

## reviews

# Overview of Transesophageal Echocardiography for the Chest Physician\*

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**Transesophageal echocardiography (TEE) is a growing technology that is frequently utilized in the critical care setting by intensivists, surgeons, anesthesiologists as well as specialists in cardiovascular diseases. The clinical application of TEE continues to emerge, and the indications and diagnostic utility of this technology as currently available are summarized in this review.**  
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**Key words:** infective endocarditis; patent foramen ovale; prosthetic heart valves; transesophageal echocardiography

**Abbreviations:** AF = atrial fibrillation; AIH = aortic intramural hematoma; ASA = atrial septal aneurysm; AVR = aortic valve replacement; BMV = balloon mitral valvuloplasty; IAS = interatrial septum; IE = infective endocarditis; LA = left atrium, atrial; LAA = left atrial appendage; LV = left ventricle, ventricular; MR = mitral regurgitation; PAU = penetrating aortic ulcer; PFO = patent foramen ovale; RV = right ventricle, ventricular; TEE = transesophageal echocardiography; TTE = transthoracic echocardiogram

**T**ransesophageal echocardiography (TEE) is the term used to describe the study of the heart from the esophagus using two-dimensional, M-mode or Doppler echocardiography. The esophagus is a muscular canal with an average diameter of 2 cm extending approximately 25 cm from the pharynx to the stomach. As it descends inferiorly into the thorax, the esophagus passes behind the trachea, left mainstem bronchus, left atrium (LA), and left ventricle (LV) before it passes through the diaphragm.<sup>1</sup> Because of the close apposition of the esophagus to the posterior surface of the heart, the sound beam must pass through only the muscular esophageal wall before reaching the pericardium, making the esophagus an ideal echocardiographic window for cardiac examination.

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## INDICATIONS FOR TEE

The most common indications for TEE are evaluation for infective endocarditis (IE), assessment of embolic risk prior to cardioversion for atrial fibrillation (AF), and evaluating the heart and aorta as a source for systemic emboli. Other clinical situations in which TEE is indicated include aortic dissection, intraoperative and perioperative cardiac monitoring, and instances in which the transthoracic echocardiogram (TTE) is diagnostically inadequate due to poor quality or limited echocardiographic windows, which is frequently encountered in patients receiving mechanical ventilation and other critically ill patients in ICU settings.

### Endocarditis

Several studies have demonstrated the role of TEE in the detection of native and prosthetic valve vegetation due to IE. The sensitivity of TEE for vegetation on native valves in patients with IE is 90 to 100%, compared to 60% for TTE.<sup>2–4</sup> In patients with prosthetic valve IE, TEE has become an essential diagnostic tool in situations in which the sensitivity of TTE is a mere 36% compared to 85% for TEE.<sup>5,6</sup> As a result, it appears justified to begin with

TEE rather than TTE in the workup of patients with suspected prosthetic valve IE. TTE can be a useful screening tool for native valve IE but should be followed by TEE if the findings are nondiagnostic.

The specificity of echocardiography for the presence of native valve IE may be lowered by erroneous diagnosis attributable to lesions that resemble vegetation such as Lambl excrescences, valvular fibrin strands, ruptured or redundant chordae, nonspecific valvular thickening, or calcification. Distinguishing a vegetation from other types of masses seen by echocardiography requires knowledge of its most and least likely echocardiographic characteristics, which are influenced by echogenicity, shape, location, and mobility.<sup>4,7</sup>

Factors that influence the sensitivity and specificity of echocardiography for detecting native valve IE also impact prosthetic valve IE. Moreover, acoustic shadowing from prosthetic material, which can obscure lesions distal to the prosthesis, can lower the sensitivity of echocardiography in the diagnosis of IE. Thus, the sensitivities for detecting prosthetic valve IE vs native valve IE are lower with TTE (35% vs 60%, respectively) compared to TEE (85% vs 95%, respectively).<sup>2,5,6,8</sup> The specificities, however, of echocardiography for prosthetic valve IE and native valve IE are similar. False-positive findings, however, may occur from the erroneous interpretation of artifactual phantoms, sewing ring suture, surgically severed or retained chordae tendinae, fibrin strands, or periprosthetic material.<sup>9</sup>

TEE is a crucial diagnostic aide in the detection of structural complications from IE such as myocardial abscesses, fistulas, mycotic aneurysms, valvular aneurysms or perforations, flail leaflets, or prosthetic valve dehiscences. These serious complications are harbingers of significant morbidity and mortality, and may warrant urgent surgical intervention.<sup>10–12</sup> Several of the following echocardiographic findings demand that surgical intervention be strongly considered: ring abscess or fistula; severe valvular regurgitation, particularly if the mitral valve is involved and can be repaired; and mechanical prosthetic valve IE (eradication of infection with antibiotic therapy alone is difficult).

Perivalvular abscess occurs more commonly with prosthetic valve IE compared to native valve IE. Myocardial abscess are found more frequently in the periaortic valvular region compared to other perivalvular areas, and they appear on echocardiograms as an echolucent region within the myocardium or fibrosa.<sup>10–12</sup> TEE in combination with clinical variables can be utilized to predict adverse outcomes in patients with IE.<sup>10</sup>

## Prosthetic Valves

TEE is used routinely to evaluate prosthetic valves, both at the time of implantation as well as for the later development of complications. Prosthetic valves are classified either as biological (*ie*, tissue) or mechanical. Biological valves are subsequently subdivided into homografts (*ie*, allografts) or heterografts (*ie*, xenografts). Mechanical heart valves are subdivided into ball-in-cage, single-tilting disk, or double-tilting disk types. Annular rings are classified as mechanical valves, although, technically, they are not prosthetic heart valves.

Homograft valves are aortic and pulmonary valves that are harvested from human cadavers. Valves are either stented or free sewn (*ie*, unstented). When implanted into the aortic position, the valve may not be stented. These unstented homografts in the aortic position may be difficult to distinguish from native aortic valves. The only evidence of an unstented homograft may be an increase in the echodensity and thickness of the aortic annulus as a result of the sutures. Stented homografts have echo appearances and flow characteristics similar to those of a porcine xenograft bioprosthesis.

Heterografts generally are made up of three leaflets, and, typically, they are porcine valves or made of bovine pericardium. A stent usually arises from each of the three commissures of the valve.

Ball-in-cage valves, when in the open position, have blood flow across the sewing ring and around the ball occluder on all sides. When the valve is closed, a small amount of regurgitation occurs around the ball.

A single-tilting disk valve generally will have two orifices, one larger than the other, within a symmetric flow profile. The bileaflet tilting disk valve, when open, will have two large valve orifices with a small narrow central orifice. Flow through the central orifice will result in relatively high velocities with localized gradients often higher than the overall gradient across the entire valve (*vena contracta*). Common complications resulting from the use of a mechanical prosthesis are listed in Table 1.

**Table 1—Common Complications of Mechanical Prosthesis**

Thrombosis/thromboembolism (most common complication)*
Thrombosis plus fibrosis on the atrial side of a disk valve in the mitral position
Valve dehiscence
Endocarditis involving the valve ring
Perivalvular abscess

\*Tricuspid mechanical prosthesis has a high rate of thrombosis despite use of full anticoagulation.

TTE generally may provide a complete hemodynamic assessment of prosthetic valve function. Many times this will be adequate, without the need for TEE. In fact, TTE is generally superior to TEE for imaging prosthetic aortic regurgitation. Indications for TEE in patients with prosthetic valve dysfunction are listed in Table 2.<sup>13,14</sup>

### *Intraoperative Monitoring*

TEE is an important intraoperative diagnostic aide during cardiac surgery, in which it is utilized to evaluate a hypotension/low-cardiac output state and to discern valve-related problems, particularly during aortic valve replacement (AVR) and mitral valve repair. Three important and often remedial reasons for hypotension/low cardiac output in this setting include the following: LV or right ventricular (RV) systolic dysfunction; hypovolemia; and outflow tract obstruction.

A complete TEE should examine the myocardium in all three coronary distributions. In this setting, the transgastric short-axis images are particularly valuable since they tend to avoid the foreshortening of the apex that is inherent in images obtained from the esophageal window.

Hypovolemia is not an uncommon cause of hypotension in the early postoperative setting, in which the pulmonary capillary wedge pressure may provide misleading data due to changes in LV compliance resulting from cardiopulmonary bypass. In this setting, TEE images reveal reduced cavity size and hyperdynamic systolic function, thereby requiring fluid resuscitation.<sup>15</sup>

As a compensatory mechanism, patients with aortic stenosis develop concentric LV hypertrophy in order to normalize wall stress. Marked concentric LV hypertrophy in this setting can present difficul-

ties for the surgeon during AVR. The sudden reduction in afterload, coupled with anemia, hypovolemia, and high catecholamine tone, leads to enhanced systolic function and an extremely small end-systolic volume. Moreover, tachycardia resulting from the high catecholamine state and the use of positive chronotropic agents may prevent adequate LV filling. These changes can result in severe hypotension, either in the operating room or in the early postoperative period (*ie*, days 1 to 3).<sup>16</sup> This is more likely to occur in elderly patients (> 15%) undergoing AVR and is associated with as much as a threefold increase in mortality.<sup>17</sup> Doppler gradients often vary with loading conditions and correlate well with invasively determined gradients. Therapy is best guided by TEE, and includes fluid administration, withdrawal of therapy with inotropic agents, and therapy with beta-blockers to slow the heart rate.<sup>16-18</sup>

TEE has become an integral part in the evaluation of patients for mitral valve repair. Data have increased the enthusiasm for earlier valve repair for mitral regurgitation (MR) caused by myxomatous degeneration of the mitral valve.<sup>19,20</sup> A quality echocardiographic examination of the mitral valve apparatus is necessary to determine the anatomic pathology of the mitral apparatus as well as the abnormal flow characteristics across it. Knowledge of the anatomic structure aids the surgeon in deciding which of the following surgical procedures to perform: chordal shortening; chordal transfer; placement of artificial (Gore-Tex; WL Gore; Sunnyvale, CA) chords; posterior leaflet quadrangular resection; posterior leaflet-sliding technique; posterior leaflet and chordal transposition to the anterior leaflet; anterior leaflet resection; and placement of an annular ring.

A thorough anatomic examination of the mitral apparatus via multiplane TEE, delineating where the pathology is and what type of pathology is being detected, becomes a necessity. During the TEE examination, the relationship of chordal attachments between the papillary muscle and the leaflet should be noted and used to define the anatomic location of the leaflets visualized.<sup>21</sup> The mitral leaflet section can be defined by visualizing a papillary/chordal attachment to a leaflet. Using multiplane views, the leaflet surface anatomy can be defined.<sup>22</sup> Based on data from Grewal et al,<sup>23</sup> 67% of myxomatous pathology of the posterior leaflet involved the middle scallop (P2). The frequency of successful repair when the pathology involves the middle scallop is approximately 70%. Therefore, it is important that the echocardiographer be familiar with this subset of myxomatous mitral valve pathologies.

The mitral annulus is the transition area where the LA, mitral valve leaflets, and LV come together. The mitral leaflets form a membranous curtain attaching

**Table 2—Indications for TEE in Evaluating Prosthetic Valve Dysfunction**

A nondiagnostic or difficult TTE
Assess for MR in mild to moderate prosthetic mitral stenosis
Stenosis in some patients to look for reversible causes (thrombosis)
Pre-BMV
Suspected prosthetic endocarditis
Evaluation for source of embolism
Look for prosthetic structural abnormalities
Thrombus
Vegetation
Cloth fragments
Inspect cardiac chambers and native valves
Left atrium and LAA function/clot
Native valve vegetations
Aortic debris
PFO

to the mitral annulus. The anterior circumferential portion of the mitral annulus that is associated with the left trigone, intertrigonal space, and the right trigone remains constant during the cardiac cycle and is not prone to dilatation because of its rigid structure.<sup>15,22,23</sup> This area is the attachment point of the anterior leaflet of the mitral valve. Its margins are defined surgically by two dimples that are raised at the border of the right and left trigone when lifting the anterior leaflet.

The annulus fibrosus of the mitral annulus becomes thinner and more poorly defined as it extends posteriorly from the left and right trigones. This portion of the annulus is poorly supported and is prone to dilatation in pathologic states.<sup>20–23</sup> The posterior leaflet of the mitral valve attaches to this portion of the annulus, explaining why the posterior leaflet accounts for 70% of native mitral regurgitant defects, with P2 accounting for 32% of all native defects. Dilatation of the annular attachment of the posterior leaflet creates increased tension on the middle scallop of the posterior leaflet, explaining the 60% occurrence of chordal tears at P2. Table 3 lists intraoperative complications during mitral valve repair, which can be detected by intraoperative TEE, and their appropriate management.

#### Cardiac Source for Embolism

TEE is uniquely suited for the detection of LA spontaneous contrast, LA thrombi, atrial septal aneurysm (ASA), right-to-left shunting through a patent foramen ovale (PFO), and atheroma of the aortic arch as potential causes of cardiac embolism. TEE remains the most sensitive and specific technique with which to detect the sources and potential mechanisms for cardiogenic embolism.<sup>24,25</sup> TEE of patients with AF before cardioversion has demonstrated an LA thrombus or LA appendage (LAA) thrombus in 5 to 15% of patients.<sup>26,27</sup> The detection

of an LA or LAA thrombus in the setting of stroke or systemic embolism is convincing evidence of a cardiogenic mechanism.<sup>26–28</sup>

Several TEE features have been associated with thromboembolism in patients with nonvalvular AF, including LA/LAA thrombus, LA/LAA spontaneous echo contrast (or “echo smoke”), reduced LAA flow velocity by pulsed-Doppler evaluation, and aortic atheromatous abnormalities.<sup>29,30</sup> The Assessment of Cardioversion Using Transesophageal Echocardiography trial demonstrated that a TEE-guided cardioversion strategy produces a similar rate of stroke (*ie*, < 1%) as that for the more traditional method of anticoagulation therapy for 3 weeks prior to the performance of elective direct current cardioversion.<sup>31</sup> As such, a negative TEE can replace moderate-term anticoagulation in patients with recent onset AF prior to direct current cardioversion.

A common part of the evaluation for cryptogenic stroke is the elucidation of a possible PFO, for which TEE is currently considered to be the reference standard for its detection. To this end, a femoral injection of agitated saline solution contrast medium combined with a Valsalva maneuver has been shown to be the most sensitive method for identifying a PFO, as the inferior vena cava flow is directed preferentially toward the interatrial septum (IAS) and foramen ovale.<sup>32</sup> Conversely, the crista interve-niens directs the superior vena cava flow away from the IAS, significantly reducing the sensitivity of an arm injection of contrast medium. A reduced degree of sedation may be necessary for this type of patient as cooperation is fundamental for the performance of a Valsalva maneuver.

Several studies have further quantitated the PFO diameter by the degree of TEE contrast intensity seen in the LA, specifically, the maximum number of microbubbles visualized in the LA within three cardiac cycles after contrast filling of the right atrium

**Table 3—Complications Detected by TEE During Mitral Valve Repair and Management\***

Complication	Management
Mitral regurgitation	Identify etiology ≤ 1 +, no intervention† 1–2 +, increase afterload with phenylephrine† ≥ 2 +, further surgery†
SAM	Increase preload (fluids) and stop inotropes If unsuccessful, further surgery
Ring dehiscence leaflet perforation	Further surgery
Mitral stenosis	If mean gradient ≥ 6 mm Hg, or MVA < 1.5 cm <sup>2</sup> , consider further surgery
Regional LV dysfunction	R/O intracardiac air. If not resolved after further pump time, consider bypass
Global RV/LV dysfunction	Assess preload, afterload, inotropes

\*Modified from Otto.<sup>47</sup> MVA = mitral valve area; SAM = systolic anterior motion; R/O = rule out.

†Values given using mitral regurgitation scale.

was determined. *Grade 1* was defined as 1 to 5 bubbles, *grade 2* was defined as 6 to 25 bubbles, and *grade 3* was defined as > 25 bubbles. This grading system provided an excellent correlation of contrast intensity to PFO diameter.<sup>33</sup>

Shunt size has been found to correlate with the incidence of future ischemic neurologic events. Large shunts (*ie*, > 20 microbubbles) have been found to correlate with a high rate (31%) of subsequent embolic events, including transient ischemic attack and stroke, despite the use of antiplatelet or anticoagulant therapy.<sup>32</sup> In contrast, small shunts (*ie*,  $\geq 3$  but < 20 microbubbles) respond well to medical therapy, with a reported 0% rate of subsequent neurologic events.

During the TEE examination for PFO, it is necessary to evaluate for the presence of ASA as well as a Chiari network because these conditions are associated with a significant number of PFOs. M-mode TEE of the IAS helps to facilitate the measurement of the septal excursion, where an excursion of  $\geq 15$  mm yields the diagnosis of ASA.<sup>34,35</sup>

### Aorta

Another value of TEE in the evaluation of cryptogenic stroke is the assessment of atheromatous disease of the aorta. Several studies have evaluated the role of various imaging techniques in the diagnosis of atheromatous aortic disease. Aortography provides only an inexact view of the aortic lumen, without clear identification of the endothelial surface. CT scanning and MRI can provide an enhanced evaluation; however, the imaging is not performed in real time. TEE is ideally suited to providing high-resolution real-time imaging, which also provides atherosclerotic plaque morphology and mobility, as well as the dynamic effect of flow. Various authors<sup>36–40</sup> have reported significant aortic atheroma in up to 50 to 60% of patients with unexplained stroke. Stroke risk is highest, however, with the identification of large (*ie*, > 4 to 5 mm), mobile, and ulcerated plaques.<sup>36–40</sup> Investigators have used various grading systems for aortic atheroma, and, to date, no single unified system has been widely accepted. All systems agree, however, that the highest risk patients are those with mobile plaques, ulcerated plaques, and plaques that protrude into the aorta by > 4 to 5 mm. As such, these plaque characteristics should be specifically reported in any patient undergoing TEE. We have chosen the following system to grade atheromatous disease of the aorta identified by TEE: grade 1, minimal intimal thickening; grade 2, extensive intimal thickening; grade 3, sessile atheroma of < 4 mm; grade 4,

protruding atheroma of  $\geq 4$  mm; and grade 5, mobile or ulcerated atheroma.

Lesions of grade 4 and 5 lesions carry a risk of peripheral embolization that is almost fourfold more than that with grade 1 lesions. Moreover, in patients undergoing coronary artery bypass grafting, these high-grade lesions have been associated with an incidence of stroke approaching 25% and an early mortality rate of 15%,<sup>38,41–43</sup> where grade 3 suggested a PFO diameter of  $\geq 10$  mm and grade 1 suggested a PFO diameter of  $\leq 2$  mm.

Aortic dissection is another condition in which the improved image resolution and Doppler sensitivity of TEE are particularly suited to rapid diagnosis. In addition to the previous “gold standard” of aortography for the diagnosis of dissection, TTE, TEE, CT scanning, and MRI have defined roles in the diagnosis of dissection. Although each of these modalities has certain advantages and limitations, the accuracy, speed, relatively low cost, portability, and capability to comprehensively evaluate the heart, aorta, and its branches for complications of dissection have made TEE an attractive first choice for the evaluation of suspected aortic dissection in both the emergency department and in critical care settings.<sup>38,44</sup>

Aortic dissection is a catastrophic condition with a high mortality rate resulting from an accumulation of blood that dissects the media from the intima and adventitia. Approximately 96% of dissections are associated with an intimal flap.<sup>38,44</sup> Approximately 70% of intimal tears occur in the ascending aorta, usually 1 to 3 cm above the right or left aortic sinus. In the remaining 30%, the tear is distal to the origin of the left subclavian artery, at the ligamentum arteriosum. The pathognomonic echocardiographic appearance of dissection is an undulating linear density (*ie*, an intimal flap) within the aortic lumen separating a true and false channel, which has different Doppler color flow patterns. Aortic dissection should be suspected whenever the normal appearance of the aortic wall consisting of a single dominant echo is replaced by two separate echoes, with one echo presumably representing the intima plus the inner media, and the second echo representing the outer media and adventitia.

Most classifications systems of aortic dissection are based on the location of the intimal tear. The most widely used DeBakey classification recognizes the following three types: types I and II originate in the ascending aorta, with type I extending beyond the aortic arch and type II confined to the ascending aorta; and type III originates in the descending thoracic aorta and extends distally.<sup>38,44</sup>

The Daily classification delineates two types of dissection. Type A involves the ascending aorta, regardless of the location of the intimal tear, and

requires emergency surgery. Type B occurs distal to the origin of the subclavian artery, sparing the ascending aorta, and can be treated medically. Prompt diagnosis and accurate anatomic assessment are critical in guiding therapy.<sup>38,45</sup>

Penetrating aortic ulcers (PAUs) occur when an ulceration of an atherosclerotic plaque erodes through the internal elastic lamina into the aortic wall media. This process may progress to life-threatening clinical sequelae such as transmural aortic rupture, intramural hematoma, saccular, fusiform, or false aneurysms of the thoracic aorta, or typical dissection.<sup>38,44</sup> PAUs are predominantly located in the descending aorta, where atherosclerosis tends to be more severe. Patients are often elderly, have hypertension and diffuse systemic atherosclerosis, and present with a sudden onset of chest or back pain. The echocardiographic features of PAUs are a crater-like out-pouching of the aorta with jagged edges associated with complex atheromatous plaque.

Aortic intramural hematoma (AIH) is a localized separation of the layers of the aortic wall by partially or totally clotted blood in the absence of an intimal tear, presumably caused by rupture of the vaso vasorum in the media.<sup>38,44,45</sup> An AIH is generally identified on TEE as an homogeneous mottled thickening of the aortic wall and an inward displacement of intimal calcification. The more formal echocardiographic criteria for the diagnosis of AIH are a  $\geq 7$  mm crescent or circular thickening of the aortic wall extending 1 to 20 cm longitudinally along the thoracic aorta, with no evidence of Doppler flow in the thickened aortic wall, and the absence of an intimal laceration or flap.

### Balloon Mitral Valvuloplasty

Another less common indication for TEE is the evaluation of the patient prior to possible balloon mitral valvuloplasty (BMV). The TEE must include a thorough assessment of the LA and LAA for evidence of clots, as well as the quantification of MR, since the presence of either a clot or  $> 2+$  MR is a relative contraindication for BMV. The mitral valve itself should be carefully evaluated for mobility, thickening, and calcification. Together with a characterization of the subvalvular apparatus, the mitral valve-echo scoring system is used to determine a patient's suitability for BMV.<sup>46</sup> An echo score of  $< 8$  suggests a stenotic mitral valve that is ideally suited for BMV, with a high margin of success. A higher score, however, does not completely preclude a BMV, and valvuloplasty would then depend on the presence and degree of commissural fusion.

## PATIENT PREPARATION

Patients must fast for 4 to 6 h before undergoing a TEE study. It is important to carefully explain the procedure to the patient to rule out any gastroesophageal-related contraindications for the procedure and to obtain informed consent. Significant gastroesophageal-related concerns include difficulty swallowing (*eg*, dysphagia and odynophagia), symptoms of esophageal diverticular disease (*eg*, foul breath and old nondigested food particles in the mouth), and GI bleeding. In those patients with suspected esophageal disease, a barium swallow or endoscopic evaluation of the esophagus is recommended to rule out diverticula, strictures, or other esophageal disorders. Special note has been made regarding the use of anticoagulant agents as well as bleeding history (if present, obtain the current international normalized ratio, hemoglobin level, or findings of other relevant clotting studies). Patients receiving long-term anticoagulation therapy with warfarin (Coumadin; DuPont; Wilmington, DE) should be noted and should have their dosing adjusted to reduce the risk of bleeding prior to the TEE procedure.

It is also important to obtain a history of the usage of alcohol, sedative and hypnotic agents, and tranquilizers, and of recreational drug use, as this may affect the dosing of medications during conscious sedation.

Informed consent should be obtained from the patient, or when incapacitated, from their next of kin. IV access to the patient is established, and drug allergies and patient medications are recorded. If an evaluation for possible PFO is intended (*ie*, to rule out a cardiac source for emboli), then a femoral venous catheter is placed immediately before the procedure.

## ESOPHAGEAL INTUBATION

Dentures and oral prostheses must be removed before the examination. IV access is established, as is supplemental oxygen, via a nasal cannula. Topical anesthesia is applied to the hypopharynx using benzocaine (Cetacaine; Cetylite; Pennsauken, NJ) or lidocaine (Xylocaine; AstraZeneca; Wilmington, DE) spray. Conscious sedation using midazolam (Versed; Roche Pharmaceuticals; Basel, Switzerland) [0.5 to 10 mg] may be given immediately preceding the procedure. In some cases, fentanyl (Sublimaze; Janssen Pharmaceutica; Titusville, NJ) may be used instead of, or in conjunction with, midazolam. In the rare patient in whom conscious sedation cannot be adequately performed, it is appropriate to consult an anesthesiologist for assistance in sedation and the passage of the TEE probe under direct visualization.

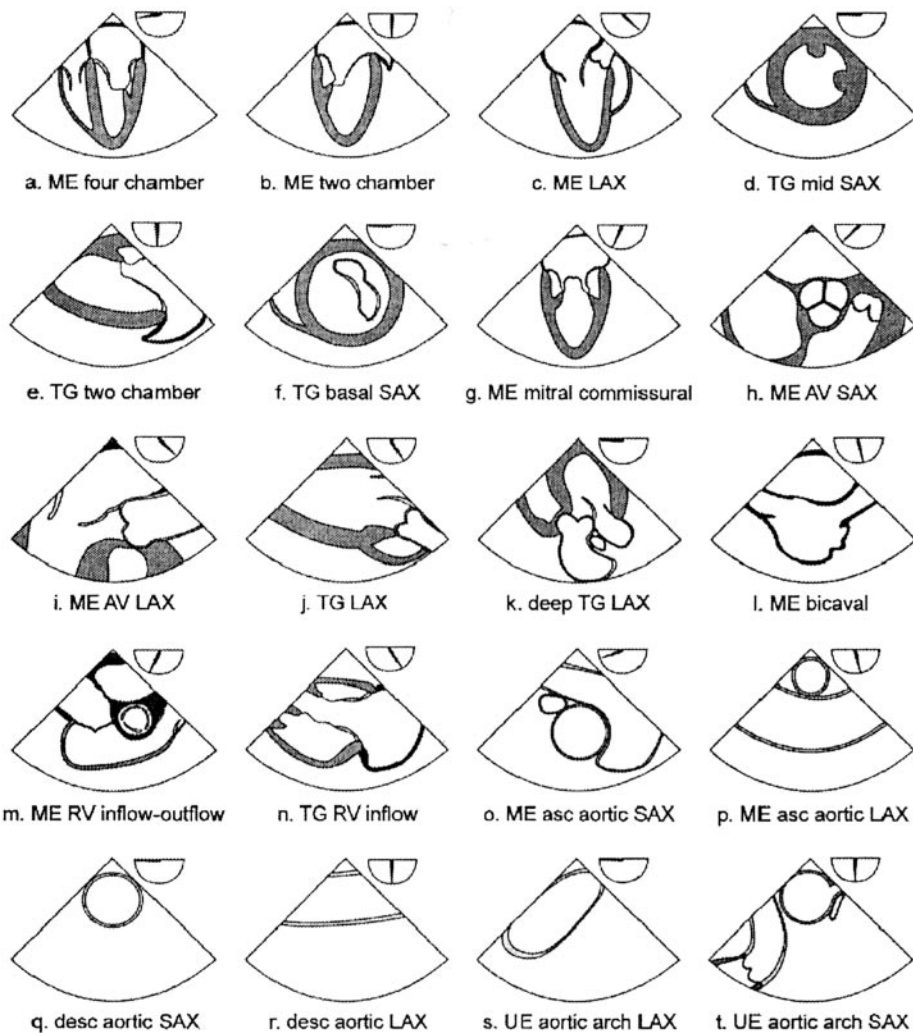


FIGURE 1. Recommended TEE views. ME = midesophageal; LAX = long axis; TG = transgastric; SAX = short axis; AV = aortic valve; asc = ascending; desc = descending; UE = upper esophageal. Reproduced with permission from Shanewise JS et al.<sup>15</sup>

The TEE transducer should be inspected for defects and cracks in the waterproof covering before insertion. The mouth should be examined for preexisting injuries and loose teeth. The TEE probe is introduced with the patient in the left lateral decubitus position with gentle flexion of the neck to facilitate entry into the esophagus. The endoscope is always inserted with the transducer facing anteriorly, guided by the index finger of the left hand. With the tip of the probe at the esophageal inlet, the patient is requested to swallow, which assists in directing the probe into the upper esophagus. The probe can be advanced unless one meets resistance, which would require readjustment of the probe centrally or removal. Once in the esophagus, the transducer should never be forced through a resistance. The tip of the transducer should be allowed to return to the neutral

position before advancing or withdrawing the probe, and excessive force should never be applied when moving the transducer in the esophagus or flexing the tip with the control wheels.

Many patients will gag until the probe is advanced beyond the carina of the trachea or > 25 cm from the incisors. Thus, a smooth and rapid initial advancement to this point is essential. Once the probe is in the esophagus, most patients become more comfortable and will accept the remainder of the examination.

#### STANDARD TRANSESOPHAGEAL VIEWS AND TECHNIQUE

The operator must familiarize himself with the basic functions, which control the operation of the

transesophageal probe. These include medial and lateral rotation, anteflexion and retroflexion, long-axis rotation, probe withdrawal and advancement, and axis change with multiplane imaging probes. Figure 1 demonstrates the 20 cross-sectional views composing the recommended TEE examination.<sup>15</sup> The approximate multiplane angle is indicated by the icon adjacent to each view.

There is no standardized order for obtaining the necessary views in the TEE examination. Moreover, it is recognized that there is individual variation in the anatomic relationship of the esophagus to the heart. In some patients, the esophagus is adjacent to the lateral portion of the AV groove, whereas in others it is directly posterior to the LA. Our general rule of thumb is to obtain the most clinically relevant views first, based on the reason for the procedure (*ie*, in AF precardioversion, obtain LAA views and velocities first), in case the procedure should have to be prematurely aborted.

### CONCLUSION

As we have reviewed in this manuscript, the ease of utilization, portability, and relatively low cost of TEE has resulted in a marked increase in its clinical application in the evaluation of patients with cardiovascular disease. This is particularly applicable to intensivists, surgeons, anesthesiologists, as well as specialists in cardiovascular diseases in the evaluation and treatment of critically ill patients.

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