TRANSOESOPHAGEAL ECHOCARDIOGRAPHY

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Over the last decade, transoesophageal echocardiography (TOE) has evolved as an essential ultrasonographic technique for rapid bedside tomographic evaluation of the cardiovascular system. Imaging from the confines of the gastro-oesophageal track reduces signal attenuation and permits the use of higher ultrasound frequencies, thereby providing an enhanced spatial resolution. Although interpretation of the structural and haemodynamic information from TOE needs training, the technique can be readily integrated in day to day clinical algorithms, particularly those that demand quick medical decision making. TOE has a wide applicability and its role currently expands beyond the realm of clinical cardiology. An increasing number of anaesthetists, surgeons, and intensivists now use it routinely for monitoring and guiding operative procedures, interventions, and managing critically ill patients. This article provides a brief overview of the indications, imaging techniques, pitfalls, and the emerging trends in the application of TOE.

HISTORY

TOE for recording continuous wave Doppler velocities of cardiac flow was first described by Side and Gosling in 1971.[1] Subsequently, the first transoesophageal M mode echocardiogram was reported by Frazin and colleagues in 1976,[2] while Hisanaga and colleagues in 1977 illustrated the use of cross sectional real time imaging using a scanning device that consisted of a rotating single element in an oil filled balloon mounted at the tip of the gastroscope.[3] The initial acceptance of TOE was offset by the logistic difficulties of introducing rigid endoscopes. The ensuing technological developments that facilitated the transition of TOE to its present clinical status included the introduction of the flexible endoscope, miniaturisation, and improvements in transducer designs, serial improvement in scanning capabilities from monoplane, biplane to multiplane views, and the addition of spectral and colour Doppler imaging. TOE is currently used in approximately 5–10% of patients being evaluated in the cardiovascular ultrasound imaging and haemodynamic laboratory.

INSTRUMENTATION

TOE can be performed as an outpatient or inpatient procedure. Fasting based on conscious sedation guidelines, an intravenous access, careful history to rule out presence of laryngeal or gastro-oesophageal diseases, and removal of dentures are prerequisites. Absolute contraindications to TOE include oesophageal stricture, diverticulum, tumour, and recent oesophageal or gastric surgery. Topical spray, intravenous sedation, a drying agent to minimise oral secretion, and use of appropriate lubrication are helpful. Once in the oesophagus, the transducer should be gently guided and never forced through resistance. Although the risk of bacterial endocarditis is extremely low and routine antibiotic prophylaxis before TOE is not advocated, it should be recommended in high risk patients such as those with prosthetic valves, multivalvar involvement, or those with a past history of infective endocarditis.

Although the study needs to examine all the regions of the heart and great vessels, examination can be initially targeted for resolving the primary issue for which TOE is being performed. Almost all views obtained by surface echocardiography can be duplicated by TOE (figs 1 and 2). TOE additionally has a distinct advantage in being able to maintain an anatomical correlation of images such that longitudinal, transverse, and off-axis images are evaluated on a continuum rather than independent views for providing an enhanced spatial assessment. The multiplane TOE transducer consists of a single array of crystals that can be electronically and mechanically rotated in an arc of 180° (fig 1). The technical aspects of the procedure have been highlighted extensively in earlier reviews.[4] Being semi-invasive, appropriate training requirements are needed and have been laid down by the American Society of Echocardiography.[5] Procedural risks are low in trained hands. However, they need to be explained clearly to the patient. These include transient throat pain, laryngospasm, aspiration, hypotension, hypertension, tachycardia, mucosal bleeding, oesophageal rupture, and rare risk of death. Benzocaine topical spray can cause toxic

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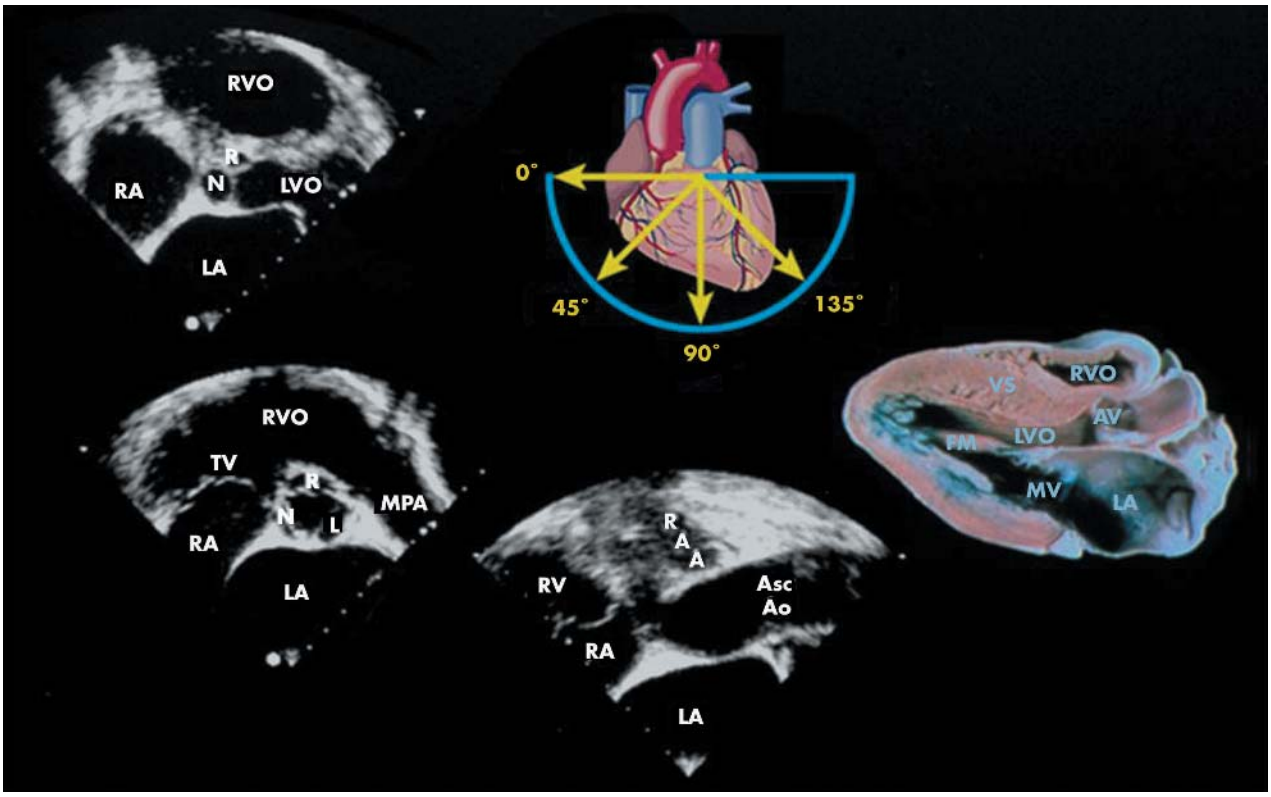

Figure 1 Multiplane transoesophageal echocardiographic (TOE) views (0˚, 45˚, 90˚, and 135˚) obtained from mid oesophagus. Asc Ao, ascending aorta; LA, left atrium, LV, left ventricle; LVO, left ventricle outflow; MPA, main pulmonary artery; MV, mitral valve; RA, right atrium; RAA, right atrial appendage; RV, right ventricle; RVO, right ventricular outflow; TV, tricuspid valve; VS, ventricular septum; R, L, and N, right, left and non-coronary aortic sinus.

methaemoglobinaemia. The treatment is administration of methylene blue in addition to supportive measures.

CLINICAL APPLICATIONS

Any condition where an echocardiographic evaluation is clinically indicated and in which the transthoracic approach does not yield good quality images is a potential indication for TOE.

Infective endocarditis

Despite technological advancements and use of harmonic imaging, TOE continues to be superior to transthoracic echocardiography for better delineation of the shape and size of vegetations. Left sided vegetations pose an increased risk of systemic embolism. The risk of embolism has been shown to increase with increasing size of vegetation.[6] TOE is also important for assessing the structural complications such as myocardial abscess, fistulas, mycotic aneurysms, valvar aneurysms or perforations, flail leaflets, or prosthetic valve dehiscence. TOE has a higher sensitivity (76–100%) and specificity (94%) than transthoracic echocardiography for diagnosing perivalvar extension of infection.[7] The cost effectiveness and incremental utility of TOE when used in conjunction with the clinical information is particularly higher in patients who have an intermediate clinical likelihood of infective endocarditis.[8] A negative TOE in a patient with suspected infective endocarditis virtually rules out an infection of the native valve, except in very early phases of the disease when vegetations may not be detected. When clinical suspicion of infective endocarditis is high and results from TOE are negative, a repeat TOE is warranted within 7–10 days, which may demonstrate previously undetected vegetations or abscess.

Evaluation of prosthetic valves

TOE is the procedure of choice for detecting abnormalities of mitral valve prostheses (perivalvar regurgitations, cusp abnormalities in tissue prosthesis, embolic events, patient–prosthesis mismatch, and malfunction of repaired valves and implanted rings) (fig 3).[9] The aortic valve lies in a plane perpendicular with the oesophagus, with a flow that has an asymmetric profile, therefore assessment of a prosthetic aortic valve by TOE may be more challenging. However, TOE is useful in detecting abnormalities of aortic valve prosthesis, particularly those related to periprosthetic tissue. A deep transgastric view is required for assessing the gradient across the prosthesis and for better assessment of prosthetic aortic valve regurgitation. TOE is also useful in diagnosing prosthetic valve thrombosis and for assessing success of thrombolytic treatment. TOE allows a close examination of the sewing ring and the occluder, thus helping differentiate pannus from a thrombus and for establishing the mechanism of an incomplete occluder opening. TOE is also useful in providing a high resolution assessment of valves in tricuspid and pulmonic positions.

Cardioembolic strokes

The likelihood of identifying a potential cardiac source of emboli depends on how thoroughly a patient is evaluated. TOE has been shown to have a higher accuracy in identifying

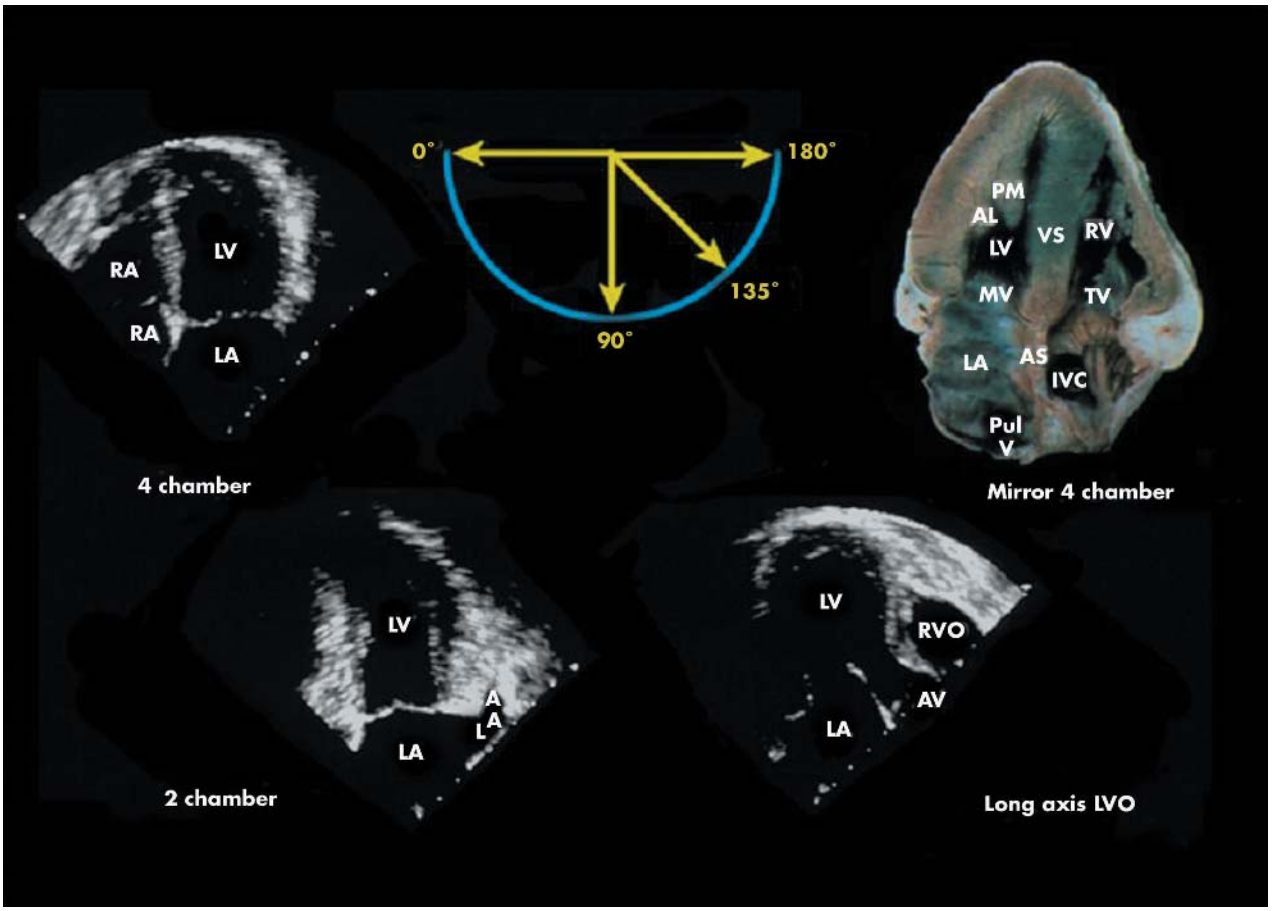

Figure 2 Multiplane (0°, 90°, 135°, and 180°) views obtained along the long axis of the left ventricle resembling apical views obtained during surface echocardiography. See fig 1 for explanation of abbreviations.

abnormal lesions in patients with cardioembolic strokes.[10] These include abnormalities of the left and right atrium and appendages, intra-atrial septum, patent foramen ovale, atrial septal aneurysm, vegetations, spontaneous contrast, left ventricular clots, and various cardiac masses. The diagnostic yield of TOE for a cardiac source of emboli in a group of patients presenting with unexplained stroke or transient ischaemic attacks is high with potential lesions identified in over 50% of the studies. However, one third of patients who have a cardioembolic stroke also have concomitant cerebral or vascular atherosclerosis, which can confound the diagnosis. Moreover, no absolute clinical or laboratory gold standard exists for diagnosing a potentially cardioembolic lesion; hence risk stratification schemes have been suggested based upon strength of the association of a given lesion with ischaemic strokes.

Atrial fibrillation

Atrial arrhythmias predispose to emboli formation. A sustained impairment or transient stunning results in poor emptying and enlargement of left atrium and left atrial appendage, leading consequently to stasis and thrombus formation. Transient paroxysms of atrial fibrillation may lead to thrombus formation in the left atrium. Left atrial thrombus may be detected in the presence of sinus rhythm.[11] Conversely, the lack of visualisation of appendage thrombi on TOE after stroke does not exclude the appendage as the embolic source. In the absence of well formed thrombi, a dense spontaneous contrast has been shown to be a strong predictor of ischaemic strokes. An annual thromboembolic event rate of 12% has been observed in patients with spontaneous echo contrast compared to 3% in patients without it.[12]

In patients with atrial fibrillation, clinical and echocardiographic markers of thromboembolism are helpful for risk stratification and include a history of hypertension, a previous thromboembolic event, and heart failure. Echocardiographic risk factors include left ventricular systolic function, left ventricular hypertrophy, left atrial enlargement, and spontaneous echocardiographic contrast. The absolute risk of stroke in atrial fibrillation shows pronounced variation with age and coexisting cardiovascular diseases, ranging from 2–18% per year depending on the investigated patient population.[13] Short term anticoagulation combined with TOE before cardioversion has been suggested to be an effective alternative to 3–4 weeks of empiric anticoagulation before cardioversion.[14]

Regarding economic analysis of TOE, facilitated acute cardioversion has been shown to result in higher initial treatment costs but lower subsequent outcome associated costs, resulting in no significant cost difference between the two strategies.[15]

Aortic diseases

Transoesophageal examination is extremely valuable for managing patients with aortic diseases (aortic dissections,

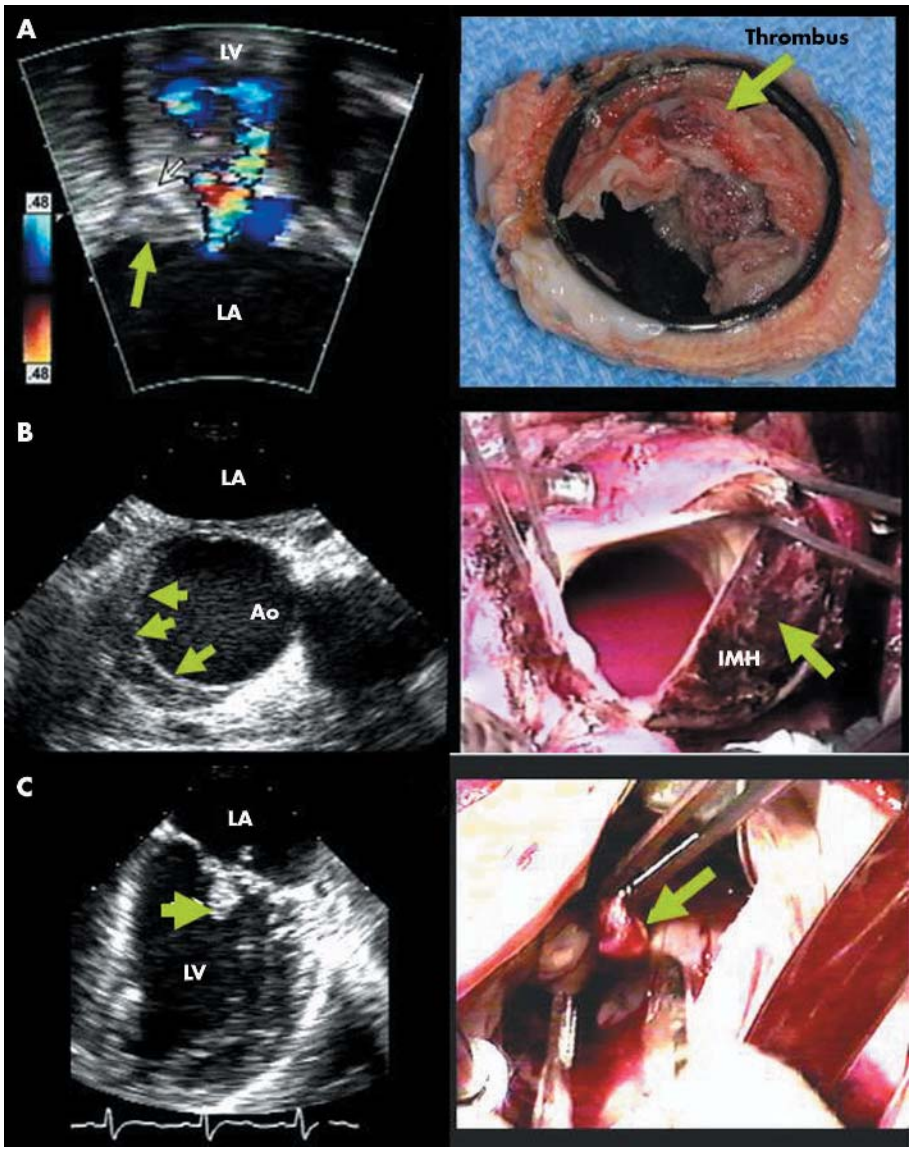

Figure 3 Panels illustrating a unique range of structural abnormalities that can be accurately detected by TOE. Panels A, B, and C show the pathological observations during surgery in the same patients (A, prosthetic valve thrombosis; B, aortic intramural haematoma (IMH); C, Papillary fibroelastoma arising from the mitral valve). Ao, aorta; LA, left atrium; LV, left ventricle.

intramural injury, and aortic trauma).[16] In a comparative imaging of multiplane TOE with spiral computed tomography (CT) and magnetic resonance imaging (MRI), the sensitivity and specificity of TOE for diagnosing aortic dissections has been reported as 98% and 95%, respectively.[17] However, care needs to be taken to differentiate reverberation artefacts. Conversely, false negatives may occur when small dissections are located within upper ascending aorta or proximal aortic arch. The reverberation artefacts may be differentiated using M mode echocardiography. The chief advantage of TOE in imaging aortic dissections is that it provides diagnostic information faster than other modalities, and it is the only modality which can be used intraoperatively during surgery. TOE has also been found useful in screening patients with suspected aortic trauma and for diagnosing acute aortic intramural haematomas (fig 3).

Studies have shown an association between large atheromas in the ascending aorta and the aortic arch and an increased risk of cerebral embolic events in patients older than 60 years. Morphologic features such as atheroma protrusion and ulceration have been shown to carry significantly higher risk of embolic events, particularly after cardiopulmonary bypass or following invasive procedures such as cardiac catheterisation or intra-aortic balloon placement. Although TOE has been used to assess atheromas and their morphologies, it is not clear whether atheroma thickness is directly related to the mechanism of stroke or represents a marker for other conditions. In a recent study, the association between previous ischaemic strokes, transient ischaemic episodes, and aortic atherosclerosis was found to be insignificant once age and sex related adjustments were made.[18] The overall importance of aortic atherosclerosis in the pathogenesis of cerebrovascular accidents is thus not clear and needs to be correlated with associated risk factors such as hypertension, coagulation, and lipid disorders.

Cardiac masses

TOE is superior to transthoracic echocardiography in delineating cardiac masses and masses adjacent to the heart, such as in the pulmonary arteries and mediastinum. It is particularly useful for differentiating structural features, such as site of attachment (fig 4), consistency as in cystic versus

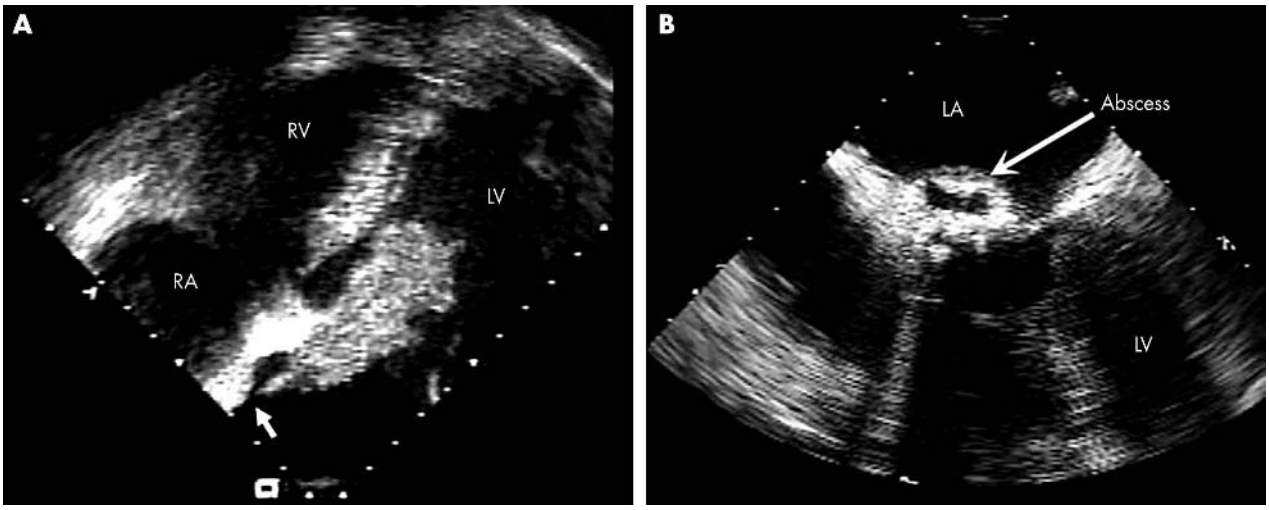

Figure 4 Panel A illustrates the use of TOE for characterising the site of attachment of a left atrial myxoma. Panel B shows the role of TOE in diagnosing myocardial abscess in a patient with longstanding infective endocarditis. LA, left atrium; LV, left ventricle; RA, right atrium.

solid, and infiltration into surrounding structures, that are useful for differentiating thrombi and benign from malignant neoplasms. TOE is particularly advantageous in the detecting masses posterior to mechanical devices or in left atrial appendages. TOE is also useful in the detection of thrombi lying in the proximal portion of the pulmonary arteries.[19]

Congenital heart diseases and intracardiac shunts

TOE is superior to routine surface echocardiography for the evaluation of specific cardiac defects, such as certain types of atrial septal defects, anomalous pulmonary venous connections, and complex cardiac malformations. The technique is particularly useful in atrial septal defects. Sinus venosus defects and anomalous pulmonary vein drainage are detected more easily by TOE as compared to transthoracic echocardiography because of the proximity of the transducer to the atrial septum. TOE is recommended in any patient with an unexplained dilatation of the right side of the heart for ruling out a sinus venosus atrial septal defect and associated pulmonary venous abnormalities.[20] TOE is also useful for visualising the margins of an atrial septal defect for defining candidates who may benefit from non-surgical device closure of the defect.

TOE has been used for detecting shunt flow across foramen ovale in adults. Patent foramen ovale and stroke remain subjects of intense investigation with no clear answers. Patent foramen ovale may also be associated with atrial septal aneurysms and presence of both these lesions have also been implicated in recurrent embolic strokes.[21]

Critically ill patients

The limited acoustic windows in critically ill patients make TOE an attractive alternative to transthoracic echocardiography. In addition to the usual indications for TOE (suspected endocarditis, source of embolus, and suspected aortic dissection), there are several indications that are unique to critical care patients. These include assessment of unexplained hypotension, suspected massive pulmonary embolism, unexplained hypoxaemia, and complications of cardiothoracic surgery. Unlike transthoracic echocardiography, TOE can visualise emboli lodged in the proximal pulmonary arteries. The right pulmonary artery can be observed for most of its course; however, the left pulmonary artery rarely can be observed beyond its first two centimetres. Less common indications for TOE in the critical care unit include continuous haemodynamic monitoring, evaluation of potential transplant donors, and guidance of central line placement. The recent development of transnasal TOE probes may allow for monitoring in the awake patient. The potential benefits of the transnasal probe include less risk for oesophageal trauma in patients with varices or coagulopathies, and less need for sedation in those with compromised respiratory or haemodynamic status.

Perioperative period and during procedures

TOE is valuable in the perioperative period and can provide incremental information for either changing the preoperative plan or prompting immediate revision of haemodynamically significant residual defects. Intraoperative TOE is extremely useful in patients undergoing valve repairs, replacements, and reoperative surgeries. In patients undergoing mitral valve repairs, TOE is extremely useful for the surgeons in making a decision about the choice of the surgical procedure which may include chordal shortening, chordal transfer, artificial chords, posterior leaflet sliding technique, anterior leaflet resection, or placement of annular ring. Routine intraoperative echocardiography has also been found to be cost effective in children undergoing cardiac surgery for congenital heart lesions.[22]

TOE also plays a role in the interventional laboratory for percutaneous interventions such as transcatheter closure of atrial septal defects and ventricular septal defects. It is used before the procedure for identifying the defect, excluding multiple defects, measuring the adequacy of the rim of the interatrial septum and its distance from the pulmonary vein and the mitral valve and superior vena cava, balloon sizing of the stretched diameter, and for proper placement of the occluder. TOE is also used as an important imaging modality for blade atrial septostomy and closure of baffle fenestrations following total caval pulmonary connection and closure of baffle leak following the Mustard or Senning surgeries.

Other interventional procedures where TOE is useful include balloon mitral valvoplasty, non-surgical reduction of ventricular septum in patients with hypertrophic

cardiomyopathy, and transseptal catheterisation for placement of catheter during radiofrequency ablation of cardiac arrhythmias.

TOE also plays an important role in patients with heart failure undergoing implantation of left ventricular assist devices for selecting the type of assist device necessary (right versus left or biventricular), optimisation of device performance, the evaluation of hypoxaemia, and the determination of the patient's ability to be weaned from the mechanical device.[23] A correct positioning of cannula under TOE guidance optimises the left ventricular filling, besides intraoperative recognition of right ventricular failure, which can decrease pump flow due to inadequate left sided filling.

PITFALLS

Despite its superior image resolution, TOE needs expertise for avoiding potential erroneous diagnosis resulting from misinterpretation of normal and abnormal anatomy (fig 5). Air within the oesophagus and stomach, or an air-filled trachea and bronchi intervening between probe and cardiac structures, can consistently produce artefacts or interfere with certain tomographic views. Reverberation signals or ghost shadows are common and result from impedance mismatch resulting in linear artefacts most commonly seen in the upper ascending and mid descending aorta. Imaging of the upper ascending aorta with the horizontal plane is limited by a blind spot caused by interposed bronchus between the oesophagus and upper ascending aorta.

Normal anatomy may be interpreted as abnormal. These include: muscular trabeculations in the atrial appendage mistaken as mass or thrombus; the terminal portion of the partition between the left atrial appendage and left upper pulmonary vein appearing as a globular mass; fat laden fossa ovalis or lipomatous hypertrophy of the atrial septum interpreted as a mass; and surgical sutures appearing filamentous or pedunculated and interpreted as mass or vegetations. Certain normal structures generate echo-free spaces and may be incorrectly interpreted as cysts or abscesses. These include the transverse and the oblique sinus. Other significant difficulties may also be encountered during TOE for adequate visualisation and quantification of aortic valve regurgitation, aortic valve and pulmonary valve gradient estimation, and non-foreshortened visualisation of the left ventricular apex. Ultrasound transducers generate heat. During prolonged monitoring, the device may be required to be shut down periodically to allow cooling.

FUTURE DIRECTIONS

Easy applicability, lower costs, portability, and instantaneous availability of test results have made TOE a valuable imaging modality in clinical cardiology. The utility of TOE in visualising cardiovascular structures and its incremental value over transthoracic echocardiography have been well established. Future miniaturisation of the TOE transducer design is likely to improve application in a wider subgroup of patients including premature infants, children, pregnant women, and patients with haemodynamic instability. A smaller probe design would help minimise discomfort from longer monitoring of cardiovascular haemodynamics and treatment. TOE provides high quality two dimensional images, which therefore provide a basis for three dimensional (3D) reconstructions. Since the atrial cavities lie close to the oesophagus, TOE is likely to be useful for 3D imaging of regurgitation jets, particularly those with eccentric orifices and orientations. Real time 3D imaging would also facilitate accurate monitoring of catheter based techniques,

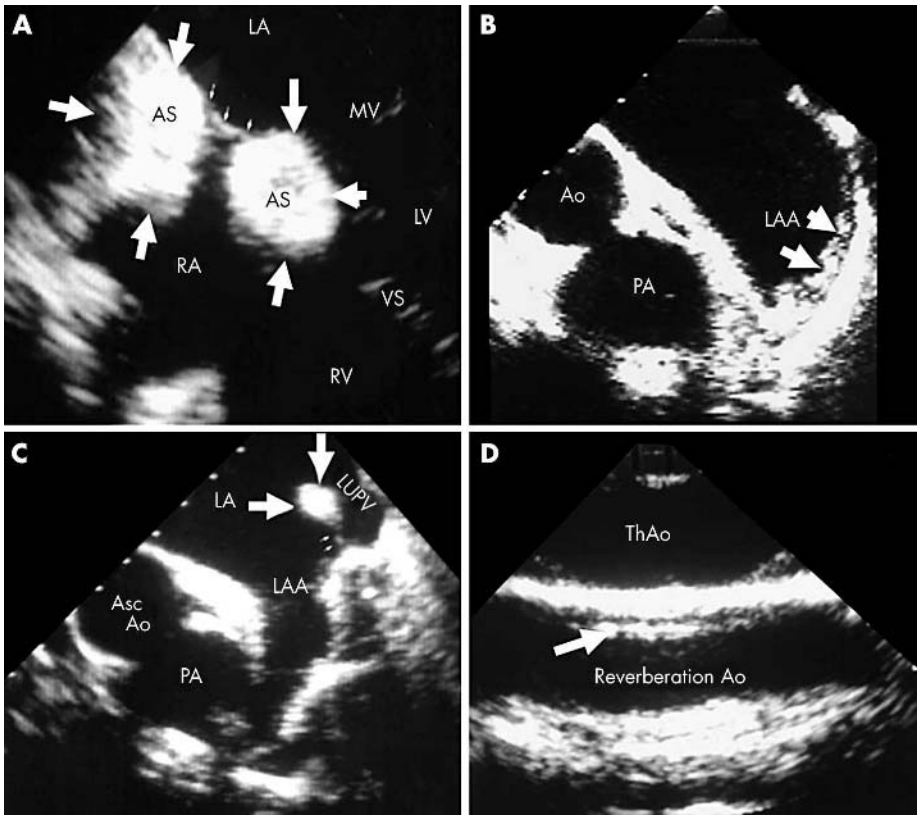

Figure 5 Figures illustrating common diagnostic pitfalls during TOE. Panel A shows a case of lipomatous inter-atrial septum, the membrane of the fossa ovalis is spared while the remaining septum is thickened resulting in a dumbbell mass like appearance. Panel B shows normal appearance of muscular trabeculations in the left atrial appendage which can be mistaken as a mass or thrombus. Panel C shows a mass like appearance of the orifice of the pulmonary vein, and panel D shows reverberation artefacts in the descending aorta that can be inappropriately labelled as a dissection flap. Ao, aorta; AS, atrial septum; LA, left atrium; LAA, left atrial appendage; LUPV, left upper pulmonary vein; LV, left ventricle; PA, pulmonary artery; RA, right atrium; RV, right ventricle; VS, ventricular septum; ThAo, thoracic aorta.

Transoesophageal echocardiography (TOE): key points

- TOE can supplement, complement, or be used as a stand alone procedure for rapid tomographic imaging of the cardiovascular system
- The most common indication is for identifying a cardiac source of embolism. A potential underlying source of embolism is identified in over 50% of patients who present with embolic strokes
- Although transthoracic echocardiography could be normal, TOE is imperative for ruling out presence of specific cardiac lesions. These include the left atrial and appendage clots, atrial septal defects, aortic dissection, and abnormal drainage of pulmonary veins
- TOE is useful in native and prosthetic valve endocarditis for detecting complications such as abscess formation and perforations. If the index of suspicion is high, in the event of an inconclusive initial examination, a repeat TOE is warranted within 7–10 days
- TOE is used for optimal selection of patients who may benefit from valve repairs, replacements, or reoperative surgeries. TOE plays an important role for intraoperative and postoperative monitoring of patients undergoing cardiac surgeries
- In the interventional laboratory, TOE is useful for guiding transseptal punctures, device closure of left-to-right shunts, paediatric interventions, and during radiofrequency ablation of arrhythmias
- Despite a superior image resolution, normal anatomical structures may be interpreted as abnormal. TOE therefore needs optimal training for avoiding potential diagnostic errors

radiofrequency ablations, and for intraoperative monitoring of surgical techniques that require appreciation of complex geometries like the valves and the subvalvar apparatus.

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