Review Article

An update on transesophageal echocardiography views 2016: 2D versus 3D tee views

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ABSTRACT

In 1980, Transesophageal Echocardiography (TEE) first technology has introduced the standard of practice for most cardiac operating rooms to facilitate surgical decision making. Transoesophageal echocardiography as a diagnostic tool is now an integral part of intraoperative monitoring practice of cardiac anaesthesiology. Practice guidelines for perioperative transesophageal echocardiography are systematically developed recommendations that assist in the management of surgical patients, were developed by Indian Association of Cardiac Anaesthesiologists (IACTA). This update relates to the former IACTA practice guidelines published in 2013 and the ASE/EACTA guidelines of 2015. The current authors believe that the basic echocardiographer should be familiar with the technical skills for acquiring 28 cross sectional imaging planes. These 28 cross sections would provide also the format for digital acquisition and storage of a comprehensive TEE examination and adds 5 more additional views, introduced for different clinical scenarios in recent times. A comparison of 2D TEE views versus 3D TEE views is attempted for the first time in literature, in this manuscript. Since, cardiac anaesthesia variability exists in the precise anatomic orientation between the heart and the oesophagus in individual patients, an attempt has been made to provide specific criteria based on identifiable anatomic landmarks to improve the reproducibility and consistency of image acquisition for each of the standard cross sections.

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Key words: Cardiac anaesthesia; perioperative Transoesophageal echocardiography; TEE views

INTRODUCTION

The significant role of perioperative TEE on surgical patients before, during, or immediately after surgery and cardiac catheterization interventional procedures, as well as in intensive care settings is well documented by IACTA.[1] This modality is being used in both government institutions and private hospitals all across India. TEE is an invasive procedure which necessitates an identification of appropriate indications and contraindications, understanding the technical aspects of probe insertion/manipulation, interpretation of the data generated by TEE, image generation/storage of data, integration of diagnostic imaging information, and generation of a report. Thus update focuses on the application of TEE in the setting of cardiac surgical patients, noncardiac surgery, and postoperative critical care. It does not address training, certification, establishing credentials and quality assurance.

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Transesophgeal Echocardiography (TEE) has the unique advantage of portability, high resolution images of normal or abnormal cardiovascular anatomy and function, easy to perform, low risk of complication and the best stepwise approach.

INSTRUMENT MANIPULATION

There are five corresponding terminology used to describe manipulation of the probe during image acquisition. Advancing the shaft of the probe distally into the esophagus or the stomach and withdrawing the tip of the probe in the opposite direction proximally called advancement or withdrawal respectively [Figure 1a]. Turning the probe to the right termed as clockwise rotation, whereas turning the probe to the left termed as counter clockwise rotation. [Figure 1b]. TEE probe may be flexed anteriorly (anteflexion), or posteriorly (retroflexion) with the large control wheel and to the left or right (probe flexion). [Figure 1c]. Flexing the tip of the tee probe can be done with the small control wheel to the patient's right or left [Figure 1d]. Finally, the array rotation buttons turn within the probe from 0 degrees or the horizontal plane "forward" to 180 degrees or from 180 to 0 degrees (backward transducer rotation).The images displayed at the top of the screen are in the near field and structures in the far field are at the bottom of the screen. At a multiplane angle of 0 degree, the patient's right sided structures will be displayed on the left of the image display. By rotating the multiplane angle forward to 90 degrees left side of the image display shows posterior structure. Approximately distance of the probe tip from lips is 20-25 cm for upper esophageal (UE) views, 30-40 cm for midesophageal (ME) views and 40-45 cm for transgastric (TG) view in an average sized adult male; however, placement of the transducer into desired location is primarily accomplished by waiting the image to develop as the probe is manipulated rather than depth markers on the probe.[2]

REGIONAL LEFT VENTRICLE ASSESSMENT AND CORONARY ARTERIAL DISTRIBUTION

In order to assess regional systolic function, the left ventricle (LV) is divided into different segments from base to the apex corresponding to the proximal, middle and apical segments of the coronary arteries. The currently recommended segmentation is a 17-segment model as described in the figure. The left ventricle is divided into 6 segments: Anterior, anteroseptal, inferoseptal, posterolateral and anterolateral. Each segment is divided into a basal, mid and apical segment and the apical cap represents the 17th segment [Figure 2].

In the operating room TEE examination of the LV requires obtaining at least 5 views: Mid-esophageal 4 chamber, Mid-esophageal 2-chamber, Mid-esophageal

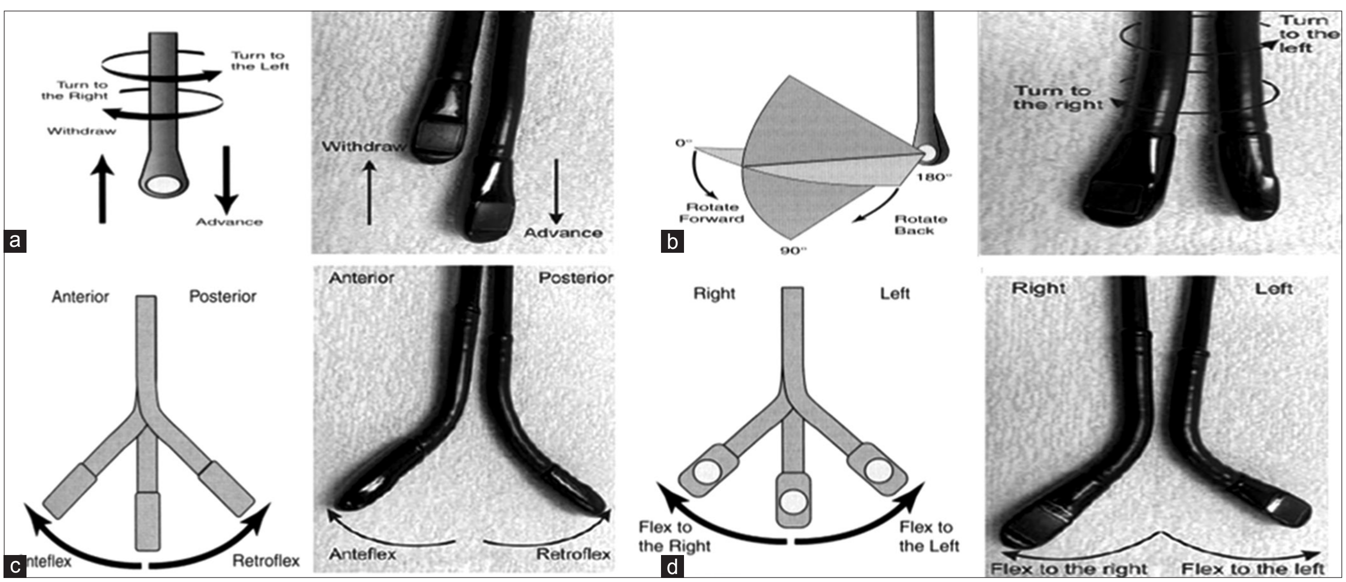


Figure 1: (a) Advance, withdraw: Pushing or pulling the tip of the TEE probe; (b) turn to right, turn to left (also referred as clockwise and anticlockwise): rotating the anterior aspect of the TEE probe to the right or left of the patient; (c) anteflex, retroflex: anteflex is flexing the tip of the TEE probe anteriorly by turning the large control wheel clockwise. Retroflex is flexing the tip of the TEE probe posteriorly by turning the large wheel anticlockwise; (d) Flex to right, Flex to left: flexing the tip of the TEE probe with the small control wheel to the patient's right or left. The probe flexion to the right and left may not be necessary and should be avoided to minimize trauma to the esophagus

long axis, Transgastric basal short-axis (‘fishmouth view’) and Transgastric mid-papillary short axis. Mid-Oesophegeal four chamber view allows the simultaneous visualization of both the left and right ventricles. Common problem of Mid-oesophegeal four chamber view is foreshortening. Segmental function of the lateral and septal walls is best assessed in this view. Mid-Oesophegeal two chamber view is good for assessing segmental function of the anterior and inferior walls and can be used for measurements of ventricular volume. Mid-esophageal long axis shows the anteroseptal wall on right side facing the posterior wall on the left, which can be evaluated for regional contractile function. TG mid-papillary short-axis view gives an idea about the portion of the territories of all three main coronary arteries perfusing the LV, detect ischemia. LV apex is visualised in transgastric long-axis view. The anterior leaflet of the mitral valve (AML) clearly visualise between the left ventricular outflow tract and the mitral valve orifice in TG basal short axis view.

IACTA RECOMMENDED COMPREHENSIVE TEE EXAMINATION

Comprehensive imaging examination

The table lists suggested standard 28 views included additional views in a comprehensive perioperative transoesophageal echocardiographic examination as it exists in 2016. Each view is shown as a 2D and 3D image. The structures imaged and the acquisition protocol in each view are listed in the adjoining columns [Figures 3-36].

In the, recommendations for Echocardiography in patients referred for cardiac surgery or percutaneous Intervention echocardiography, the authors have recommended TEE or intra cardiac echocardiography, in all patients before intra cardiac percutaneous intervention to exclude potential cardiac sources of emboli that might be dislodged during intervention. The routine preoperative use of TEE to identify and manage aortic atheromatous disease is recommended in patients with increased risk for embolic stroke, including those with histories of cerebrovascular or peripheral vascular disease and those with evidence of aortic atherosclerosis or calcification by other imaging modalities, including preoperative or intraoperative MRI, CT, or chest radiography. TEE may allow the surgeon to individualize the surgical technique and potentially reduce the incidence of embolic stroke.

New guidelines on TEE for aortic sources of embolism[8], on diastology and LV diastolic function[9] for ASD and patent foramen ovale have been recently introduced, this year in clinical practice. These are essential to the perioperative echocardiographer and should be adopted. We recommend these additional TEE views to be carried out to complete an echocardiography based examination before, during and after cardiac surgery.

Three-Dimensional Transoesophageal Echocardiography and its Advantages over 2D TEE

3D echocardiography, a relatively new technology enables the echocardiographer to provide the real

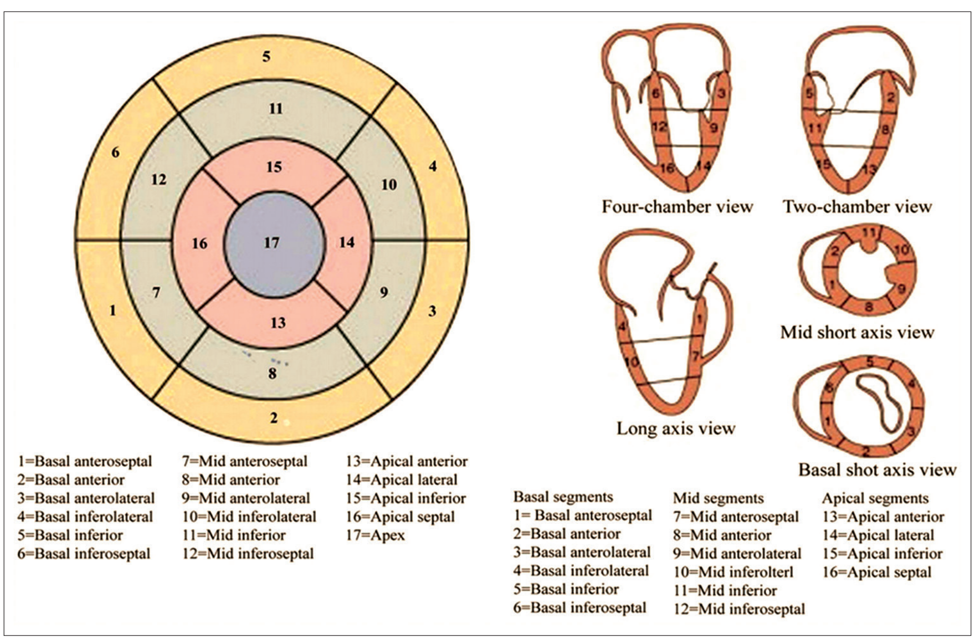


Figure 2: Nomenclature of 17 different segments of the left ventricle in coronary artery disease

Twenty eight standard views + additional views [Figures 3-36]

MIDESOPHAGEAL FIVE CHAMBER VIEW

Transducer angle:0-10 degree

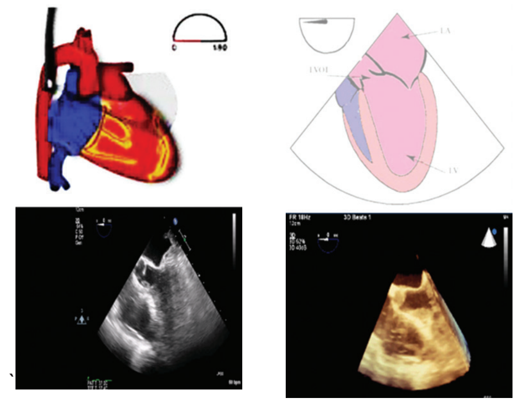
Level:Mid - esophageal

Structures imaged:

- Aortic valve
- LVOT
- LA/RA
- LV/RV/IVS
- MV (A2A1-P1)
- TV

Clinical Utility:

For any thrombus in the five chamber with all regional wall motion abnormalities (RWMA), right ventricle and left ventricle



2D TEE 3D TEE

Figure 3

MIDESOPHAGEAL FOUR CHAMBER VIEW

Multiplane angle range:

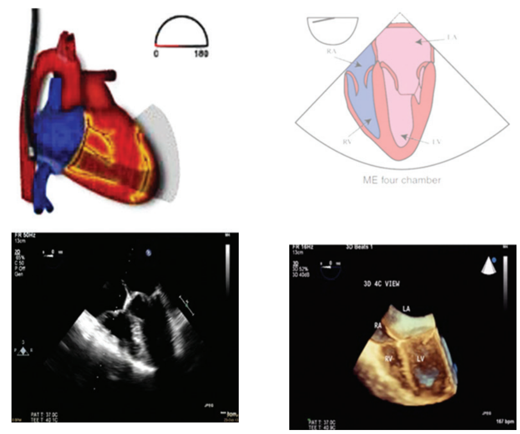
- 0~20 degrees
- Sector depth: ~12-14 cm

Anatomy imaged:

- Left ventricle and atrium
- Right ventricle and atrium
- Mitral and tricuspid valves
- Interatrial and interventricular septum
- Pulmonary venous baffle, AV valves, ventricular function

Clinical Utility:

- Ventricle function: Global and regional
- Intracardiac chamber masses: Thrombus, tumor, air, foreign bodies
- Mitral and tricuspid valve evaluation: Pathology, pathophysiology
- Congenital or acquired interatrial and ventral septal defects
- Hypertrophic obstructive cardiomyopathy evaluation.
- Suction event diagnosed with perioperative/postoperative TEE soon after HVAD activation (HeartWare left ventricular assist device.[3]
- large ostium secundum ASD[4]
- Postop. Atrial switch operation[5,6]
- Assessment for baffle obstruction or leak, evaluation for PH (MR jet)
- LA myxoma
- Posterior and AV rims, maximal ASD diameter
- Device relationship to AV valves[4]



2D TEE 3D TEE

Figure 4

ME MITRAL COMMISSURAL VIEW

Multiplane angle range:

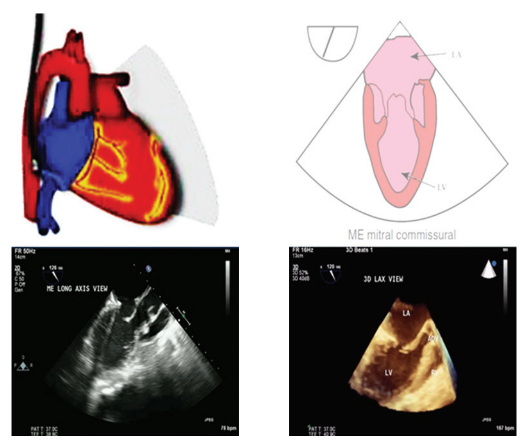
- 60-70 degrees
- Sector depth: ~ 12cm

Anatomy imaged:

- Left ventricle and atrium
- Mitral valve

Clinical Utility:

- Left ventricle function: global and regional
- Left ventricle and atrial masses: thrombus, tumor, air; foreign bodies
- Mitral valve evaluation: pathology, pathophysiology
- Ventricular diastolic evaluation via transmitral Doppler flow profile analysis
- Recommended for mitral valve vegetations.
- (Mitral commissural view) with the probe then rotated slightly to the left to reveal the left-sided pulmonary veins.



2D TEE 3D TEE

Figure 5

Contd...

Contd...

MID ESOPHAGEAL TWO-CHAMBER VIEW

Multiplane angle range:

80-100 degrees

Sector depth: ~ 12-14 cm

Anatomy imaged Left ventricle, atrium, and atrial appendage:

Mitral valve

Left pulmonary veins: turning probe to left

Coronary sinus (short axis or long axis by turning probe tip to left)

Clinical Utility:

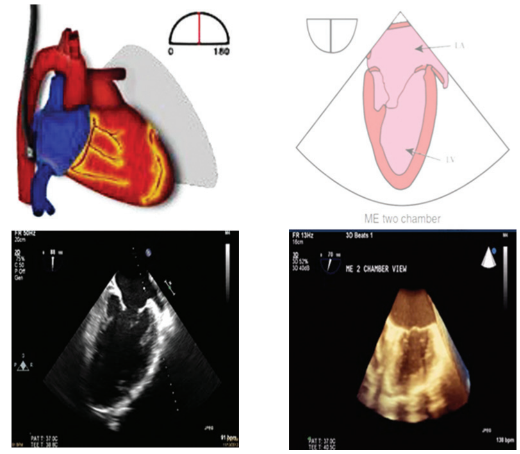
Left ventricle function: global and regional

Left ventricle and atrial masses: thrombus, tumor, air; foreign bodies

Mitral valve evaluation: pathology, pathophysiology

Ventricular diastolic evaluation via transmitral and pulmonary vein Doppler flow profile analysis

Coronary sinus evaluation: coronary sinus catheter placement; dilation secondary to persistent left superior vena cava



2D TEE 3D TEE

Figure 6

MID ESOPHAGEAL LONG AXIS VIEW

Multiplane angle range:

120-160 degrees

Sector depth: ~ 12-14 cm

Anatomy imaged:

Left ventricle and atrium

Left ventricular outflow tract

Aortic valve

Mitral valve

Ascending aorta

Dome/roof of LA Device[4]

Clinical Utility:

Left ventricle function: global and regional

Left ventricle and atrial masses: thrombus, tumor, air; foreign bodies

Mitral valve evaluation: pathology, pathophysiology;

Ventricular diastolic evaluation via transmitral Doppler flow profile analysis

Aortic valve evaluation: pathology, pathophysiology

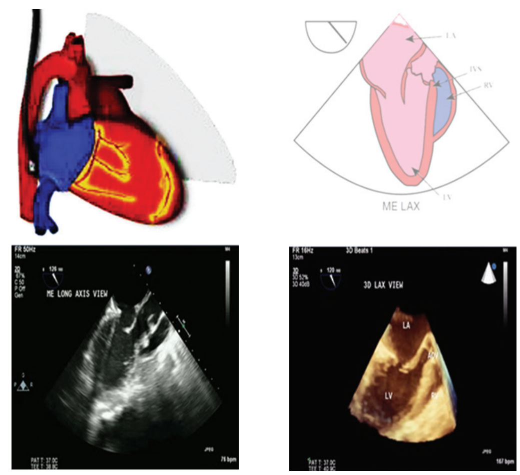
scending aorta pathology: atherosclerosis, aneurysms, dissections

Hypertrophic obstructive cardiomyopathy evaluation

Relationship to LA dome/roof[4]

Native aortic valve endocarditis, prosthetic mitral valve thrombosis

Midesophageal long-axis views with the probe rotated toward the left pulmonary veins



2D TEE 3D TEE

Figure 7

MID ESOPHAGEAL AORTIC VALVE: LONG AXIS VIEW

Multiplane angle range:

120-160 degrees

Sector depth: ~ 8-10 cm

Anatomy imaged:

Aortic valve

Proximal ascending aorta

Left ventricular outflow tract

Mitral valve

Right pulmonary artery

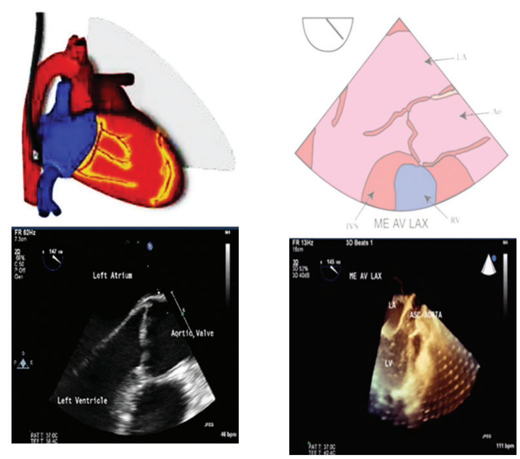
Clinical Utility:

Aortic valve: pathology; pathophysiology

Ascending aorta pathology: atherosclerosis, aneurysms and dissections

Mitral valve evaluation: pathology, pathophysiology

Duration of AV opening during LVAD support can be easily measured using M-mode during TEE.[3]



2D TEE 3D TEE

Figure 8

Contd...

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MID ESOPHAGEAL ASCENDING AORTA LONG AXIS VIEW

Multiplane angle range:

100-150 degrees

Sector depth: ~ 12cm

Anatomy imaged:

Ascending aorta

Right pulmonary artery

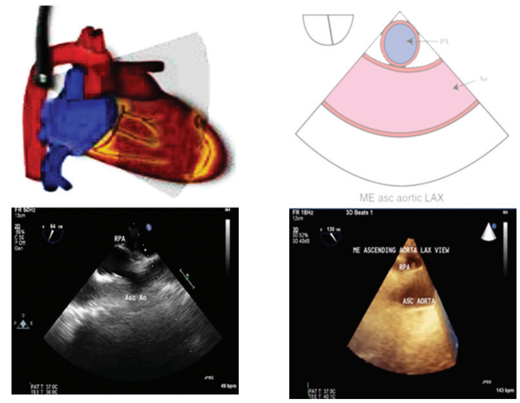
Clinical Utility:

Ascending aorta pathology: atherosclerosis, aneurysms, and dissections

Anterograde cardioplegia delivery evaluation

Pulmonary embolus/thrombus

Probe Tip Depth (from lips) Upper Esophageal (20-25 cm)



2D TEE

3D TEE

Figure 9

MID ESOPHAGEAL ASCENDING AORTA: SHORT AXIS VIEW

Multiplane angle range:

0-60 degrees

Sector depth: ~ 12cm

Anatomy imaged:

Ascending aorta

Superior vena cava (short axis)

Main pulmonary artery

Right pulmonary artery

Left pulmonary artery (turn probe tip to left)

Pulmonic valve

Clinical Utility:

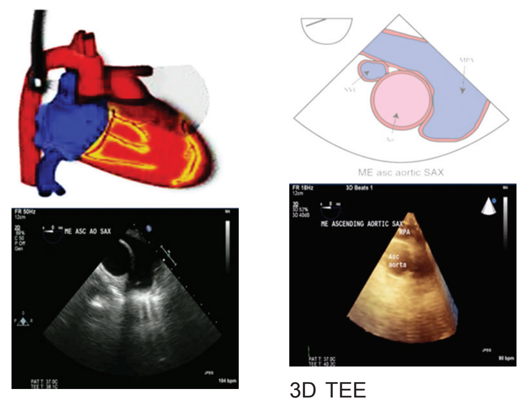
Ascending aorta pathology: atherosclerosis, aneurysms, and dissections

Pulmonic valve: pathology; pathophysiology

Pulmonary embolus/thrombus evaluation

Superior vena cava pathology: thrombus, sinus venosus atrial septal defect

Pulmonary artery catheter placement



2D TEE

3D TEE

Figure 10

MIDESOPHAGEAL RIGHT PULMONARY VEIN VIEW

Transducer Angle:

0-30 degrees

Level:

Upper-esophageal

Maneuever (from prior image):

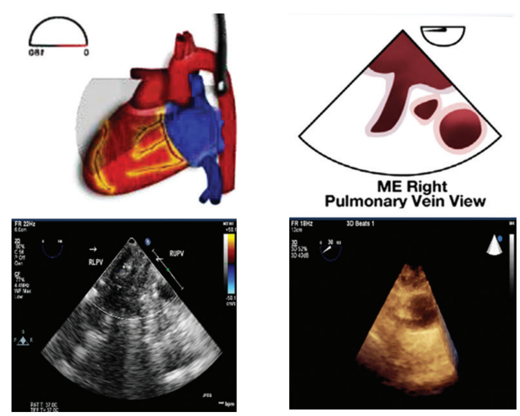
Continous wave (CW), advance

Clinical Utility:

Mid-ascending aorta

Superior vena cava

Right pulmonary veins



2D TEE

3D TEE

Figure 11

Contd...

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MID ESOPHAGEAL AORTIC VALVE: SHORT AXIS VIEW

Multiplane angle range:

30-60 degrees

Sector depth: ~10-12 cm

Anatomy imaged Aortic valve:

Interatrial septum

Coronary ostia and arteries

Right ventricular outflow tract

Pulmonary valve

Posterior and aortic rims, maximal ASD diameter[4]

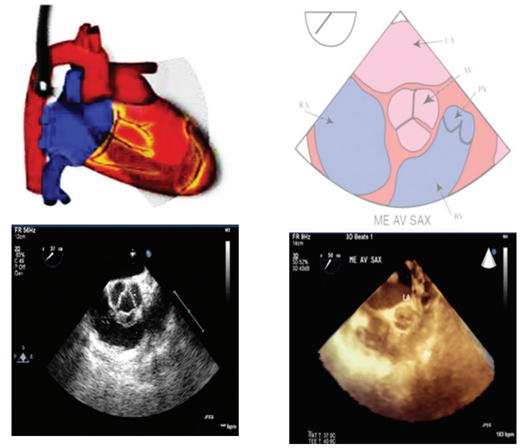
Clinical Utility:

Aortic valve: pathology; pathophysiology

Ascending aorta pathology: atherosclerosis, aneurysms and dissections

Left and right atrial masses: thrombus, embolus, air, tumor, foreign bodies

Congenital or acquired interatrial septal defects evaluation



2D TEE

3D TEE

Figure 12

MID OESOPHAGEAL RIGHT VENTRICULAR INFLOW-OUTFLOW VIEW

Multiplane angle range:

` 60-90 degrees

Sector depth: ~ 10-12 cm

Anatomy imaged:

` Right ventricle and atrium, Left atrium

RVOT, PAX

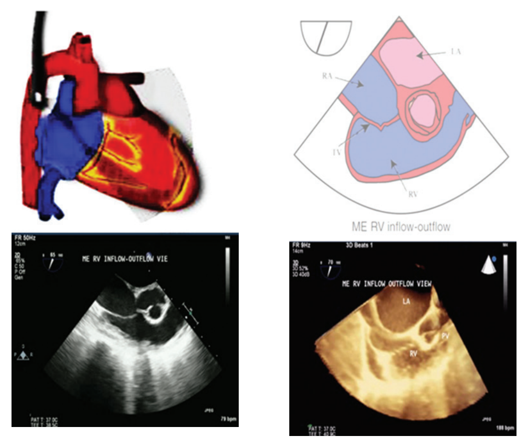
Clinical Utility:

` Right ventricle and atrial masses and left atrial: thrombus, embolus, tumor, foreign bodies.

` Pulmonic valve and sub pulmonic valve: pathology; pathophysiology

` Pulmonary artery catheter placement

` Tricuspid valve: pathology; pathophysiology



2D TEE

3D TEE

Figure 13

ME MODIFIED BICAVAL VIEW

Structures imaged:-

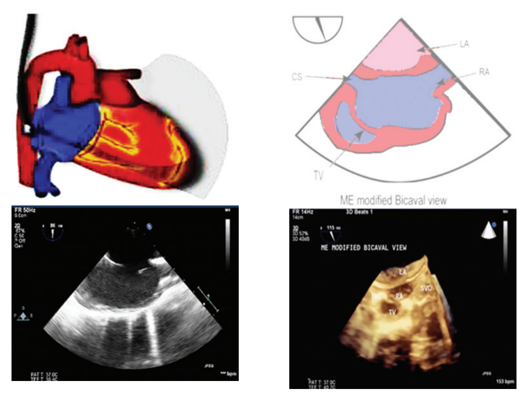
- Right atrium
- LA
- Interatrial septum
- Inferior vena cava
- TV

Probe Adjustments:

Probe rotated toward right as in bicaval view.

Clinical utility:

For cannula placement in the SVC/IVC in all minimally invasive procedures e.g., Robotic Group



2D TEE

3D TEE

Figure 14

Contd...

Contd...

MID ESOPHAGEAL BICAVAL VIEW

Multiplane angle range

80-110 degrees

Sector depth: ~ 8 - 10 cm

Anatomy imaged:

Right and left atrium

Superior vena cava (long axis)

Inferior vena cava orifice: advance probe and turn to right to visualize inferior vena cava in the long axis, liver, hepatic and portal veins, IAS, RPV, IVC, SVC

Clinical Utility:

Right and left atrial masses: thrombus, embolus, air, tumor, foreign bodies

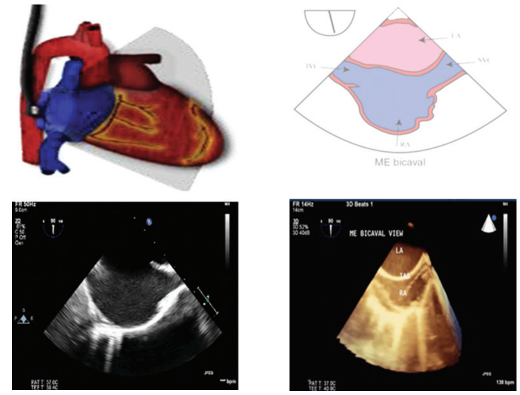
Superior vena cava pathology: thrombus, sinus venosus atrial septal defect

Inferior vena cava pathology (thrombus, tumor)

Femoral venous line placement

Coronary sinus catheter line placement

Right pulmonary vein evaluation: anomalous return, Doppler evaluation for left ventricular diastolic function



2D TEE 3D TEE

Figure 15

UPPER OESOPHAGEAL RIGHTT AND LEFT PULMONARY VEIN VIEW

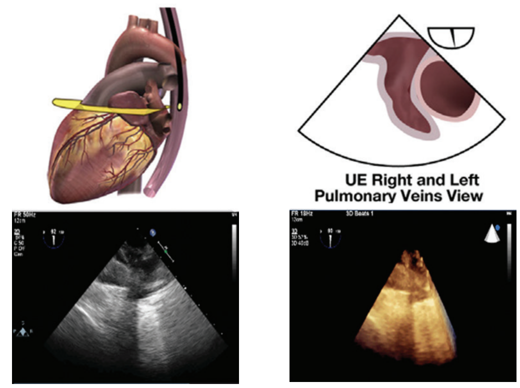
Transducer angle: 90-110 angle

Level: Upper- esophageal

Maneuver (from prior image): withdraw, CW for the right veins, CCW for the left veins

Structures imaged: pulmonary vein (upper and Lower)

Pulmonary artery.



2D TEE 3D TEE

Figure 16

MIDESOPHAGEAL LEFT ATRIAL APPENDAGE VIEW

Transducer Angle:

90-110 degrees

Level: Midesophageal

Maneuever (from prior image):

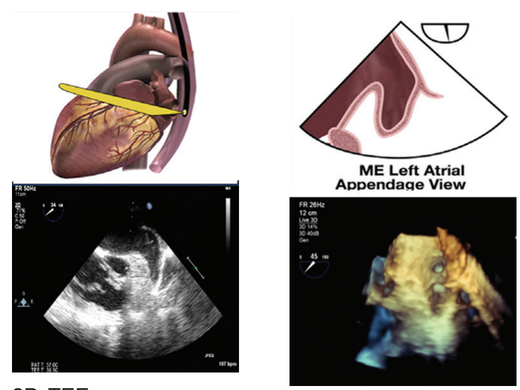
Advanced

Clinical Utility:

Left atrial appendage

Left upper pulmonary vein

Recommendation - TEE is superior to TTE in assessment of anatomy and function of LAA in a variety of clinical contexts, such as before cardioversion, ablation of atrial arrhythmias, and percutaneous procedures for LAA closure.



2D TEE 3D TEE

Figure 17

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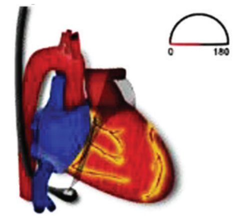
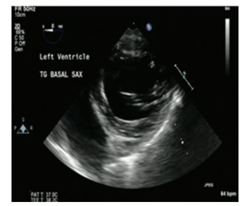
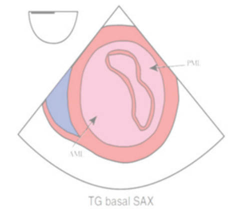
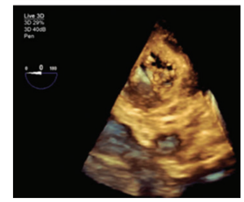
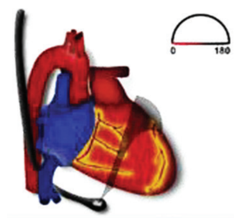
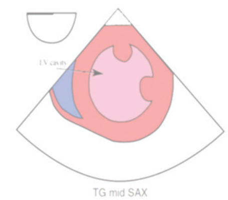
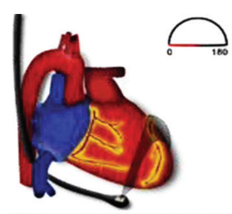
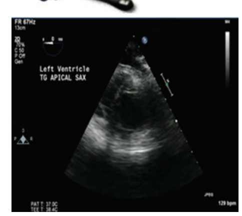
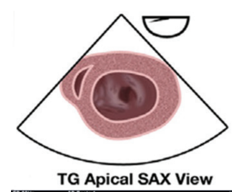
TG BASAL SHORT AXIS VIEW Multiplane angle range: 0-20 degrees Sector depth: ~ 12cm Anatomy imaged Left and right ventricle: Mitral valve Tricuspid valve	**Clinical Utility:** Mitral valve evaluation ("fish-mouth view"): pathology, pathophysiology Tricuspid valve evaluation: pathology, pathophysiology Basal left ventricular regional function Basal right ventricular regional function	  2D TEE Figure 18	  3D TEE
TG MID PAPILLARY SHORT AXIS VIEW Multiplane angle range: 0-20 degrees Sector depth: ~ 12cm Anatomy imaged: Left and right ventricles Papillary muscles	**Clinical Utility:** Mid-left and right ventricular regional and global function Intracardiac volume status	  2D TEE Figure 19	  3D TEE
TRANSGASTRIC APICAL SHORT AXIS VIEW Transducer angle: 0-20 degrees Level: Transgastric Anatomy imaged: Left ventricle (apex) Right ventricle (apex)	**Clinical Utility:** From the TG midpapillary short-axis (SAX) view (0-20), the probe is advanced while maintaining contact with the gastric wall, to obtain the TG apical short-axis (SAX) view The right ventricle (RV) apex is imaged from this view by turning to the right (clockwise). This view allows evaluation of the apical segments of the left and right ventricles.	  2D TEE Figure 20	  3D TEE

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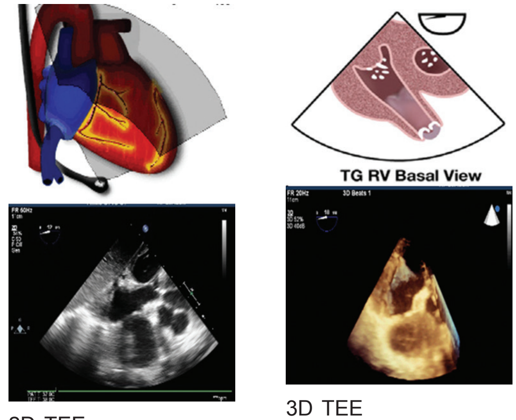
TRANSGASTRIC RIGHT VENTRICLE BASAL VIEW

Transducer Angle:
0-20 degrees
Level:
Transgastric
Maneuever (from prior image):
Anteflex

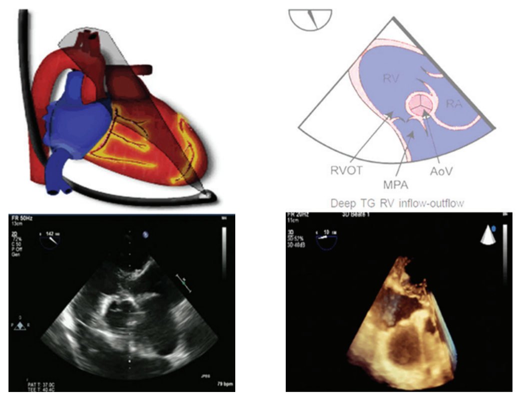
Clinical Utility:
Left ventricle (mid)
Right ventricle (mid)
Right ventricular outflow tract
Tricuspid valve (SAX)
Pulmonary valve



2D TEE 3D TEE
Figure 21

TRANSGASTRIC RIGHT VENTRICLE INFLOW OUTFLOW VIEW

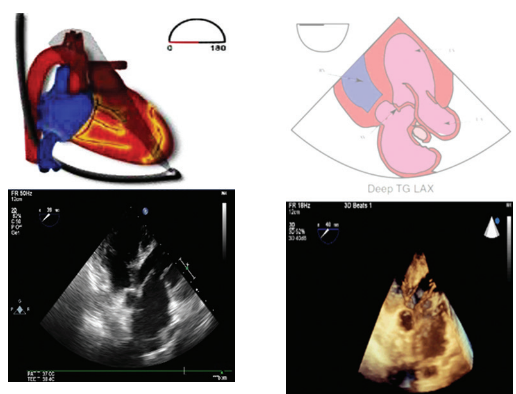
Transducer Angle:
0-20 degrees
Level:
Transgastric
Maneuever (from prior image):
Right-flex
Clinical utility:
Right atrium
Right ventricle
Right ventricular outflow tract
Pulmonary valve



2D TEE 3D TEE
Figure 22

DEEP TRANSGASTRIC FIVE-CHAMBER TRANSESOPHAGEAL ECHOCARDIOGRAPHIC VIEW

Comments - Detect the degenerated Aortic bioprosthetic Aortic valve



2D TEE 3D TEE
Figure 23

Contd...

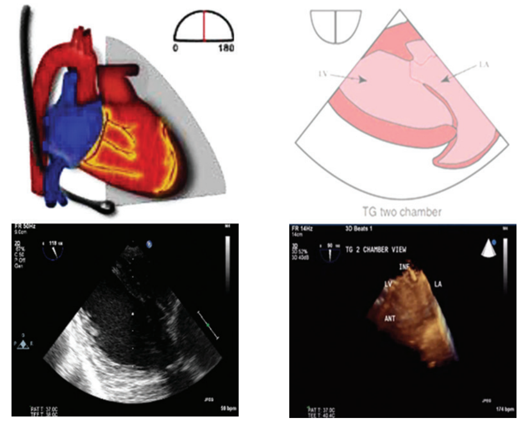
Contd...

TRANSGASTRIC TWO-CHAMBER VIEW

Multiplane angle range:
- 80-100 degrees
- Sector depth: ~ 12cm

Anatomy imaged:
- Left ventricle and atrium
- Mitral valve: chordae and papillary muscles
- Coronary sinus

Clinical Utility:
- Left ventricular regional and global function (including apex)
- Left ventricular and atrial masses: thrombus, embolus, air, tumor, foreign bodies
- Mitral valve: pathology and pathophysiology



2D TEE 3D TEE

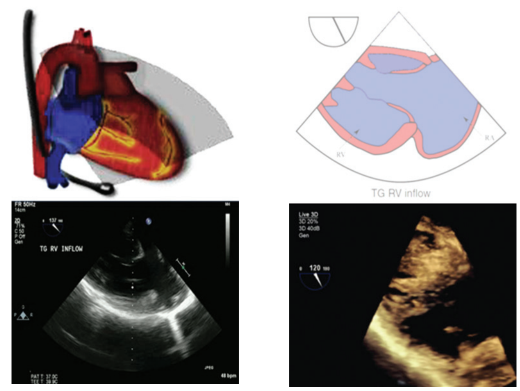
Figure 24

TG RIGHT VENTRICULAR INFLOW VIEW

Multiplane angle range:
- 100-120 degrees
- Sector depth: ~ 12cm

Anatomy imaged:
- Right ventricle and atrium
- Tricuspid valve: chordae and papillary muscles

Clinical Utility:
- Right ventricular regional and global function
- Right ventricular and atrium masses: thrombus, embolus, tumor, foreign bodies
- Tricuspid valve: pathology and pathophysiology
- Probe Tip Depth Deep Transgastric (45-50 cm)



2D TEE 3D TEE

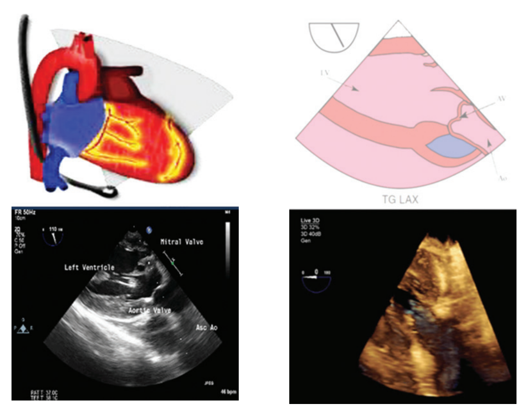
Figure 25

TG LONG AXIS VIEW

Multiplane angle range:
- 110-130 degrees
- Sector depth: ~12 cm
- Probe adjustments
- Neutral leftward

Anatomy imaged:
- Mitral leaflets
- Mitral subvalvular apparatus
- Left ventricle (anteroseptal and inferolateral walls: basal and mid segments)
- LV outflow tract
- Aortic valve and proximal ascending aorta

Clinical Utility:
- Left ventricular (LV) systolic dysfunction (anteroseptal and inferolateral walls)
- Doppler interrogation of aortic valve.



2D TEE 3D TEE

Figure 26

Contd...

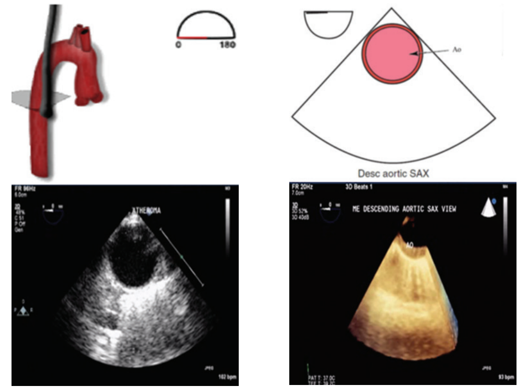
Contd...

ME DESCENDING AORTA: SHORT AXIS VIEW

Multiplane angle range:
- 0 degrees
- Sector depth: ~ 6cm

Anatomy imaged:
- Descending thoracic aorta
- Left pleural space

Clinical Utility:
- Descending aorta pathology: atherosclerosis, aneurysms, and dissections
- Intra-aortic balloon placement evaluation
- Left pleural effusion
- Concentric IMH[7]



2D TEE 3D TEE

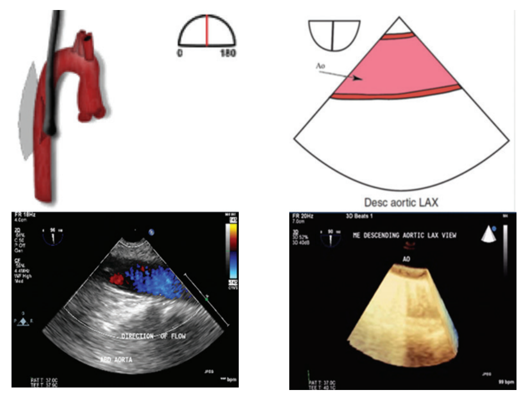
Figure 27

ME DESCENDING AORTA: LONG AXIS VIEW

Multiplane angle range:
- 90-110 degrees
- Sector depth: ~ 6cm

Anatomy imaged:
- Descending thoracic aorta
- Left pleural space

Clinical Utility:
- Descending aorta pathology: atherosclerosis, aneurysms, and dissections
- Intra-aortic balloon placement evaluation
- Left pleural effusion



2D TEE 3D TEE

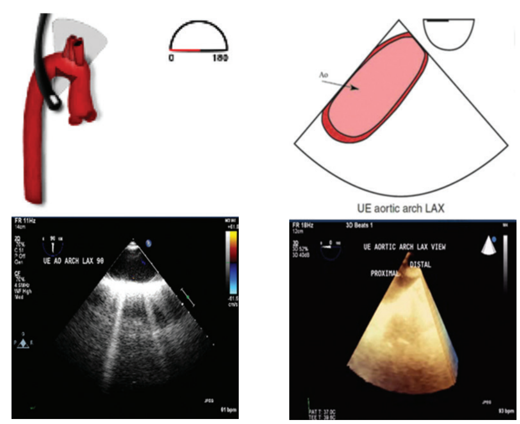
Figure 28

UE AORTIC ARCH: LONG AXIS VIEW

Multiplane angle range:
- 0 degrees
- Sector depth: ~ 10cm

Anatomy imaged:
- Aortic arch; left brachiocephalic vein; left subclavian and carotid arteries; right brachiocephalic artery

Clinical Utility:
- Ascending aorta and arch pathology: atherosclerosis, aneurysms and dissections; aortic CPB cannulation site evaluation



2D TEE 3D TEE

Figure 29

Contd...

Contd...

TG BASAL LONG AXIS VIEW

Multiplane angle range:

110-130 degrees

Sector depth: ~12 cm

Probe adjustments

Neutral leftward

Anatomy imaged:

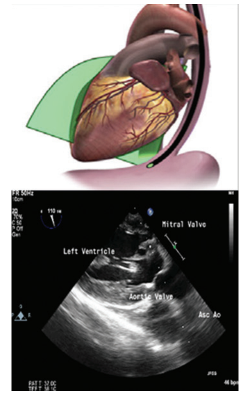
Mitral leaflets

Mitral subvalvular apparatus, LVOT, LV, AOV, Proximal Aorta

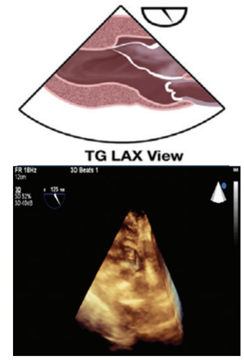
Clinical Utility:

Left ventricular (LV) systolic dysfunction (anteroseptal and inferolateral walls)

Doppler interrogation of aortic valve.



2D TEE



3D TEE

Figure 30

UE AORTIC ARCH: SHORT AXIS VIEW

Multiplane angle range:

90 degrees

Sector depth: ~ 10cm

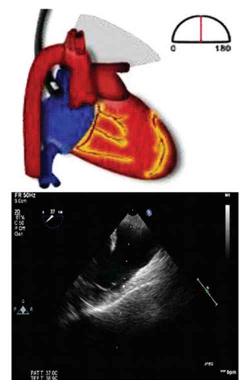
Structures imaged:

Aortic arch; left brachiocephalic vein; left subclavian and carotid arteries; right brachiocephalic artery; Main pulmonary artery and pulmonic valve

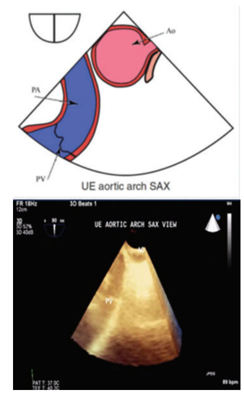
Clinical Utility:

Ascending aorta and arch pathology: atherosclerosis, aneurysms and dissections; pulmonary embolus; pulmonary valve evaluation (insufficiency, stenosis, Ross procedure); pulmonary artery catheter placement

Aortic atherom



2D TEE



3D TEE

Figure 31

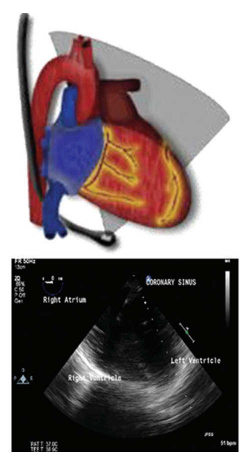
LOWER ESOPHAGEAL CORONARY SINUS VIEW

Angle: ~ 0°-10°

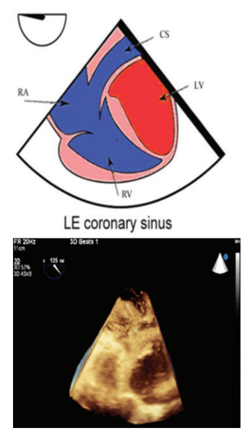
Sector depth: ~12-14cm Retroflexed

Structures imaged: Coronary sinus in LAX

Clinical Utility: Placement of retrograde cardioplegia cannula, Recognition of LSVC in congenital heart disease



2D TEE

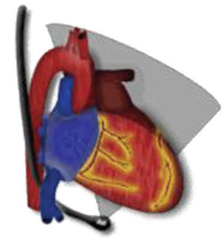
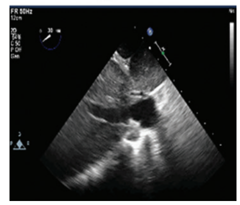
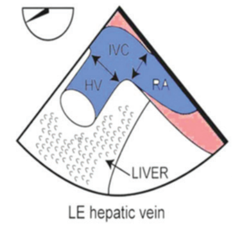
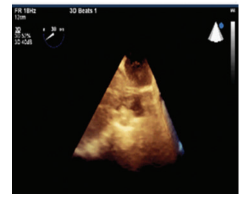
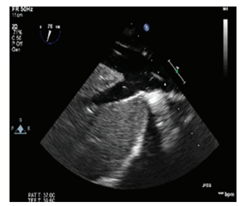
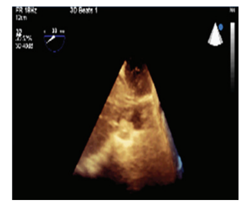
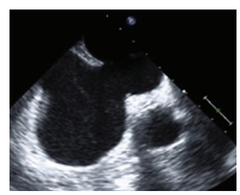
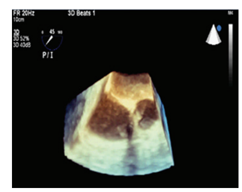
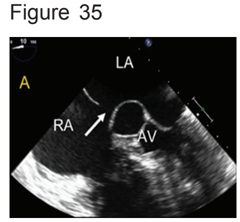
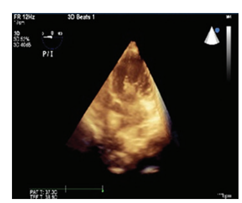


3D TEE

Figure 32

Contd...

Contd...

LOWER ESOPHAGEAL (LE) HEPATIC VIEW Primary diagnostic uses: Inferior venacava collapsibility and diameter Hepatic venous flow velocity. Image settings: Angle: ~20° Probe adjustments: Rightward.	**Required Structures:** Right atrium Hepatic vein IVC. Deep	  2D TEE Figure 33	  3D TEE
TRANSGASTRIC MODIFIED HEPATIC VEIN VIEW	**Transducer Angle:** 0-20 degrees Level: Lower-esophageal Maneuever (from prior image): Continuous wave (CW), advance Clinical utility: Interior vena cava (IVC) Hepatic veins Inferior vena cava (IVC) diameter for right atrium (RA) size.	 2D TEE Figure 34	 3D TEE
Mid- to upper esophagus Basal transverse view[4]	Structures - SVC, superior aortic, RUPV Comments - Device relationship in atrial roof	 2D TEE Figure 35	 3D TEE
Modified midesophageal four-chamber view[4]	**Clinical Utility:** Ostium secundum ASD with a deficient aortic rim. LVAD outflow graft, as assessed by TEE. In a modified mid-esophageal 4-chamber view[3]	 2D TEE Figure 36	 3D TEE

time images that contains all pertinent information. These systems generally acquire a volumetric data set, with greater depth than 2D echocardiography. 3D TEE provides the better understanding of spatial relationships between the dissection flap and surrounding structures such as the aortic valve and origin of coronary ostia, as well as allow the better morphologic and dynamic evaluation of aortic dissection which are not appreciated with two-dimensional TEE, thereby provides the decision making for surgeons in the operating room[10] [Figure 37].

The first study demonstrating the clinical utility of live/real time three-dimensional echocardiography was published from the University of Alabama at Birmingham, Alabama.[11] Basically, two-dimensional images are acquired in three-dimensions and the three-dimensional data set can then be cropped at any

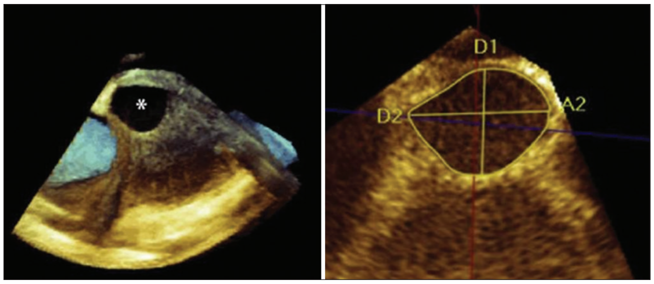


Figure 37: Three-dimensional TEE showing the entry tear of a type B aortic dissection located in the proximal descending aorta. (Left) Live 3D image showing a large entry tear (asterisk). (Right) Maximum orthogonal diameters (D2 and D1) are 17 and 11 mm, and area measured by full volume is 1.5 cm^2

desired angulation to view different cardiac structures comprehensively. Unlike 2D imaging where a fixed imaging plane requires the acquisition of standard views, 3D echocardiography is inherently volumetric and offers the potential for capturing a single dataset from which multiple questions can be answered through cropping. Therefore, a complete 3D TEE study involves acquisition of several full-volume datasets and then targeted acquisitions using 3D zoom and 3D color Doppler imaging.

Much of the 3D datasets can be obtained hand in hand with 2D acquisition and it is often the 2D images that guide 3D assessment. A distinct advantage is viewing stenotic lesions as well as the vena contracta of regurgitant jets en-face providing accurate and reproducible direct measurements of stenotic and regurgitant orifice areas. These facilitate quantitative assessment of valvular stenosis and regurgitation and obviate several pitfalls inherent in the Doppler measurements which are traditionally used for evaluation of severity of these lesions. 3D TEE also provides more reliable assessment of LV and RV volumes, ejection fraction and mass as compared to 2D TEE because no geometric assumptions are made regarding the shape of the ventricles. 3D TEE is useful in identifying AV morphology and can differentiate easily a bicuspid AV with a raphe from a tricuspid configuration. 3D TEE is useful in characterizing the morphology of various LV and RV muscular trabeculaions, cardiac tumors and thrombi since the technique facilitates sectioning and en face visualization of these masses. 3D TEE can also view congenital cardiac defects such as ASDs and VSDs en-face providing accurate assessment of their size and also their relationship to surrounding structures. This information is of great value to the interventional cardiologist and surgeon when considering defect closure. 3D TEE images are based on 2D TTE images and are dependent on their quality and hence it is important to acquire the best quality 2D images for 3D acquisition.

HOW TO SWITCH 2D TO 3D

All this is inbuilt in all modern machines with knobology. As an example, to move from 2D to 3D TEE if in 2D TEE the descending thoracic aorta is visualized in SXA (0^0) by turning the probe to the left from the ME 4C view (0^0). The near field image of the circular aorta. Advance and withdraw the probe to image the entire descending aorta. Decrease the display depth. Then, for 3D live mode with a slight tilt down better images a SAX section of the aorta intimal surface. The near field aortic wall is, however, poorly visualized. 3D full volume mode is a better choice to image a wider sector of the aorta and the thin wall of a dissection flap. The more diagnostic issues seen on 3D are then, aorta atherosclerosis, aorta dissection, aorta aneurysm, left pleural effusion, AI severity pulse wave Doppler and IABP position.

Finally, the advent of real-time three-dimensional (3D) echocardiography at the turn of the 21st century has provided unprecedented anatomic and functional details of many cardiac structures implicated as cardiac sources of embolism and allowed guidance of percutaneous treatments of sources of cardiac embolism (e.g., percutaneous closure of LA appendage (LAA) in patients with atrial fibrillation).

Three-Dimensional and Multiplane Imaging can highlight areas often missed or overlooked when it comes to cardiac source of embolism. It improves the diagnostic accuracy of cardiac tumors, more precise assessment of LA and LAA size and morphology, LV thrombus, provide incremental diagnostic information on aortic plaques and also helps in assessing atrial septal anatomy, also delineate the point of attachment on the interatrial septum in case of LA myxoma.

CLINICAL UTILITY OF 3D TEE

It has a superior reproducibility to 2D TEE, with a closer correlation to CMR-derived volumes. Hence it is the only potential modality that directly measures myocardial volume and LV Mass, especially in patients with asymmetric or localized hypertrophy or dilated ventricle, without geometric assumptions about LV shape and distribution of wall thickening. For these reasons, rather than 2D TEE, just as ASE and EACVI have done recently, we too recommend 3D TEE over 2D

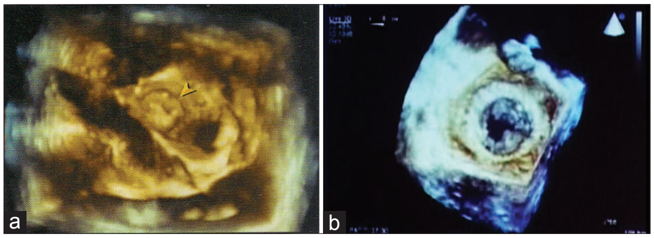


Figure 38: (a) 3D transesophageal echocardiography assessment of valvular vegetations of the mitral valve vegetation (arrowhead) (b) Thrombotic complication on bioprosthetic valve heparin induced (HITTS) well seen on 3D TEE

TEE, for the routine assessment of LV volumes and ejection fraction (EF) and for details of seeing origin and extent of vegetation [Figure 38a and b].[12]

In patients with cancer, Three-dimensional echocardiography appears to be the preferred technique of choice for monitoring the cardiac effects of chemotherapy, detecting cancer therapeutics-related cardiac dysfunction (CTRCD) and monitoring LV function. It has an advantage over 2D TEE which includes better accuracy in detecting LVEF, better reproducibility, and lower temporal variability compared with in patients with cancer treated with chemotherapy especially in 3D TEE ME4 chamber view, full volume. Costs, availability, Real-time three-dimensional echocardiography has been used to improve regional wall motion analysis during resting and stress echocardiography.[13]

In tetralogy of fallot, Three-dimensional imaging with en-face views of the TV as seen from the right atrium and from the right ventricle can be particularly helpful when image quality and temporal resolutions are adequate.

LIMITATIONS OF 3D TEE

Three-Dimensional Measurements Assessment of LV volumes by 2DE is limited by malrotation, angulation, foreshortening, and relies on geometric assumptions for volumetric calculations, resulting in an underestimation of the true volumes, particularly in ventricular remodelling. Also need for training of operators, cost, high reliance on image quality, currently limit the wide application of 3DE in the oncologic setting.

Its function is also limited by low frame rates and poor resolution hence limited use in pediatric cases for the diagnosis of congenital heart defects.

CONCLUSION

It has been an attempt by the authors to present with 2D and 3D TEE views as comparison, with clinically accepted twenty eight views along with additional views to perform a comprehensive TEE examination. This also includes a suggested protocol of image acquisition. The standardised approach outlined in this update provides a useful framework for an assessment during cardiac surgery and also shows better resolution of 3D TEE over 2D TEE views, in most cardiac situations.

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Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Kanchi Muralidhar, Deepak Tempe, Murali Chakravarthy, Naman Shastry, Poonam Malhotra Kapoor, Prabhat Tewari, *et al*. Practice guidelines for perioperative transesophageal echocardiography: Recommendations of the Indian association of cardiovascular thoracic anesthesiologists. 2013;Volume 16(4), 268-278.
2. Jan N. Hilberath, MD, Daryl A. Oakes, MD, Stanton K. Shernan, MD, Bernard E. Bulwer, MD, Michael N. D'Ambra, MD, and Holger K. Eltzschig. Safety of Transesophageal Echocardiography. J Am Soc Echocardiogr 2010; 23:1115-27.
3. Raymond F. Stainback, Jerry D. Estep, Deborah A. Agler, Emma J. Birks, Merri Bremer, Judy Hung *et al*. Echocardiography in the Management of Patients with Left Ventricular Assist Devices: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr 2015; 28:853-909.
4. Frank E. Silvestry, Meryl S. Cohen, Laurie B. Armsby, Nitin J. Burkule, Craig E. Fleishman, Ziyad M. Hijazi *et al*. Guidelines for the Echocardiographic Assessment of Atrial Septal Defect and Patent Foramen Ovale: From the American Society of Echocardiography and Society for Cardiac Angiography and Interventions. J Am Soc Echocardiogr 2015; 28:910-58.
5. Meryl S. Cohen, Benjamin W. Eidem, Frank Cetta, Mark A. Fogel, Peter C. Frommelt, Javier Ganame *et al*. Multimodality Imaging Guidelines of Patients with Transposition of the Great Arteries: A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance and the Society of Cardiovascular Computed Tomograph. J Am Soc Echocardiogr 2016; 29:571-621.
6. Sherif F. Nagueh, Otto A. Smiseth, Christopher P. Appleton, Benjamin F. Byrd, Hisham Dokainish, Thor Edvardsen *et al*. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am

Soc Echocardiogr 2016; 29:277-314.

7. Goldstein SA, Evangelista A, Abbara S, Arai A, Asch FM, Badano LP *et al*. Multimodality Imaging of Diseases of the Thoracic Aorta in Adults: From the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr. 2015; 28(2):119-82.
8. Muhamed Saric, Alicia C. Armour, M. Samir Arnaout *et al*. Guidelines for the Use of Echocardiography in the Evaluation of a Cardiac Source of Embolism, Journal of the American Society of Echocardiography January 2016:29(1); 1-42
9. Sherif F. Nagueh, Otto A. Smiseth, Christopher P. Appleton, Benjamin F. Byrd *et al*. Recommendations for the Evaluation of Left Ventricular Diastolic Function by Echocardiography: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr 2016; 29:277-314.
10. Cindy J. Wang, Cesar A. Rodriguez-Diaz, and Muoi A. Trinh. Use of real-time three-dimensional transesophageal echocardiography in type A aortic dissections: Advantages of 3D TEE illustrated in three cases. Ann Card Anaesth. 2015 Jan-Mar; 18(1): 83–86.
11. Pothineni KR, Inamdar V, Miller AP, Nanda NC, Bandarupalli N, Chaurasia P: Initial experience with live/real time three-dimensional transesophageal echocardiography. Echocardiography 2007; 24:1099-110.
12. Roberto M *et al*. Recommendations for Cardiac Chamber Quantification by Echocardiography in Adults: An Update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr 2015; 28:1-39.
13. Juan Carlos Plana. Expert Consensus for Multimodality Imaging Evaluation of Adult Patients during and after Cancer Therapy: A Report from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. J Am Soc Echocardiogr 2014; 27:911-39.