

Better With Ultrasound

Transesophageal Echocardiography



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Transesophageal echocardiography (TEE) is a safe and minimally invasive tool that can routinely provide high-quality anatomic and hemodynamic information in the severely ill. Despite its potential for frontline acute care clinicians, TEE use has typically been reserved for diagnostic experts in the cardiac-surgical milieu. With the continued evolution of point-of-care ultrasound into increasingly sophisticated domains, TEE has gained steady uptake in many nontraditional environments for both advanced echocardiographic assessment as well as answering more goal directed, fundamental questions. This article introduces the workings of the TEE transducer, presents a systematic approach to a goal-directed hemodynamic assessment, and includes a series of illustrative figures and narrated video presentations to demonstrate the techniques described. CHEST 2019; 155(1):194-201

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The use of point-of-care ultrasound is becoming increasingly fundamental to the care of acutely ill patients, whether they are in the ED, the operating room (OR), or the ICU. From a critical care perspective, the taxonomy of ultrasound has been standardized and can be broken down into general critical care ultrasound (thoracic, abdominal, and vascular ultrasound) and critical care echocardiography, which is itself composed of both basic and advanced scopes. A basic cardiac examination addresses common, everyday questions for patients in shock such as left ventricular (LV) function, right ventricular (RV) size and function, the pericardium for effusion, gross left-sided valvular evaluation, and elements related to a patient's volume status.

An advanced critical care echocardiography examination addresses more complex and quantitative elements and may more closely resemble the scope of a comprehensive, diagnostic echocardiogram.¹

The conventional dogma has been that the basic examination called for a transthoracic echocardiogram (TTE) approach and an advanced examination may call on either TTE or transesophageal echocardiography (TEE) to address the questions at hand. Because comfort with TEE increases at the point-of-care, the emphasis is shifting to a more pragmatic approach; no matter the complexity of the examination (basic vs advanced), one should use the echo modality (TTE or TEE) that is best able to

ABBREVIATIONS: LV = left ventricular; OR = operating room; RV = right ventricular; SVC = superior vena cava; TEE = transesophageal echocardiography; TTE = transthoracic echocardiogram

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answer the clinical question at hand; indeed there is increasing recognition of the role of TEE for basic cardiac examinations.²

More liberal use of TEE is being seen in environments outside of the ICU as well. From an anesthesia perspective, TEE has moved from the exclusive realm of the cardiac OR to many types of high-risk surgeries.^{3,4} In the ED, use of TEE has been described and safely deployed in high-risk patients such as those in cardiac arrest.⁵ Hemodynamic assessment with TEE is performed as a matter of routine in some ICUs,⁶ and its use in critical care is expanding in general⁷ as more cardiac point-of-care ultrasound users acquire advanced-level skills and more ICUs recognize the many advantages of the tool.

General Advantages of TEE

The key arguments that support TEE as an influential, versatile hemodynamic tool for acute care providers can be summarized as follows.

1. Consistent, High-Quality Image Acquisition

Image acquisition via a transthoracic approach can be challenging in acutely unwell patients, especially those who are obese, mechanically ventilated, in a postoperative state (with associated surgical dressings), or all three. In stark contrast, image acquisition via transesophageal approach is almost universally associated with easily obtained high-quality images. Indeed, the fewer degrees of freedom associated with TEE is a major advantage: a provider performing a TTE examination is “free” to place the transducer anywhere on the patient’s chest, whereas TEE restrains the probe within the narrow esophagus and therefore consistently directs it to a position where good-quality images can be obtained. Common barriers such as hyperinflated lungs, adipose tissue, and surgical dressings are rendered irrelevant.

2. Favorable Safety Profile

The risks associated with TEE, discussed in detail later in this article, are sufficiently low that they are difficult to quantify accurately. As such, and because of the major advantages associated with the acquisition of high-quality cardiac images, the balance of risk and benefit in performing a transesophageal examination in a critically ill patient is often very favorable.

3. Rapid Examination Completion

A TEE can be performed rapidly by an experienced provider. Given the general ease of image acquisition, the total examination time is often comparable to a TTE

examination despite the time required for transducer insertion.

4. Ease of Learning

It appears that a goal-directed TEE examination can be learned in a relatively short time,⁸ provided that the clinician is already adept at basic-level TTE.⁵ Because the basic image interpretation and clinical integration skill sets are nearly identical whether looking at TTE or TEE images, all that remains to be learned is transducer insertion and image acquisition.

5. Need for a Hemodynamic Monitoring Tool

The pulmonary artery catheter has fallen out of favor in many parts of the world, especially in the management of a critically ill medical patient.⁹ A host of potential noninvasive or less invasive tools have emerged as potential candidates to replace it,¹⁰ but thus far all have substantial drawbacks, a limited evidence base, or both. TEE is able to meet the goals commonly required of hemodynamic monitoring,¹¹ possesses a comparatively long track record of safe use, and is less invasive compared with many of the alternatives. In addition to its hemodynamic role, the diagnostic and anatomic information it provides is frequently influential in the acutely ill.

Complications Associated With TEE

TEE-related risk has been well studied and supports the assertion that the procedure has an excellent safety profile. Because of the differing fashion in which ambulatory, intraoperative, and critical care TEE examinations are carried out, there is variation in safety, and the data must be analyzed with this in mind. In ambulatory TEE, for example, the patient’s airway is not secured and the examination is typically performed in an environment with less intensive monitoring than an OR or ICU, making the administration of sedative medications more challenging. Related to this, with awake patients who tend to cough, gag, and move, the risk of esophageal injury appears to be higher.

Important potential risks of TEE, which are generally less common in critically ill patients, include the following.

1. Sedation-Related Complications

Complications that can be tied to the administration of sedative medications are very rare in critically ill patients. The risk of transient dysrhythmia is low, perhaps on the order of 1%.^{12,13} Similarly, transient hypotension may affect 1% of patients.¹⁴

2. Bleeding

The rate of minor bleeding in critically ill patients is unknown, but is very low in intraoperative patients; minor bleeding rates were 0.01% in one study of 7,200 cardiac OR patients.¹⁵ Rates of major bleeding episodes are also rare, ranging from 0.03% to 0.8% in intraoperative studies,^{15,16} with two studies in critically ill patients having no bleeding episodes described.^{13,14}

3. Esophageal Perforation

This most feared complication associated with esophageal intubation is extremely rare. The largest retrospective review, involving 10,419 TEE examinations, had no incidents of esophageal perforation.¹⁷ Combining the five largest reviews¹³⁻¹⁷ reveals a total of three episodes of esophageal perforation in almost 30,000 examinations; it therefore seems reasonable to argue that the risk of this complication is so low that it is difficult to quantify accurately, but may be on the order of 1:10,000 attempts.

The list of potential contraindications to TEE should be remembered. Although there is no evidence or even expert consensus to guide us, most would consider recent esophageal surgery, esophageal trauma, esophageal stricture, Zenker diverticulum, or esophageal fistula to be absolute contraindications. Other conditions such as esophageal varices or a history of gastric surgery represent either absolute or very strong relative contraindications. Care should be exercised when the patient history is incomplete or with a history of dysphagia.¹⁸

TEE transducer cleaning and maintenance can present unexpected barriers for new users. The probe must be thoroughly cleaned and disinfected per the manufacturer's instructions after each use. Although this can be done by the operator, it is generally better performed by the hospital's sterile supply department in a manner analogous to the cleaning of gastroscopes and other endoscopic equipment.

Technique 1: Understand How the Transducer Functions

When training to perform critical care TEE, as with any technical skill, there is no substitute for hands-on experience (Figs 1, 2; Video 1). Reading about probe movements does not translate into ability, and this article is best matched with simulated practice or supervised, in vivo experience. Nearly all ultrasound machines found in point-of-care environments have

TEE probe capability, aside from the newer hand-held devices. An in-depth understanding of your ultrasound machine and a working knowledge of the knobology required for image optimization, Doppler assessments, and taking measurements on the device is a prerequisite.

A TEE probe looks and functions much the same as an endoscope. The piezoelectric crystals project from the phased-array transducer lens at the tip of the probe and can be rotated to generate a multitude of planes of interrogation; this is called the omniplane angle (although it is often referred to by other names such as multiplane or multibeam). The buttons to adjust omniplane rotation, two wheels to control flexion (anteroposterior flexion and left-right lateral flexion), and a lock lever are on the handle of the probe (Fig 1). The TEE probe has a built-in thermometer designed to prevent thermal injury by automatically turning off the probe when the temperature reaches 42°C. Although the continuous knowledge of core temperature is advantageous, in the pyretic critically ill patient, this may result in pauses or cessation of the examination because the transducer may more easily reach this ceiling temperature.

Aside from the gross movements of the endoscope itself (eg, advancing/withdrawing, turning), the bulk of image acquisition steps and optimizations with TEE must be made using remote manipulation of the ultrasound beam from the handle of the probe. The major movements of the probe and their controls are described here using terminology consistent with that used by the American Society of Echocardiography and previously published descriptions of critical care TEE within CHEST.^{19,20} There are four ways to manipulate the TEE image.

1. Advance and withdraw. Advancing requires the sonographer to push the probe distally into the esophagus or stomach, whereas withdrawal pulls the probe proximally.
2. Turn right or left. Turning refers to the clockwise or counterclockwise movement of the entire probe. The direction of the turn, right or left, applies to the patient's right and left side, respectively.
3. Rotation. Rotation describes adjustment of the omniplane angle. Forward rotation increases the omniplane from 0 through 180° and backwards rotation from 180 through to 0° (Fig 2). There is no universal consensus for the terms "rotation" and "turning" with respect to transducer movements; the terms are often used interchangeably.

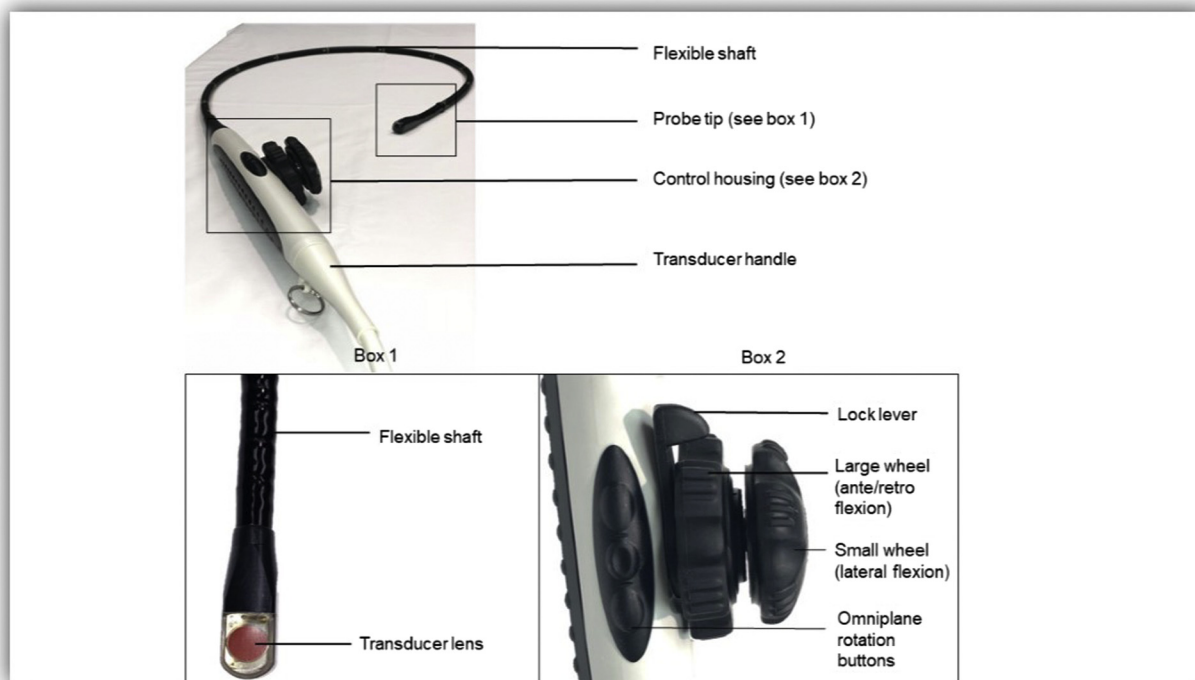


Figure 1 – Transesophageal ultrasound transducer.

4. Flexion. Anteflexion and retroflexion describe flexion of the probe toward the anterior and posterior of the patient, respectively. These movements are achieved by turning the large wheel clockwise (anteflexion) and counterclockwise (retroflexion). The small wheel controls lateral flexion: clockwise rotation flexes the probe leftward and counterclockwise flexes the probe rightward (Fig 2).

Technique 2: Insert Transducer Into Esophagus

The invasive nature of TEE and the risks of iatrogenic injury may result in a sense of trepidation otherwise foreign to many sonographers (Video 2); however, as discussed previously, TEE has a very reassuring safety profile.^{17,21} Proper preparation and a gentle, centrally aligned probe insertion technique are the best ways to mitigate risk.

Patients should be deeply sedated before probe insertion. In some cases, neuromuscular blockade is advantageous, rendering the patient passive on the ventilator and thus facilitating accurate assessment of preload sensitivity.^{6,22} In resuscitative scenarios such as cardiac arrest, sedation and paralysis may not be safe to administer, and transducer insertion may proceed without medication; insertion is often more straightforward in such situations because of loss of motor tone.

The transducer can be inserted from the head or side of the bed depending on the clinical scenario, space constraints, and operator preference. If there are significant anatomic challenges, probe insertion can be facilitated by direct or video laryngoscopy.²³ Some operators choose to make one or two attempts at insertion and then move to video laryngoscopy thereafter, although this is rarely necessary in the authors' experience. In most cases, a tactile approach, as described here, will suffice.

1. Use a bite block to ease the passage of the TEE probe; this helps guide the probe along the midline of the mouth and pharynx and acts as a safeguard against damage if the neuromuscular blockade is not being used or wears off.
2. Ensure the lock lever is in the off position to eliminate any fixed flexion.
3. Insert the TEE probe with the front of the transducer tip (typically the flatter aspect, where the ultrasound beam will originate) placed along the floor of the mouth so that, as it is advanced into the esophagus, the beam will be directed anteriorly.
4. Once the probe has been placed in the mouth, have an assistant perform a jaw thrust maneuver (chin lift if in C-spine precautions or if a lone operator). To move past the posterior oropharynx, its contour

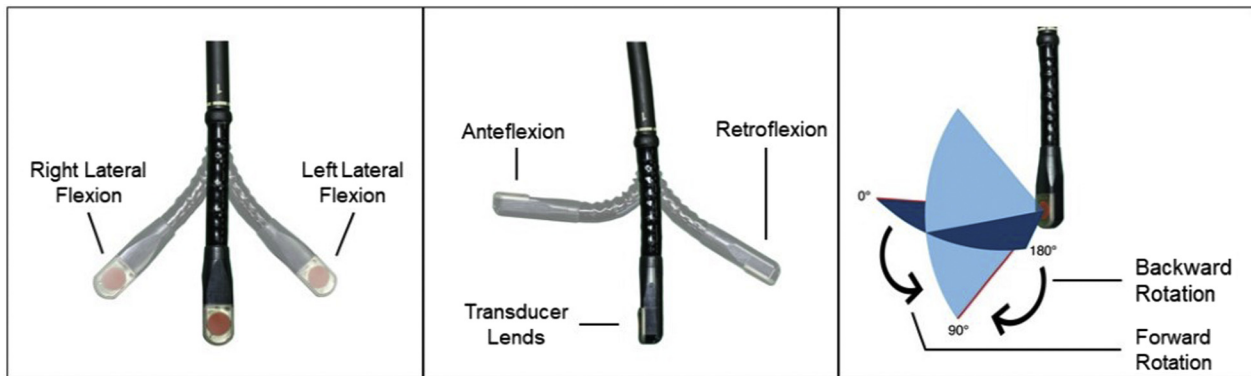


Figure 2 – Movements of the transesophageal ultrasound transducer.

may be matched by the probe through gentle anteflexion.

5. Advance the probe with gentle pressure. As the probe passes through the hypopharynx, there may be a “catch” of some slight resistance (frequently attributed to the cricopharyngeus muscle) that gives way as the probe enters the esophagus. Aggressive force is never necessary.
6. The most common pitfall of probe insertion is deviation from the midline, which may lodge the probe in the piriform sinus and lead to trauma. The assistant performing the jaw thrust will often be able to feel the probe if it is grossly deviated to one side and can inform the sonographer if readjustments to the midline are required.

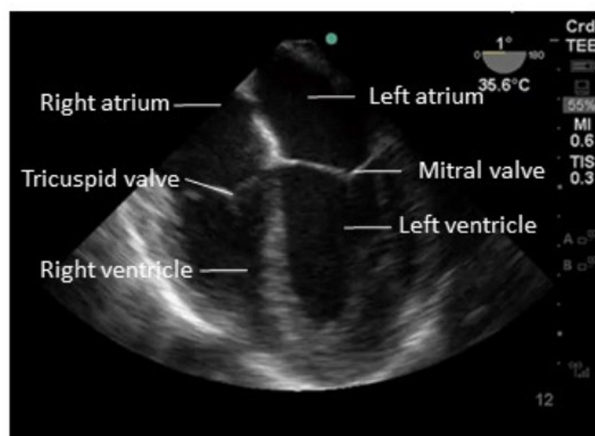
Technique 3: Obtain Four Core Views for Goal-Directed Examination

In an unstable patient, a goal-directed TEE examination requires only four core views (Fig 3; Video 3).^{5,24} Comprehensive studies as described by the American Society of Echocardiography call for 28 views, many of which are used for advanced valvular or diastolic function assessments and are frequently beyond the concerns of the resuscitative physician.²⁰ Other experts have suggested a 15-view examination,¹⁹ which is more in keeping with a typical examination performed in the cardiac OR. We propose that initial mastery of the four-view examination allows the operator to address the most commonly posed questions while achieving comfort with TEE probe insertion and all probe movements. As clinical complexity or operator skill set increases, scaling the probe movements to achieve additional views is straightforward and may be directed at rapidly achieving comfort with a more comprehensive, 15-view approach.

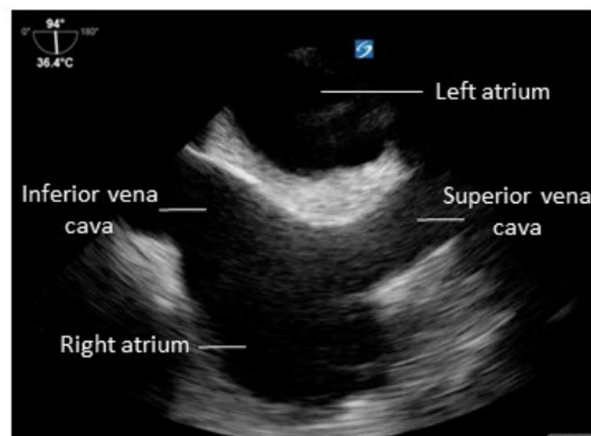
Although four views may be considered oversimplified by some experts, a four-view TEE examination has been shown to influence diagnostic and therapeutic choices in resuscitative scenarios and affords a structure for teaching TEE.⁷ Mastery of the four-view examination will impart the required dexterity with probe manipulation and insertion and has the significant advantage of being generally very quick to perform.

The four core views for a goal-directed TEE include the mid-esophageal four-chamber, mid-esophageal long axis, bicaval, and transgastric short-axis views.²⁴ Image acquisition will vary slightly from patient to patient, so probe position and omniplane angle cannot be prescribed exactly for all patients. Online simulators provide a convenient illustration of basic transducer manipulation (see pie.med.utoronto.ca/tee). A basic guide for acquisition of each of the core views is found here and demonstrated in Video 3.

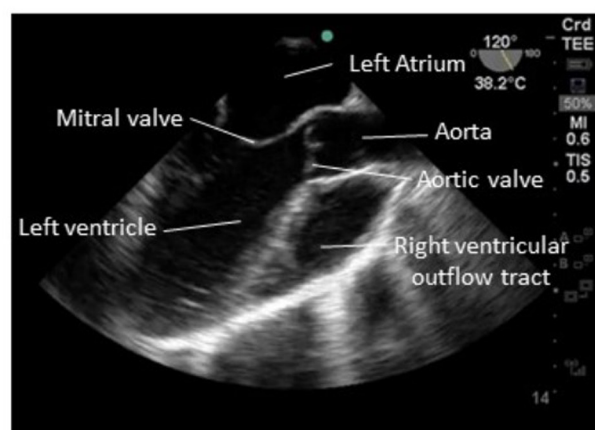
1. Mid-esophageal four-chamber view. This is the most straightforward view to acquire and is achieved readily by inserting the probe into the mid-esophagus with the omniplane at 0°. Advance the probe slightly if the aortic valve is prominent on screen and withdraw slightly if the coronary sinus is visible or the left atrium is not seen in the near field. Slight retroflexion of the probe will elongate the ventricle if the image appears foreshortened. The left and right atria, ventricles, tricuspid valve, and mitral valve can be readily assessed. The mid-esophageal four-chamber view is a reflection of its TTE counterpart, the apical-four chamber view. Use this view for a general assessment of LV and RV function, pericardium, as well as a two-dimensional and color Doppler assessment of the mitral and tricuspid valves. The size of the left and right ventricles can be compared when RV dilatation is suspected.



Mid-esophageal four-chamber



Bicaval



Mid-esophageal long axis



Trans-gastric short axis

Figure 3 – The four essential views for a goal-directed transesophageal examination. TEE = transesophageal echocardiography.

2. Mid-esophageal long-axis view. With the probe remaining in the mid-esophagus, rotate the omniplane to between 120 and 140°. Turn the probe slightly leftward to bring the anatomic structures of interest into view. Here the aortic valve as well as the aortic root, the left ventricle, mitral valve, left atrium, and the left ventricular outflow tract can all be appreciated. This view is analogous to the TTE parasternal long-axis view. Use this view to further inform the assessment of LV function and to evaluate the aortic and mitral valves; a proximal dissection of the ascending aorta can also be detected, as can obstruction of the LV outflow tract.
3. Mid-esophageal bicaval view. The final view obtained in the mid-esophagus, this view requires rotation of the omniplane to approximately 90° and a rightward turn of the probe to bring the inferior vena cava, superior vena cava (SVC), both atria, and intra-atrial septum into view. Use this view for procedural guidance (eg, central venous catheter insertion, extracorporeal membrane oxygenation cannulation), assessment for an intra-atrial shunt, and evaluating preload sensitivity by using M-mode to calculate SVC variation.
4. Transgastric short axis papillary muscle view. To acquire this view, advance the probe into the stomach. To be confident that the probe is sufficiently deep to allow for the antelexion that will soon ensue, ensure you have passed the coronary sinus (runs posteriorly along the back of the heart and is found approximately at the level of the gastroesophageal junction), as well as gastric rugae and/or liver in the near field. Once in the stomach, antelex the probe to bring it in contact with the fundus of the stomach. The omniplane angle should be at 0°. Advance or withdraw a neutral probe gently to fine tune a short-axis view at

the mid-papillary muscle level. Here the left and right ventricles in short axis will be visible, and for the first time all walls of the left ventricle can be assessed. Use this view for gross assessment of LV function, assessment for regional wall motion abnormalities, assessment of the dependent regions of the pericardium for effusion (or clot in the postcardiac procedural setting), and evaluation of septal kinetics as they relate to RV dysfunction.

Technique 4: Perform Goal-Directed Examination TEE

The order with which these views are obtained will vary depending on the clinical scenario. If there are no pressing indications to perform a particular view first, it is wise for clinicians to routinely use the same order, ensuring the completeness of the examination. The typical method for performing a goal-directed shock examination is described here and demonstrated in Video 4.

Insertion of the probe into the mid-esophagus allows near immediate visualization of the mid-esophageal four-chamber view. The operator completes an eyeball assessment of LV and RV function and assesses for any pericardial collections. The mitral and tricuspid valves can be evaluated in 2-dimensional and with color Doppler if a severe lesion is suspected. Next, move to the mid-esophageal long axis view to assess the aortic valve, aortic root, and mitral valve for significant pathology and corroborate the eyeball assessment of LV function. Moving on to the bicaval view allows assessment for preload responsiveness using SVC variation with M-mode and to check for atrial septal defect or patent foramen ovale in cases of severe hypoxemia. Finally, obtain the transgastric short-axis view to evaluate the pericardium and LV function one last time and to examine the interventricular septum for signs of RV dysfunction.

With practice, this goal-directed examination can be completed within minutes, quickly differentiating causes of shock and respiratory failure and informing changes in diagnosis or therapeutic management. From mastery of these four views, users can rapidly gain fluency in the additional core views and expand the scope of their TEE examinations to suit their cognitive abilities and the unique complexities of the patient circumstances.

Conclusion

TEE is a safe and minimally invasive tool that reliably provides high-quality hemodynamic assessment

regardless of body habitus or severity of illness. Diagnostic and therapeutic utility can be found with as few as four core views: the mid-esophageal four-chamber, mid-esophageal long axis, bicaval, and transgastric short axis. Mastery of these views can be easily scaled to provide answers to more complex questions for those users with appropriate echocardiographic knowledge.

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Additional information: The Videos can be found in the Supplemental Materials section of the online article.

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