Transesophageal Echocardiography – An Overview

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The first esophageal M-mode probe was introduced in 1976 by Dr. Leon Frazin [1]. The use of M-mode transesophageal echocardiography was limited to attempts to monitor left ventricular function during cardiovascular surgery [2]. With the introduction of two-dimensional transducers in 1981 the use of TEE use in the operating room during general anesthesia became more widespread. The higher transducer frequencies (5.0 –7.5 MHz) currently used in TEE permit higher resolution, and the close proximity of most cardiac structures to the esophagus has resulted in superior imaging with better spatial resolution and more detailed image quality. Following modification of the probe design and further improvement in imaging in the mid-1980s, TEE became a useful and popular tool in the outpatient clinic as well.

The introduction of various Doppler techniques enabled investigation of intracardiac blood flow and assessment of valvular function. The first transducers were capable of imaging in the transverse plane only, perpendicular to the shaft of the scope. The biplane TEE transducer introduced in the early 1990s has a second imaging array parallel to the shaft of the scope, the longitudinal plane. This addition provides more diagnostic information on vertically oriented structures – superior vena cava, interatrial septum, left atrial appendage, right ventricular outflow tract, and ascending aorta. The multiplane transducer currently used worldwide consists of a single array of crystals that can be mechanically rotated in a 180° arc. This produces a continuum of two-dimensional tomographic images. Multiplane imaging improves visualization of cardiac structures from different views. Although comparable views can in some cases be obtained using a biplane transducer with lateral or medial transducer flexion, this is often not possible.

Safety and risks

TEE is an invasive procedure and should not be used for routine screening without appropriate indications. TEE can be performed in outpatient or inpatient settings. The patient has to fast for at least 4 hours prior to the procedure, and his or her history is evaluated for symptoms of dysphagia or gastroesophageal disease. Table 1 summarizes the absolute and relative contraindications. The risk of the procedure may be higher in patients with bleeding disorders or a previous esophageal surgery. Dentures, if any, should be removed and local pharyngeal anesthesia is administered. The patient is awake or mildly sedated with intravenous short-acting benzodiazepine, most commonly midazolam. To avoid the risk of aspiration the patient should be in the left lateral decubitus position. The need for endocarditis prophylaxis is controversial because no significant bacteremia or endocarditis is encountered with endoscopy unless biopsy is performed. However, endocarditis prophylaxis should be considered for high risk patients – namely, patients with prosthetic valves, poor dentition, or previous infective endocarditis [3]. A transthoracic study should precede TEE whenever possible.

TEE = transesophageal echocardiography

Table 1. Contraindications of TEE

Absolute
Esophageal obstruction (a mass or stricture) [4,5]*
Undiagnosed active GI bleeding [5]*
Perforated viscus [4,5]*
Instability of cervical vertebrae [6]
Recent oral intake within 4 hours [5]
Uncooperative patient [5]
Relative
Previous therapeutic chest irradiation [4]
Esophageal varices or diverticula, esophagitis [7]*
Severe atlantoaxial joint disease – inability to flex the neck [4]
Compromised cardiorespiratory status [8]**
Bleeding diathesis or over-anticoagulation [6]

* If any doubt exists, upper endoscopy or barium swallow should be performed prior to TEE

** Prophylactic tracheal intubation should be considered.

Complications of TEE are rare today. In the European Multicentre Study TEE was performed in 10,218 patients. Premature termination was necessary in 90 procedures (0.88%) due to patient intolerance (n = 65), pulmonary, cardiac and bleeding-related complications (n = 18), or other reasons. One of the bleeding complications was due to a malignant lung tumor with esophageal infiltration and was fatal; the mortality rate was 0.01% [4,8]. The Mayo Clinic reported their experience with 3,827 patients [9]. Complications (major and minor) occurred in 2.9% (n = 111). Major complications included laryngospasm (n = 5), sustained ventricular tachycardia (n = 1), congestive heart failure (n = 2), and death in one patient with postmortem myocarditis and presumably fatal arrhythmia [9]. Both studies reflect relatively early experience.

Indications

TEE is performed in the outpatient clinic as well as in the hospital, including intraoperatively. Table 2 summarizes the current indications for the procedure. Valvular heart disease TEE enables more reliable and accurate visualization of native and prosthetic mitral valve than the transthoracic approach. TEE permits the assessment of the extent of valvular and subvalvular calcifications and evaluation of left atrium and left atrium appendage. The mobility and the presence or absence of thrombus is important in the assessment of patients undergoing mitral balloon valvuloplasty [7,9,11]. TEE can guide catheter and balloon placement during mitral balloon valvuloplasty and allows follow-up of the iatrogenic atrial septal defect that may occur in the catheter's trans-septal course [9]. From the esophageal level TEE provides an unobstructed view of the mitral valve and left atrium and demonstrates the mechanism and severity of the regurgitation [12], which is essential for accurate surgical or medical treatment. The maximum regurgitant jet area, reversal of pulmonary venous systolic flow, blunting of the systolic component of pulmonary venous forward flow or higher antegrade velocities across the mitral

Table 2. Indications for TEE

Outpatient clinic

Native valve
- Severity and mechanism of mitral regurgitation [5,9].
- Assessment of patients with MS undergoing mitral balloon valvuloplasty [5,7,9].
- Aortic valve — TEE somewhat better than TTE, especially for sub-optimal TTE [9] and for visualization of sub-aortic membrane [7]
- Tricuspid and pulmonic valves — anterior location in the chest; usually little benefit of TEE [10].

Prosthetic valve
- Greater benefit of TEE over TTE for prosthetic mitral valve than for aortic.
- Prosthetic valve endocarditis [11], prosthetic valve obstruction [12], structural deterioration for biological valve if TTE non-diagnostic; mechanical is extremely rare [12]. TEE is indicated in suspected valve malfunction and non-diagnostic TTE [4]

Endocarditis
- Vegetations, abscesses, valve perforation, new valvular regurgitation [3].
- Prosthetic endocarditis — abscess/cavity formation, mycotic aneurysm, prosthetic dehiscence and regurgitation [13]

Intracardiac masses
- TEE similar to TTE for atrial myxomas and left-sided cardiac tumors, but for masses (right heart masses) TEE is better [9].

Source of embolism
- Thrombi in LA and LAA, spontaneous echocontrast, atrial septal aneurysm, PFO, embolism debris [9,14,15], strands [16]

Atrial fibrillation
- For absence of LA and other intracardiac thrombus [16] before cardioversion

Pulmonary embolism
- Thrombi in right atrium, IVC, proximal PA [11], RV dysfunction [5], PAP [18].

Thoracic aortic disease
- Intimal flap, false lumen [7], LV wall motion abnormalities from disease obliteration of the coronary ostia by dissecting membrane, AR due to aortic root dilatation or AVP, extravasation of blood into the mediastinum, pericardium [11], intramural hematoma [19], thoracic aortic plaque [7].

Congenital heart disease
- ASD, anomalous pulmonary venous return, postoperative — residual shunts and disease obstructions, during interventions [4]

Coronary disease
- Left main stenosis [20], coronary artery anomalies [21]

In hospital/intra-operative

ICCU
- Complications of acute MI: VSD, papillary muscle dysfunction/rupture, aneurysm, pseudoaneurysm [6]

Critically ill
- To determine the type of hemodynamic deterioration bedside, estimation of filling status, patients with chest trauma [22]

Cardiac surgery and other interventions
- During CABG for detection of ischemia [7], mechanism of valvular disease, to assure success of valvular surgery, need second intervention before chest closure [4], guidance for aortic cross-clamp: avoiding areas of severe atheroma, postoperative complications [10], extent of ventricular myectomy in HOCM [4]
- Guide during balloon valvuloplasty and angioplasty for aortic coarctation [4], ASD closure [23].

Non-cardiac surgery
- Ventricular contractility and filling status, perioperative MI and ischemia [7].

Non-diagnostic TTE
- COPD, obesity, chest deformities [6].

AR = aortic regurgitation, ASD = atrial septal defect, AVP = aortic valve prolapse, CABG = coronary bypass graft, COPD = chronic obstructive pulmonary disease, HOCM = hypertrophic obstructive cardiomyopathy, IVC = inferior vena cava, LA = left atrium, LAA = left atrium appendage, LV = left ventricle, MS = mitral stenosis, PA = pulmonary artery, PAP = pulmonary artery pressure, PFO = patent foramen ovale, RV = right ventricle, TTE = transthoracic sechocardiography, VSD = ventricular septal defect.

valve correlate with the severity of mitral regurgitation [9,11]. A floppy prolapsing mitral valve may be difficult to differentiate from vegetations by the transthoracic approach but is easily detected by TEE [24]. Diagnosis of valvular perforation is indicated by eccentric mitral regurgitant jet arising from a thickened and heterogeneous valvular area or by an echo "dropout" in a mitral leaflet [24]. TEE can define the etiology of native aortic regurgitation (flail perforated aortic cusp) or identify an aortic root abscess. In aortic stenosis the aortic valve area obtained by planimetry in TEE correlates with transthoracic Doppler study or cardiac catheterization. It may be useful in patients with sub-optimal transthoracic examination, but continuous wave Doppler with TEE is not superior to TTE in estimation of the aortic valve gradients [11].

Transthoracic echocardiography is usually insufficient in the evaluation of prosthetic mitral regurgitation because of acoustic shadowing that occurs in the left atrium. TEE enables the differentiation of "normal," "closing volume" inherent regurgitation of all mechanical prostheses from abnormal pathologic perivalvular regurgitation that requires intervention. In general, normal regurgitant jets are transvalvular, short in length (3 cm), narrow, holosystolic in duration, and do not show aliasing by color flow Doppler (with the exception of Medtronic-Hall valves) [12]. TEE is highly sensitive in detecting mitral prosthetic pathology and is the technique of choice for evaluation of prosthetic mitral regurgitation, endocarditis, embolic complications related to prostheses, and valve malfunction of tissue prosthetic valve, valve repair or ring implantation [9]. Prosthetic valve thrombosis is more common in mechanical than tissue valves. Thrombus may cause significant valve obstruction and may be catastrophic. Fibrinolytic therapy is an alternative to surgical treatment (redo valve replacement) for obstructed left-sided prosthetic valves and is considered the treatment of choice for tricuspid valve thrombosis [12]. The distinction between thrombus and fibrous tissue (pannus) is essential if thrombolytic therapy is considered. A clinical predictor for thrombus formation is inadequate anticoagulation (international normalized ratio <2.5). Pannus is more common in the aortic position. Specific features for pannus formation include a small dense mass, not visualized in 30% of cases. Pannus does not extend beyond the prosthesis. Abnormal prosthetic valve motion by TEE is more common in valve thrombosis than in pannus. Thrombi associated with mitral prosthesis, extend beyond the surgical ring into the left atrium and atrial appendage, are large and have a soft ultrasonic density similar to that of the myocardium [12]. Since the amount of thrombotic material needed to cause restriction of prosthetic tricuspid valve leaflets is small, a thrombus is rarely visualized, even in TEE [25].

The left ventricular outflow tract is easily investigated by the transthoracic approach. Thus, the estimation of severity of prosthetic aortic regurgitation is usually feasible with conventional TTE, but the presumed mechanism – transvalvular versus paravalvular regurgitation – and the anatomic lesion responsible for the regurgitation are better seen with TEE [12].

As for native aortic valves, TEE in addition to TTE is inadequate for recording prosthetic aortic valve gradient and may underestimate it. The only available view is the deep transgastric view. Cinefluoroscopy may be necessary in selected cases to assess prosthetic aortic valve function [12].

Endocarditis

The diagnosis of infective endocarditis may be established by the presence of fever, systemic symptoms, physical findings and positive blood cultures. Some patients have culture-negative endocarditis, which may be due to partial treatment, or to fungal or fastidious slow-growing organisms. The modified Duke criteria for diagnosis of infective endocarditis include evidence of endocardial involvement – valvular vegetations, valvular regurgitation, ventricular dysfunction and associated lesions – perivalvular abscesses, shunts, ruptured chordae, leaflet aneurysm or perforation. The yield of visualization of vegetations with transthoracic echocardiography is 60–77% and increases to 96% with transesophageal imaging [3]. Although TTE may be as sensitive as TEE in detecting tricuspid vegetations [11], TEE is superior in visualizing the mitral, aortic and pulmonic valves. Transesophageal imaging provides better estimation of vegetation size. Patients with a vegetation diameter >10 mm have a significantly higher incidence of embolization than those with a vegetation diameter <10 mm [3]. TEE is especially useful in evaluating prosthetic valve endocarditis, having a sensitivity of 85% compared with only 40% for TTE [11]. TEE enables high resolution imaging of the heart from the posterior (atrial, low pressure) side, where most of the vegetations are found in mitral and tricuspid positions. TEE also enables better visualization of left ventricular outflow tract, where aortic prosthetic vegetations are present. TEE also detects complications of endocarditis – namely, abscess or cavity formation, mycotic aneurysm, prosthetic valve dehiscence and regurgitation. Transesophageal echocardiography should be included among the major criteria in the diagnosis of prosthetic valve endocarditis [13].

Paravalvular abscess reflects extensive valvular dysfunction and is a relative indication for surgery. Clinical parameters – such as valvular involvement, presence of prostheses, infection with virulent organism, persistence of bacteremia – and transthoracic echocardiography have been shown to be insensitive predictors of abscess. The only statistically significant correlate was the presence of new atrioventricular or bundle branch block. The sensitivity and specificity of transthoracic echocardiography were found to be 28% and 90% respectively. The sensitivity and specificity of transesophageal imaging is 78 and 100% respectively. TTE should be considered for all patients with endocarditis [26]. A normal echocardiogram has a negative predictive value $>85\%$. All patients with an initial false negative TEE had either prosthetic valve thickening or degenerative disease of their native valve

TTE = transthoracic echocardiography

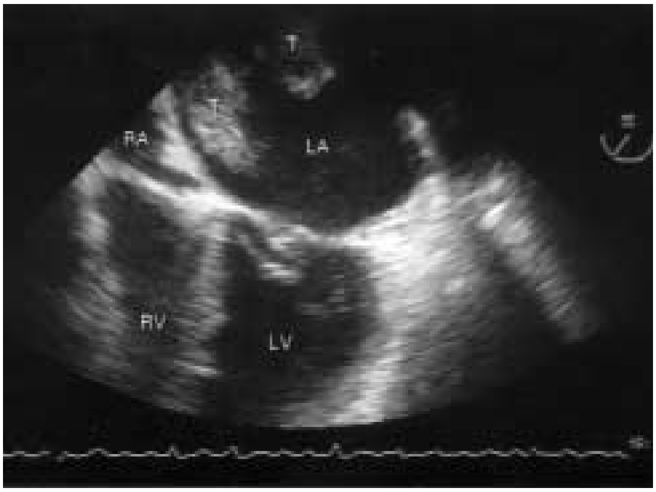

Figure 1. Apical four-chamber view in a patient with mitral stenosis and dilated left atrium, showing a very large thrombus that was not visualized in transthoracic echocardiogram. LA = left atrium, LV = left ventricle, RA = right atrium, RV = right ventricle, T = thrombus.

[11]. A normal TEE is thus of high predictive value in patients suspected of endocarditis and may prevent an extended course of antibiotic treatment and hospitalization. However, ongoing suspicions of endocarditis in a patient with a prosthetic valve or significant native valvular disease warrant close follow-up and possibly repeat TEE.

Intracardiac masses

Transesophageal echocardiography can differentiate intracavitary from extracavitary masses. Atrial myxoma is the most common cardiac tumor, which is usually attached to the interatrial septum. TEE is widely used for the detection of thrombus in the left atrium before mitral balloon valvuloplasty and before cardioversion in atrial fibrillation [Figure 1]. It can distinguish a thrombus in the left atrial appendage, an area usually inaccessible to the transthoracic approach – from pectinate muscles, the component of the normal anatomy of the apex of the left atrial appendage [7]. The sensitivity and specificity of TEE for detecting thrombus in the left atrium in rheumatic mitral valve disease, verified by surgery, were 97% and 100% respectively [27]. TEE permits a clear view into the superior vena cava, and tumors or thrombi attached to pacemaker wires or intravenous lines may be visualized. In diagnosing pericardial tumors and masses adjacent to the heart, TEE does not replace computed tomography and magnetic resonance imaging.

Source of embolism

The most frequent indication for TEE is detection of a cardioembolic source [9]. Conventional echocardiography is sub-optimal in the presence of chest deformities, obesity or obstructive lung disease, and inadequate to visualize the left atrial appendage, interatrial septum and prosthetic valves. Spontaneous echo contrast, atrial septal aneurysm, patent foramen ovale and intraaortic debris – all considered potential sources of embolism – can be adequately detected by TEE [9]. In 1,469 patients including candidates for mitral valvuloplasty and patients with cerebral or peripheral embolism, 183 patients had thrombi in the left atrial appendage detected by TEE; only two thrombi were visualized by TTE [4]. The majority of thrombi in the left atrium occur within the left atrial appendage, an area that is visualized well by TEE. Left atrial appendage thrombi usually occur in association with one of five clinical conditions, namely: atrial fibrillation, mitral stenosis, prosthetic mitral valves, severe left ventricular dysfunction, or left atrial dilatation [28].

Atrial fibrillation is the most common cause of cardioembolic stroke. Approximately 20% of these patients have rheumatic valve disease, 70% have non-valvular atrial fibrillation, and the remaining 10% have no obvious heart disease (lone atrial fibrillation). Atrial fibrillation associated with rheumatic valve disease carries an 18-fold increase in the risk of stroke, while non-valvular atrial fibrillation is associated with an approximately fivefold increase in risk [28]. The risk of stroke in atrial fibrillation increases with the patient's age. It is highest during the first year after the onset of atrial fibrillation. Patients who present with systemic embolic event in the setting of atrial fibrillation are at very high risk for a recurrent systemic embolic event, the incidence being 10–20% per year [28]. Embolic stroke is the principal risk of both direct-current cardioversion and chemical cardioversion, and two approaches are used for its prevention. With one strategy, warfarin (INR 2.0–3.0) is administered for at least 3 weeks before and 4 weeks after cardioversion. With the other approach, heparin is immediately administered and TEE is performed after 12–24 hours. If TEE fails to reveal a left atrial or other intracardiac thrombus, or significant spontaneous contrast (swirling), chemical or electrical cardioversion may be attempted, and anticoagulation is continued for 4 weeks. Both strategies provide substantial, although not absolute protection against cardioversion-associated stroke. A 3 week regimen of warfarin therapy may be ineffective or TEE may fail to detect tiny thrombi. The traditional "no need" approach to anticoagulation for atrial flutter or atrial fibrillation occurring less than 48 hours before cardioversion is associated with low, but not zero, risk of embolism [17]. All patients with atrial fibrillation and cerebral ischemia should be considered for anticoagulation. If a patient with stroke is not a candidate for anticoagulation or surgery, TEE has no therapeutic implication. If the patient is a candidate for measures to prevent future stroke, TEE is the procedure of choice. Spontaneous echo contrast echoes are faint or dense dynamic microbubbles, the result of red cell aggregation from low flow velocity. Because of the higher transducer frequencies used in TEE probes, spontaneous echoes in the left atrium can be identified more frequently by TEE than by conventional echocardiography [4]. Left atrial spontaneous echo contrast is a strong independent risk factor for thrombotic and embolic events [11]. A significant association was found between spontaneous echo contrast and mitral stenosis, mitral valve prostheses, atrial fibrillation, and left atrial size. While TEE-detected spontaneous echo contrast is a marker for increased cardioembolic risk [29], there is no evidence to date that anticoagulation can lower that risk [28].

A patent foramen ovale is normally present in 10–25% of the general population and occurs in up to 40% of younger patients with stroke. TEE facilitates evaluation of the size of atrial septal defect and shunt flow through it, and can visualize a sinus venosus defect not seen with the transthoracic approach [7]. A patent foramen ovale can be identified after injection of agitated saline. If, after reaching the right atrium, the agitated saline enters the left atrium within five heart beats, a patent foramen ovale may be suspected [30]. The finding of a patent foramen ovale by itself is insufficient evidence to presume a diagnosis of paradoxical embolism. Clinically silent deep vein thrombosis may occur in 50% of patients with suspected paradoxical embolism through a patent foramen ovale [28]. There are no data on treatment options. Many patients are empirically treated with anticoagulation. Surgical closure of the opening is occasionally performed [28]. Recently, patent foramen ovales have been closed by inserting an umbrella via the cardiac catheterization technique, assisted by TEE for optimal location [23].

An atrial septal aneurysm is a redundancy of the tissue of the fossa ovalis that is at least 1.5 cm in length and demonstrates mobility (maximal excursion between the left and right atria of at least 1.5 cm). According to autopsy data, atrial septal aneurysms occur in approximately 1% of the population [28]. Atrial septal aneurysm was found to be an isolated structural defect in 32% of patients [31]. In 54% atrial septal aneurysm was associated with interatrial shunting (atrial septal defect, patent foramen ovale, sinus venosus defect). In only 1% were thrombi attached to the region of the atrial septal aneurysm. Prior clinical events compatible with cardiogenic embolism were associated in 44% of patients with atrial septal aneurysm; in 24% of patients with presumed cardiogenic embolism no other potential cardiac sources of embolism were present. The length of an atrial septal aneurysm, extent of bulging, and the incidence of spontaneous oscillations were similar in patients with and without previous cardiogenic embolism; however, associated abnormalities such as atrial shunts were significantly more frequent in patients with possible embolism [31]. This anomaly may be due to a congenital connective tissue defect that manifests over time and occurs more with increasing age. Standard TTE has been of limited value. Because of the superiority of the transesophageal technique for visualizing posterior structures such as the atrial septum, atrial septal aneurysms have been described much more frequently by TEE.

Transesophageal echocardiographic detection of intraaortic atherosclerotic "debris" correlates with cerebrovascular and peripheral embolic events. This term refers to the echocardiographic appearance of increased echodensity and thickening of the intima of the aorta, usually associated with irregularity or disruption of the intimal surface. Plaques located proximal to the ostium of the left subclavian artery have been found in 60% of patients aged 60 years or older with ischemic stroke, but the association with ischemic stroke, recurrent brain infarction and other vascular events was particularly strong when the plaques were >4 mm thick [14]. A blind zone exists in the upper portion of the ascending aorta where the air-filled trachea is interposed between the esophagus and the aorta and impedes visualization. The presence of protruding atheromas was strongly associated with the risk of embolic event [29]. Among the various types of mobile aortic lesions, the disrupted protruding plaques are a major risk factor for stroke and embolic events in the elderly. The TEE features – disrupted atheromas with characteristic ulcerations or echolucency within the plaque, suggestive of intraatheroma hemorrhage – were present in 76% of patients with mobile aortic lesions and cerebral or peripheral embolic events [15]. There are currently no data on the use of any treatment for this entity.

The prevalence of ischemic stroke in patients with infective endocarditis ranges between 15% and 20%, with most strokes occurring at presentation or within 48 hours of diagnosis. The risk of a late stroke in patients with controlled infection is 5%. Anticoagulation has no role in native valve endocarditis but increases the risk of intracerebral hemorrhage. Mitral valve strands are thin, <1 mm wide, highly mobile filamentous projections attached to the atrial surface of the mitral leaflets. The hypothesis is that mitral valve strands represent Lambl's excrescences, which are small filiform processes on the ventricular surface of the aortic valve. Among patients under 50 years old with cardioembolic stroke or transient ischemic attack, 16% had mitral valve strands on TEE examination [16].

The American Society of Echocardiography and the American Heart Association Committee on the Use of Echocardiography have recommended that TTE be used routinely in the evaluation of patients with ischemic stroke only when there is clinical evidence of heart disease. For patients under the age of 45, an age group in which atherosclerotic cerebrovascular disease is less prevalent and cardioembolic stroke may be more likely, transthoracic echocardiography may be indicated [28]. The routine use of TEE for evaluation of patients with ischemic stroke is even more controversial. TTE and TEE are complementary procedures. The transthoracic approach is superior for visualizing the left ventricular apex, left ventricular thrombi, and certain aspects of prosthetic valves. The strength of TEE lies in its ability to visualize the thoracic aorta, and its superior visualization of the left atrium, its appendage and the interatrial septum. If a clear indication for anticoagulation is identified on the transthoracic study, further evaluation, namely TEE, is not needed. If the transthoracic echocardiography is negative, TEE is indicated [23] and is most helpful in patients under age 45 years with obvious heart disease [29].

Pulmonary artery emboli

Echocardiography can detect abnormalities of the right ventricle in 40% of patients with pulmonary embolism – right

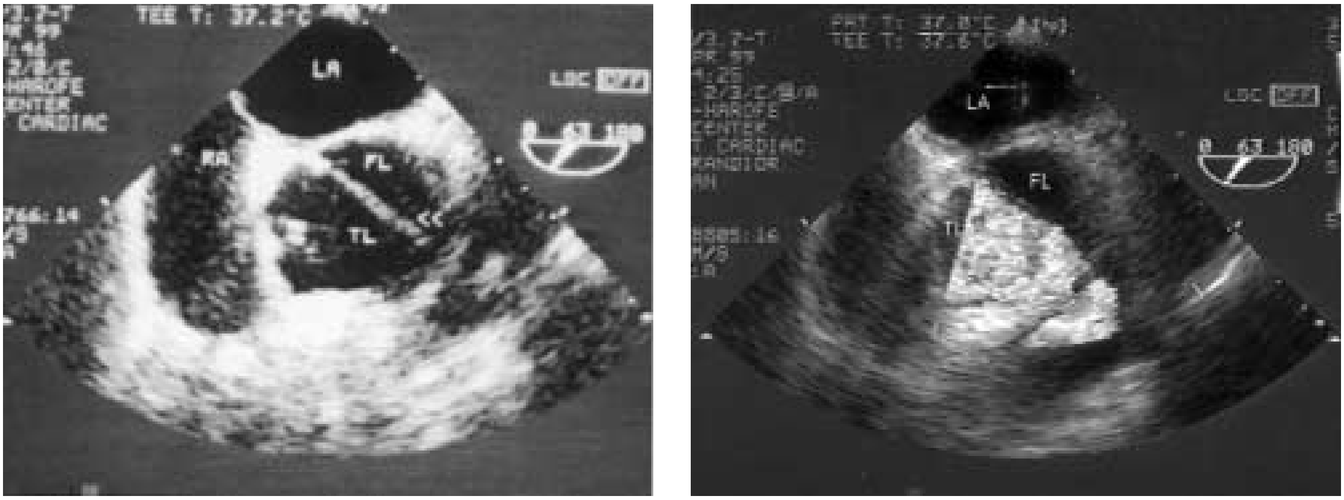

Figure 2. Horizontal upper esophageal image in a patient with chronic aortic dissection after aortic valve surgery. An intimal flap (arrow), dividing true lumen (TL) and false lumen (FL), is seen in the ascending aorta.

ventricular pressure overload, regional right ventricular dysfunction with hypokinesis of the free wall of the right ventricle [5]. Accurate calculation of pulmonary pressure can be achieved by measuring the tricuspid regurgitant flow velocity [18].

TEE can detect thrombi in the right atrium or inferior vena cava, which are a potential source of pulmonary embolism, emboli in transit, right ventricular dilatation and dysfunction, right atrial enlargement and pulmonary hypertension. TEE allows high resolution images of the main pulmonary artery and the proximal portions of the left and right pulmonary arteries. It may be especially useful for detecting pulmonary artery emboli in critically ill patients in whom radionuclide scans are non-diagnostic and pulmonary angiography is problematic. TEE permits visualization of proximal pulmonary emboli but not distal ones [11]. A few cases of true paradoxical embolism in transit have been described by TEE.

Aortic dissection

Echocardiography plays a central role in the diagnosis of patients with an aortic dissection. TTE is diagnostic in 75% of Type A (all dissections involving the ascending aorta), and 40% of Type B dissection (distal to the left subclavian artery, sparing the ascending aorta) and shows aortic regurgitation, pericardial effusion, and areas of left ventricular dysfunction [32]. Unstable patients are best evaluated by TEE in the emergency room or in the operating theater.

Stable patients can be evaluated by computed tomography or magnetic resonance imaging. The sensitivity and specificity of TEE for the diagnosis of aortic dissection are 99% and 98% respectively. In general, dissections of the ascending aorta require emergency surgery, whereas dissections involving the descending aorta may be treated medically. Linear artifacts in the ascending aorta can mimic intimal flaps as well as mirror image artifacts in the transverse and descending aorta that give the appearance of a false lumen. In aortic dissection two lumens separated by an intimal flap are seen within the aorta [Figure 2]. The true lumen shows systolic anterograde flow with systolic expansion and diastolic collapse. The false lumen shows diastolic expansion and systolic collapse often with thrombus formation. An intimal tear is seen as a disruption in the continuity of the flap. In non-communicating dissection a double lumen is divided by a dissection membrane, but without an intimal tear and no or very slow flow. The false lumen is created by a hemorrhage into the wall after rupture of vasa vasorum [11]. These intramural hematomas have specific TEE features, carry a high morbidity and mortality, behave like a classic aortic dissection and should be managed similarly [19]. TEE, however, does have some limitations in diagnosing aortic dissection. TEE can miss dissection of the distal ascending aorta, involvement of aortic branches and entry site. In contrast, the rapidity, the possibility of bedside examination, assessment of aortic regurgitation, myocardial infarction and pericardial effusion are major assets of TEE in the diagnosis of aortic dissection [32].

Congenital heart disease

Pediatric patients are usually ideal candidates for transthoracic echocardiography, but in some children transthoracic images may be sub-optimal due to tachypnea, mechanical ventilation, or previous thoracic surgery. In small children and infants the procedure is usually performed under general anesthesia. TEE may be valuable in assessing atrial septal defect and patent foramen ovale. Sinus venosus-type defects can be associated with anomalous pulmonary venous return, which is more easily seen by TEE than by transthoracic echocardiography. TEE can be used during interventions – aortic or pulmonic balloon valvuloplasty in congenital aortic or pulmonic stenosis, closure of patent ductus arteriosus, and for guidance of bedside balloon atrial septostomy in newborns. TEE may be used during corrective or palliative repair procedures to assess ventricular function and structural features, and to identify residual shunts and obstructions. The use of TEE in children should be restricted to selected patients due to risk associated with anesthesia, especially in cyanotic patients and those in low output states [4].

Transesophageal stress echocardiography

Pharmacological stress as well as simultaneous atrial pacing have been applied as stress modalities. Its advantage is a better acoustic window of the heart, yielding superior image quality in almost all patients. Transesophageal dobutamine stress echocardiography in patients after coronary artery bypass graft had better sensitivity and specificity than transthoracic stress echocardiography: 93% and 93% versus 78% and 86% respectively [33]. According to another small study [34], sensitivity and specificity of transesophageal dobutamine echocardiography was 82% and 93%, respectively, and correlated with lesser minimal luminal diameter (< 1.25 mm) of the stenosed artery.

Coronary artery assessment

Transesophageal Doppler echocardiography can be used for quantitating stenosis of the proximal part of the left coronary artery [35], which was identified in 90% of patients, while right coronary artery was detected in < 50% [7]. The diagnosis of ostial stenosis of the left main coronary artery is usually made by use of coronary angiography. However, positioning of the catheter across the obstruction may obscure this diagnosis during contrast injection. Although a damping of arterial pressure when the catheter enters the left coronary artery may suggest ostial stenosis, it may not be possible to make this diagnosis with certainty during cardiac catheterization. TEE correctly identified 96% of 24 left main stenoses [20]. Anomalies of coronary arteries seen by TEE have also been described [21], as have aneurysms and pseudoaneurysms of native coronary arteries and saphenous vein grafts [36,37]. Two-dimensional techniques are limited in obtaining optimal views of all segments of the coronary arteries because of their spatial orientations. Three-dimensional echocardiography may produce any cross-sectional views and reconstruct 3-D images. The left main, anterior descending, circumflex, and right coronary arteries were visualized from 3-D echocardiography in 100%, 100%, 98% and 72% respectively. The sensitivity and specificity of 3-D echocardiography in detecting significant stenosis (> 50%) were 84% and 97% [38]. Contrast injection may enhance diagnostic capabilities even further.

Perioperative TEE

TEE provides supplementary information that can guide management in the immediate post-bypass period and in the postoperative setting after cardiovascular surgery [22]. Studies that compared correlation of new segmental wall motion

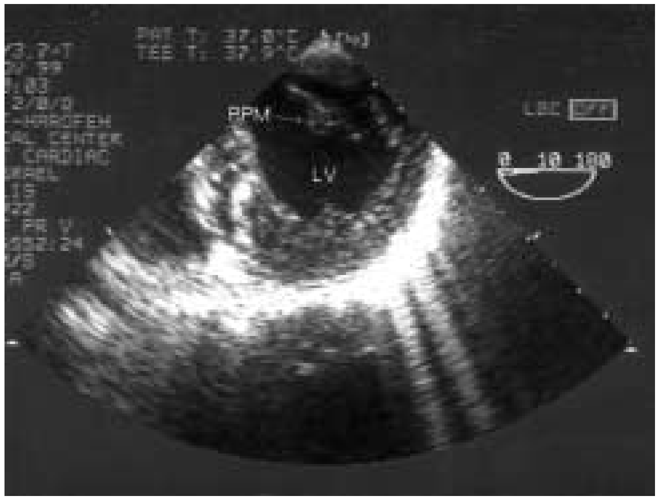

Figure 3. Severe mitral regurgitation due to ischemic rupture of the posteromedial papillary muscle. Transgastric view showing ruptured head of papillary muscle (PPM) in the left ventricle (LV).

abnormalities with ischemic ST segment changes during coronary artery bypass grafting proved TEE to be a more sensitive method for detection of myocardial ischemia than ECG [7]. An acute decrease or cessation of segmental contraction (new segmental wall motion abnormalities) is almost certainly due to myocardial ischemia resulting from inadequate revascularization, or to stunned myocardium from cooling during bypass. Inadequate revascularization may require placement of additional grafts, while stunned myocardium requires only supportive measures until its function returns. TEE can definitely evaluate valvular function before and after valvular surgery for subsequent prompt correction if necessary. It can affect the surgical plan [39] by detecting unsuspected valvular insufficiency or unsuspected left atrial thrombi, or can prevent unnecessary intervention in a normally functioning valve. In mitral valve repair intraoperative TEE determines the mechanism of mitral valve dysfunction and predicts specific surgical techniques. Significant persistent mitral regurgitation is an indication for putting the patient back on cardiopulmonary bypass for further surgery during the same thoracotomy [10]. Three-dimensional TEE may become the optimal tool for the surgeon for the pre-, peri- and post-corrective surgical periods.

In non-cardiac surgery TEE is valuable for detecting intraoperative ischemia or infarction in patients at high risk for cardiac complications.

Critically ill patients

The use of the transthoracic approach in echocardiographic evaluation of critically ill patients is sometimes insufficient in the presence of mechanical ventilation and TEE should be used. In hypotensive patients TEE may offer a clearer diagnostic picture and exclude potential causes for a patient's hemodynamic instability [22]. The last may result from hypovolemia, left or right ventricular failure, massive pulmonary embolism, or pericardial tamponade. TEE is the technique of choice in the bedside determination of the type of hemodynamic deterioration and has immediate consequences for patient management [22]. It allows an estimation of filling status, ventricular contractility and afterload. Pulmonary artery catheterization is more invasive and should be initiated only when the hemodynamic instability is of cardiac origin. In intensive coronary care units TEE has been useful for evaluating major post-infarction complications such as ventricular septal defect and mitral regurgitation due to extensive wall damage or papillary muscle rupture [Figure 3]. In brain-dead patients – possible donors of organs for transplantation – TEE may be useful to evaluate cardiac function.

Chest trauma

Transthoracic images are often limited in victims of multitrauma. TEE permits evaluation of ventricular function and myocardial contusion, valvular anatomy and function, pericardial effusion and evidence of tamponade aortic injury. Extensive aortic dissection is rare after blunt trauma because of the high associated mortality. Patients usually have a contained hematoma around the aortic dissection [22]. Transection of the thoracic aorta is well described at the level of the ligamentum arteriosum. A true medial aortic dissection is rare in blunt chest trauma [22]. TEE can identify the intimal flap and origin of dissection. Doppler enables differentiation of the true lumen from the false lumen [7]. TEE should be used to evaluate all patients with an enlarged mediastinum and hemodynamic instability on admission. The major limitation of TEE in the evaluation of great vessels is the inadequate view of the distal part of the ascending aorta [22]. CT angiography should be used only if TEE cannot provide evidence of aortic lesions.

Conclusion

TEE and TTE complement each other and this approach remains the primary technique. TEE provides high quality imaging of cardiac structures. The indications for TEE have greatly expanded in the last few years with the development of multiplane transducer and color flow Doppler. In some conditions (endocarditis, prosthetic valve failure, dissection of aorta), TEE findings dictate what the appropriate care of the patient should be, making additional procedures unnecessary. In other conditions TEE diagnosis can guide therapy – anticoagulation in the patient with intracardiac thrombus, and appropriate management of the surgical patient in the operating room and postoperative period.

TEE is an outpatient procedure with short-term low risk examination and without major contraindications. It should not be forgotten, however, that TEE is an invasive procedure and is associated with some risk and discomfort to the patient. Developments in the field will no doubt yield TEE probes that will be even further reduced in size, making the procedure less invasive and reducing the need for sedation. Furthermore, the introduction of new techniques of real-time 3-D echocardiography will enable the diagnosis of coronary artery disease by TEE and even better anatomic resolution of cardiac structures.

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