parasternal Short-Axis (SAX) View

TEE from its relatively fixed position utilizes the omniplane to develop alternative imaging planes. In the setting of transthoracic imaging, the operator becomes the “omniplane” by holding the probe steady on the chest and simply rotating the probe on the chest in a clockwise or counterclockwise fashion. From the parasternal LAX view, with the patient remaining in the same position, the transducer probe is

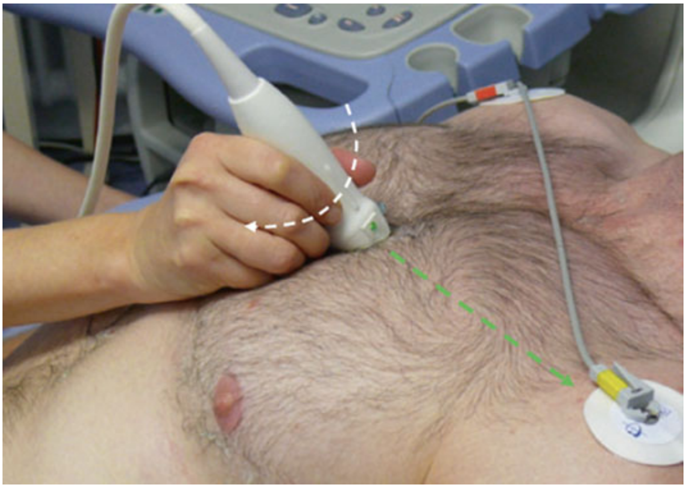

Fig. 14.5 Parasternal SAX probe position shown for a supine patient. The indicator is pointed toward the patient's left shoulder (direction noted by *green dashed arrow*). Through angling the probe superiorly to inferiorly as shown by the *white arrow*, the short axis of the aortic valve, mitral valve, and LV can be imaged (with permission from Springer Science + Business Media: Price [8])

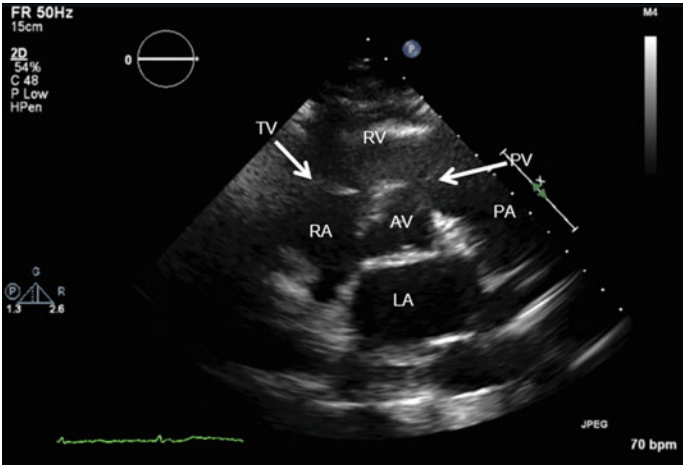

Fig. 14.6 Parasternal SAX view of the AV. *LA* left atrium; *RA* right atrium; *TV* tricuspid valve; *RV* right ventricle; *PV* pulmonic valve; *PA* pulmonary artery; *AV* aortic valve

rotated clockwise until the indicator is pointed toward the patient's left shoulder to obtain the parasternal SAX (Fig. 14.5). By angling the probe superiorly to inferiorly, a short-axis view of the aortic valve (Fig. 14.6; Video 14.2) and mitral valve (Fig. 14.7; Video 14.3), and LV (Fig. 14.8; Video 14.4) can be assessed. The

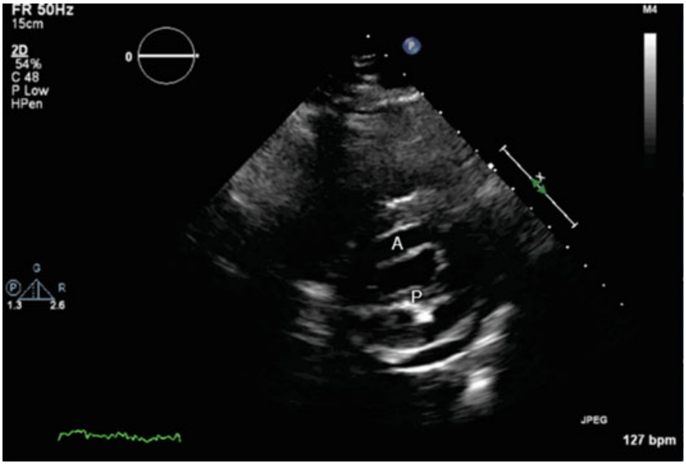

Fig. 14.7 Parasternal SAX basal view of the mitral valve with the leaflets open during diastole. *A* anterior leaflet; *P* posterior leaflet

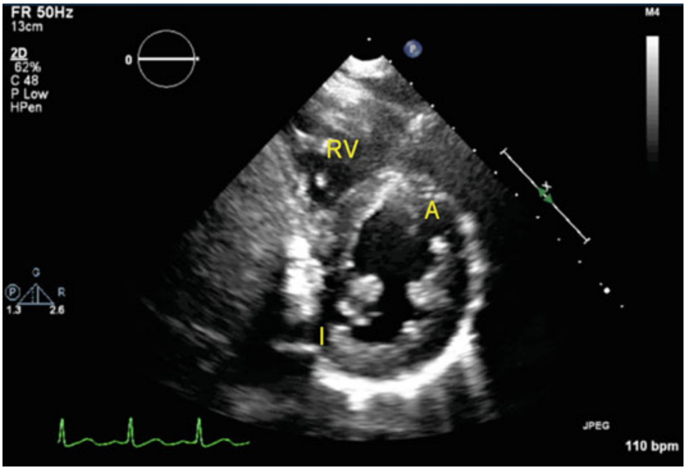

Fig. 14.8 Parasternal SAX mid-papillary view of the LV. *RV* right ventricle; *A* anterior LV wall; *I* inferior LV wall

angling can be analogous to anteflexion and retroflexion of the TEE probe to obtain superior to inferior structures.

In the parasternal SAX view of the aortic valve, overall chamber sizes of the left atrium, right atrium, and right ventricle can be appreciated. This view is analogous to the ME RV inflow-outflow view. Because of the Doppler alignment, the degree of tricuspid and pulmonic regurgitation can be assessed. Finally, in the parasternal SAX of the aortic valve and mitral valve, calcifications and morphology of valves can be evaluated. Continuing to angle the probe inferiorly, the mid-papillary SAX view of the LV will be imaged. This view allows for evaluation of regional wall motion, degree of LV hypertrophy, and presence of hypovolemia analogous to the TG mid-papillary short-axis view in TEE.

Apical Four-Chamber View

Similar to the ME four-chamber view, a transthoracic four-chamber view can image the same structures, however from the aspect of the LV apex. To obtain the apical four-chamber view, the patient remains in LLD position with the left arm extended above the head and the transducer probe is placed at the apex of the heart identified by the point of maximal impulse. The indicator is pointed toward the patient's left axilla while slight angle adjustments should be made to align the septum in the center of the imaging sector (Fig. 14.9). The four chambers of the heart should be visible, with the left atrium and LV on the right side of the imaging sector and the right atrium and RV on the left side of the imaging sector (Fig. 14.10; Video 14.5).

Though this view can be more difficult to consistently obtain than parasternal views, it yields large amounts of helpful information. All four chambers of the heart can be evaluated for dilation, systolic function of the RV and LV can be assessed, color flow Doppler interrogation of the mitral and tricuspid valves, and pericardial effusions can be appreciated in the apical four-chamber view. Lastly with improved comfort in obtaining this view, mitral valve inflow and lateral wall tissue Doppler imaging may provide insight into diastolic function.

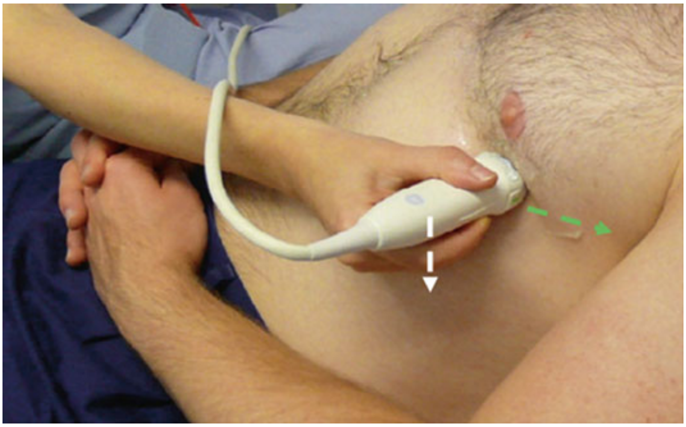

Fig. 14.9 Apical four-chamber probe position shown for a supine patient. The probe is placed at the apex of the heart (point of maximal impulse) and the indicator (*green arrow*) is pointed toward the patient's left side. The *white arrow* indicates the lateral movement of the tail of the probe to center the four chambers on the image (with permission from Springer Science+Business Media: Price [8])

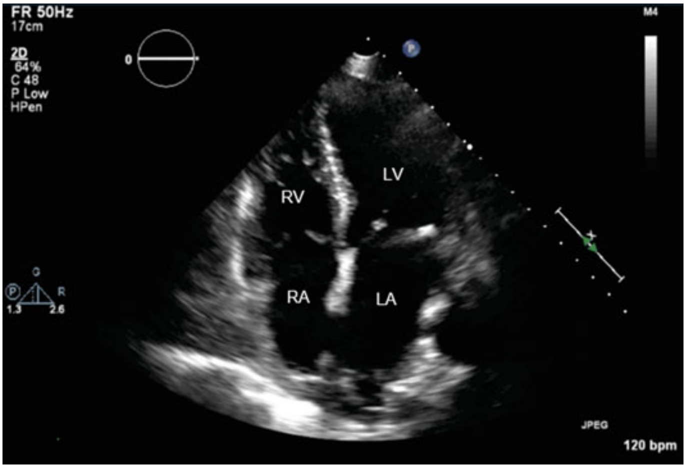

Fig. 14.10 Apical four-chamber view. *RA* right atrium; *RV* right ventricle; *LA* left atrium; *LV* left ventricle

Again envisioning the ultrasound operator as the "omniplane," counterclockwise rotation of the probe while keeping the location of the probe unchanged will develop the apical four-chamber view to an apical two-chamber view and further to the apical long-axis views. This is akin to increasing the omniplane in TEE from the midesophageal four-chamber view to the midesophageal two-chamber and long-axis views.

Subcostal Views

In critically ill patients, especially those that are receiving positive pressure ventilation and positive end expiratory pressure (PEEP), the parasternal and apical views may be difficult to obtain or of poor quality. The subcostal view can be used in this subset of patients. The increased intrathoracic pressure will "push" the heart in a caudal direction, improving subcostal imaging. The subcostal four-chamber view is obtained by placing the probe just below the xiphoid, with the indicator pointed toward the patient's left side and the ultrasound beam directed superiorly toward the heart (Figs. 14.11 and 14.12). The inferior vena cava (IVC) entering into the RA can be developed with counterclockwise rotation of the probe (Fig. 14.13; Video 14.6). The diameter and collapsibility of the IVC can be used to aid in the determination of fluid responsiveness and estimates of central venous pressure.

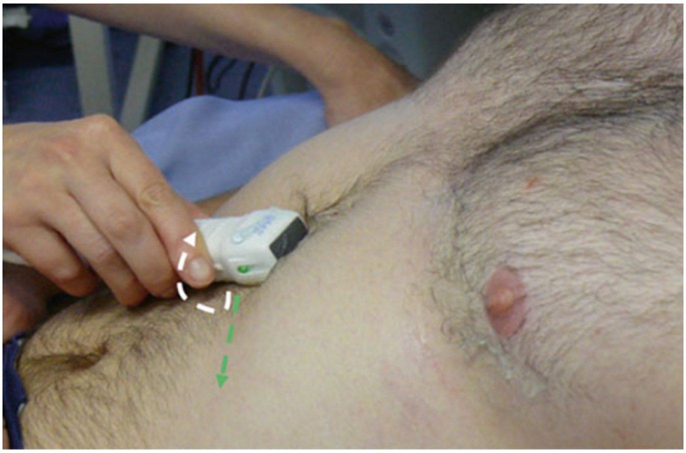

Fig. 14.11 Subcostal probe position shown for a supine patient. The probe is placed just below the xyphoid with the indicator (*green arrow*) pointed toward the patient's left. To view the IVC, the probe is rotated counterclockwise (*white arrow*) (with permission from Springer Science +Business Media: Price [8])

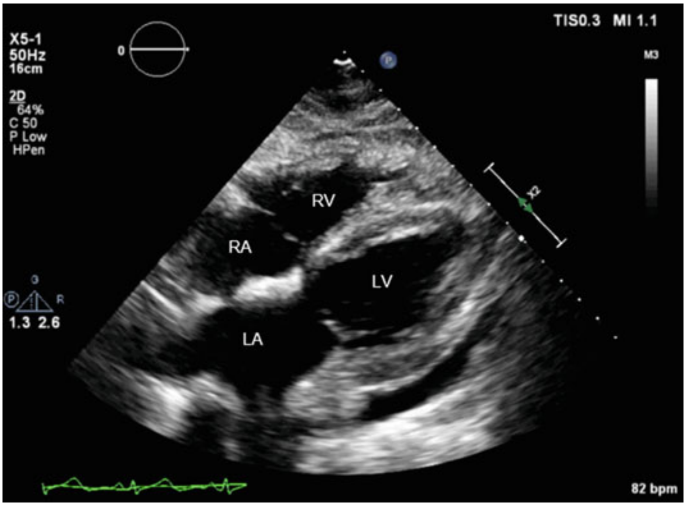

Fig. 14.12 Subcostal four-chamber view. *RA* right atrium; *RV* right ventricle; *LA* left atrium; *LV* left ventricle

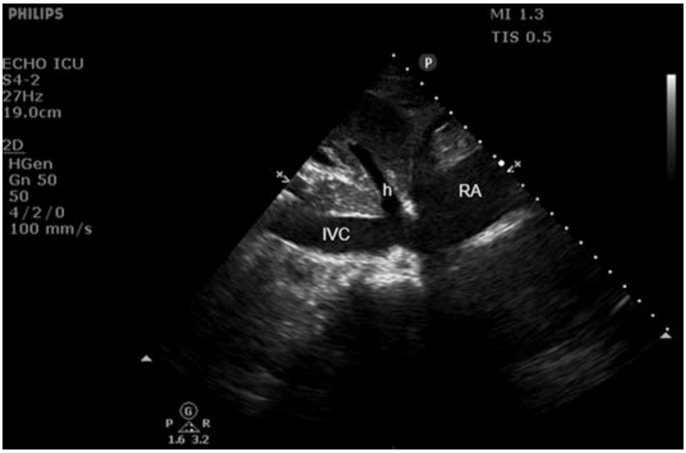

Fig. 14.13 Subcostal IVC view. *IVC* inferior vena cava; *RA* right atrium; *h* hepatic vein

Examples of Hemodynamic Compromise

Bedside TTE is commonly used to assess volume status or fluid responsiveness in the critically ill patient population. Though potentially difficult, estimating fluid responsiveness is important in the management of septic shock as hypovolemia is associated with worse outcomes but over-resuscitation has also been found to increase mortality [5]. In conjunction with other clinical data, a finding suggestive that patients may require additional resuscitation is a collapsed or obliterated LV cavity seen in the parasternal SAX view during systole (Fig. 14.14; Video 14.7). Though the results should be interpreted with caution, respiratory variation of the IVC is also commonly used as a predictor of fluid responsiveness [6]. Patients with a respiratory variation of more than 40 % are more likely to respond to a fluid challenge (Video 14.6).

Life threatening causes of hemodynamic instability that warrant immediate intervention include cardiac tamponade and pulmonary embolism. Cardiac tamponade or concern that a pericardial effusion is causing hemodynamic instability (Fig. 14.15; Video 14.8) requires consultation with a cardiothoracic surgeon immediately. Though a bedside TTE should not be the only tool used to diagnose a pulmonary embolism, there are findings that raise the suspicion that the patient has a pulmonary embolus. Dilation of the RV is often significant, although it is non-specific for a pulmonary embolus (Fig. 14.16). A more specific finding is the distinct echocardiographic pattern of regional RV dysfunction in the mid-free wall with sparing of the apex, also known as the McConnell's sign [7] (Video 14.9). The tethering of the right ventricular apex to the hyperdynamic left ventricle is thought to be responsible for the preserved apical wall motion. As discussed in Chap. 11, the sensitivity and specificity of McConnell's sign has been called into question. However, this finding raises the level of clinical suspicion for an acute pulmonary embolus.

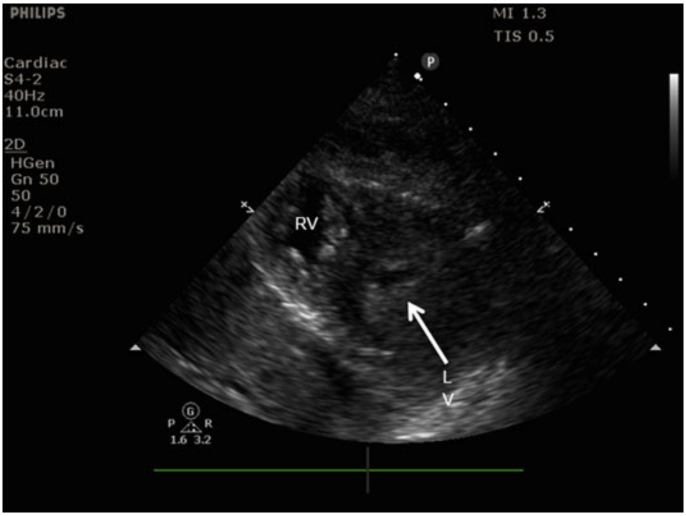

Fig. 14.14 End systolic parasternal SAX view showing an obliterated LV cavity in a patient with hypovolemia. This patient also has significant left ventricular hypertrophy (LVH). *RV* right ventricle; *LV* left ventricle

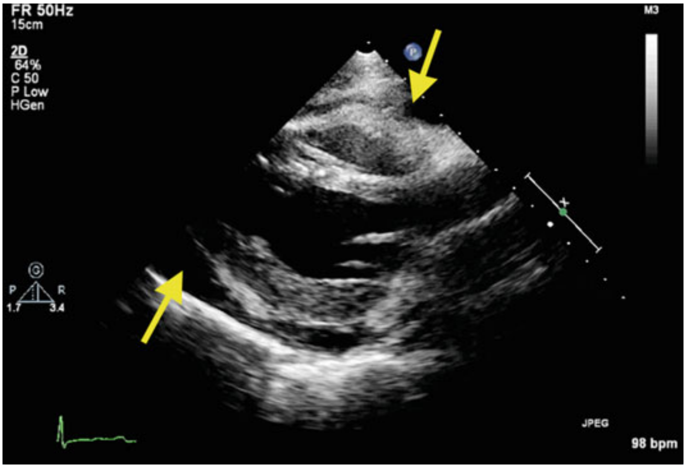

Fig. 14.15 Parasternal SAX view demonstrating a pericardial effusion (*yellow arrows*) that resulted in hemodynamic instability. Please see Video 14.8 to observe the dynamic component of the effusion

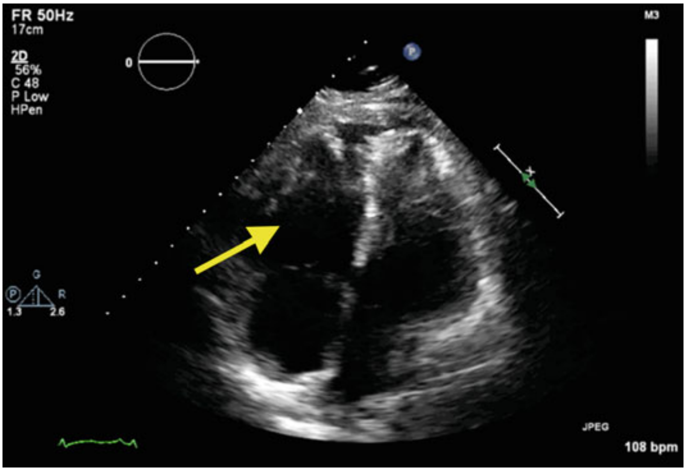

Fig. 14.16 Apical four-chamber view in a patient with a dilated RV (*yellow arrow*) due to an acute pulmonary embolus

Conclusion

Bedside TTE is a valuable, noninvasive, point-of-care diagnostic tool that has been shown to be helpful in perioperative and hemodynamically unstable patients. Adding TTE to a basis of TEE knowledge requires that the operator learn additional "windows" to the heart, however the normal anatomy, pathologic states, and cardiac physiology remain unchanged. Once past this hurdle of new "windows," it becomes relatively easy to integrate TTE into practice to identify gross abnormalities in the unstable patient.

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