Ultrasound Morphology of the Heart: Transesophageal Examination

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4.1 Introduction

A transesophageal echocardiography (TEE) examination is effective to assist in the hemodynamic treatment of patients during cardiovascular anesthesia and to make a diagnoses in the operating room during cardiac operations and in the intensive care unit. More and more anesthesiologists are involved in this practice and they provide a remarkable contribution to scientific and practical progress of perioperative echocardiography. Executing TEE requires time, but there are a lot of advantages for hemodynamic monitoring and diagnosis, which explains the increasing interest in TEE for many years.

The heart is a very complex three-dimensional structure with a lot of anatomic components bound together; therefore, perfect knowledge of the anatomy is very important to understand two-dimensional echo images of the heart. The operator's experience is very important; we think that TEE should be used in all cardiac surgery patients without contraindications, especially at the beginning of the learning curve. The simplified TEE examination usually requires 5–10 min. During the examination, the TEE operator or an anesthesiologist or a nurse can check the stability of the patient.

Sometimes images are very bad because of anatomic conditions (cardiac cavity dilatation) or air in stomach (it is possible to improve the image after suction). Instrument settings and adjustments are important for optimizing image quality and the diagnostic capabilities of TEE. Many TEE probes can obtain an image with more than one transducer frequency. Increasing the imaging frequency improves resolution but decreases penetration. Structures closer to the probe, such as the aortic valve (AV), are imaged best at a higher frequency, whereas structures farther away from the probe, such as the apical regions of the left ventricle (LV), are imaged best at a lower frequency. The depth is adjusted so that the structure being examined is centered in the display, and the focus is moved to the area of interest. Overall image gain and dynamic range (compression) are adjusted so that the blood in the chambers appears nearly black and is distinct from the gray scales representing tissue. Time compensation gain adjustments are set to create uniform brightness and contrast throughout the imaging field. The color flow Doppler (CFD) gain is set to a threshold that just eliminates any background noise within the color sector. Decreasing the size and depth of the color sector increases the aliasing velocity and frame rate. Decreasing the width of the two-dimensional imaging sector also increases the frame rate.

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4.2   Patient Safety

Rarely TEE can cause serious and even fatal complications; effort should be made to detect preexisting esophageal or gastric problems before performing TEE. Contraindications to TEE include esophageal stricture, diverticulum, tumor, and recent esophageal or gastric surgery. The TEE transducer should be inspected for defects and cracks in the waterproof covering before insertion. The mouth should be examined for preexisting injuries and loose teeth. The TEE probe may be inserted into an anesthetized, tracheally intubated patient with or without the use of a laryngoscope by displacing the mandible anteriorly and inserting the probe gently in the midline. Flexing the neck will help in some cases. If insertion of the probe is not easy, a laryngoscope can be used to expose the glottis and permit direct passage of the probe posteriorly into the esophagus. Once the transducer is in the esophagus, it should never be forced through a resistance. The tip of the transducer should be allowed to return to the neutral position before the probe is advanced or withdrawn, and excessive force should never be applied when the transducer is moved in the esophagus or when the tip is flexed with the control wheels. Cleaning and decontamination of the probe should be performed after each use.

4.3   The Simplified TEE Examination

The comprehensive, intraoperative TEE examination, recommended in the guidelines written by the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists in 1999 consists of a series of 20 cross-sectional views of the heart and great vessels. The views are designated by the transducer location (i.e., the echo window), a description of the imaging plane (e.g., short axis, long axis), and the main anatomic structure in the image.

One should not start to study immediately a pathological element (surgical indication); one should use a standard protocol to practice the TEE examination. One should get only one cardiac structure (valve or cavity) in focus, and analyze it and its relationship to other structures. It is very important to move the scan plane and build up a three-dimensional structure from the two-dimensional image. Everyone has to develop a personal approach to the intraoperative TEE examination; we suggest a simplified intraoperative TEE examination that reduces the number of views from the 20 standard views, and is able to analyze all the main heart structures. The main advantage of this systematic approach is the minimization of the manipulation of the TEE probe to perform a complete examination of major cardiac structures.
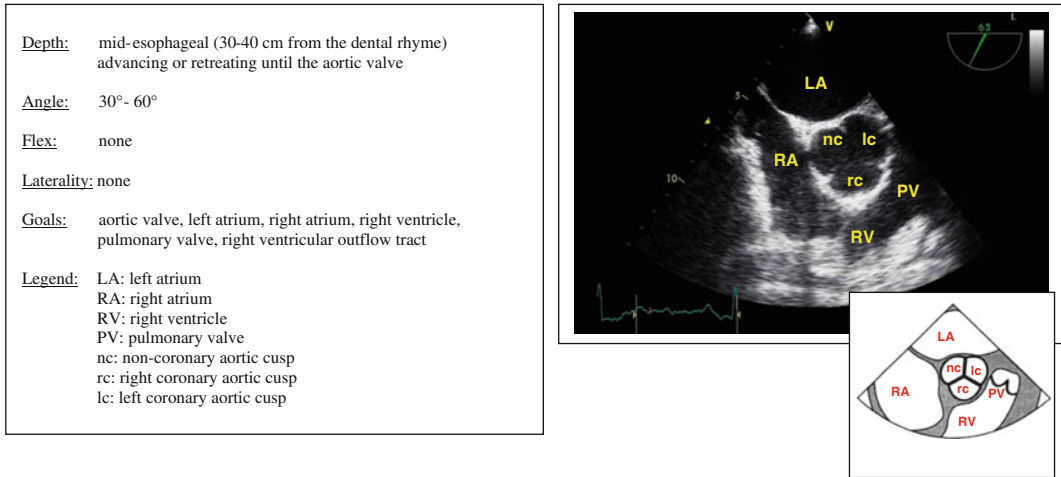
The cardiac examination is performed at three locations. The first location is the mid esophagus at the AV level, the second is a few centimeters distal in the mid esophagus at the level of the mitral valve, and the final location is in the stomach at the level of the LV. After completion of the cardiac examination, the aorta is evaluated throughout its thoracic course.

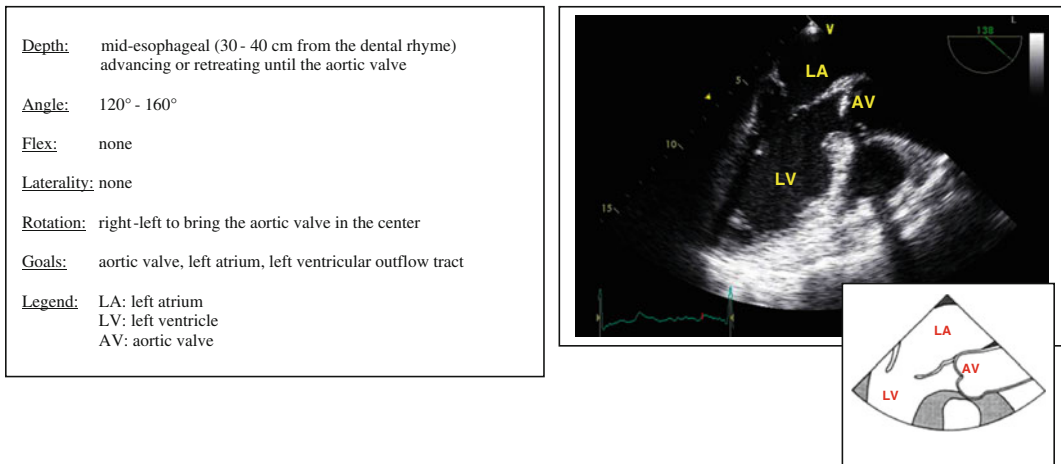### 4.3.1   Mid-Esophageal AV Level

4.3.1.1   Mid-Esophageal AV Short-Axis View

After the probe has been inserted, it is advanced until the leaflets of the AV are seen. The imaging plane is then rotated to approximately 45° to obtain the mid-esophageal AV short-axis view. The primary structure visualized is the AV in the short axis. The size of the AV in comparison with the atrial chambers in addition to the mobility of the aortic leaflets and any leaflet calcification is carefully noted (Fig. 4.1).

The primary diagnostic goals of this view are to define the general morphology of the AV (e.g., bicuspid vs. tricuspid) and to determine if aortic stenosis is present. The intra-atrial septum can be observed for openings consistent with an atrial septal defect or patent foramen ovale.

Depth: mid-esophageal (30-40 cm from the dental rhyme)
            advancing or retreating until the aortic valve

Angle: 30°- 60°

Flex: none

Laterality: none

Goals: aortic valve, left atrium, right atrium, right ventricle,
            pulmonary valve, right ventricular outflow tract

Legend: LA: left atrium
            RA: right atrium
            RV: right ventricle
            PV: pulmonary valve
            nc: non-coronary aortic cusp
            rc: right coronary aortic cusp
            lc: left coronary aortic cusp

Fig. 4.1 Mid-esophageal aortic valve short-axis view

Depth: mid-esophageal (30 - 40 cm from the dental rhyme)
            advancing or retreating until the aortic valve

Angle: 120° - 160°

Flex: none

Laterality: none

Rotation: right-left to bring the aortic valve in the center

Goals: aortic valve, left atrium, left ventricular outflow tract

Legend: LA: left atrium
            LV: left ventricle
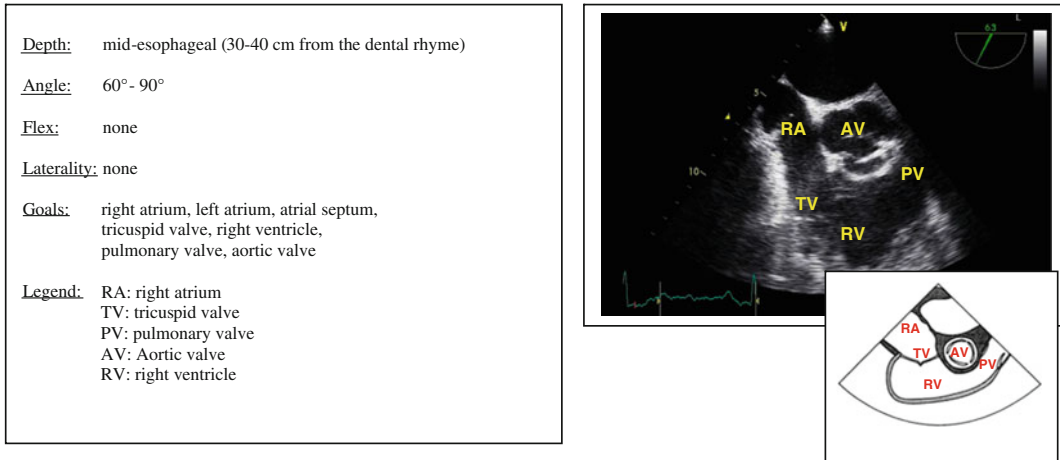   AV: aortic valve

Fig. 4.2 Mid-esophageal aortic valve long-axis view

4.3.1.2 Mid-Esophageal AV Long-Axis View

The mid-esophageal AV long-axis view is obtained by further rotating the imaging angle to approximately 110–130°. A slight turn of the probe toward the patient's right may be necessary to optimize this image. The view is complete when the left ventricular outflow tract, AV, and proximal ascending aorta are displayed together. Additional structures to observe are the outflow tract itself, the sinus of Valsalva, and the sinotubular junction (Fig. 4.2).

The primary diagnostic goal of this view is to evaluate AV function. The proximal ascending aorta should be inspected for calcification, enlargement, and protruding atheroma. An important limitation of this view is that the aortic cannulation site in the distal ascending aorta cannot be visualized. After completion of a two-dimensional examination, AV function is evaluated further with CFD imaging.

Depth: mid-esophageal (30-40 cm from the dental rhyme)

Angle: 60° - 90°

Flex: none

Laterality: none

Goals: right atrium, left atrium, atrial septum,
              tricuspid valve, right ventricle,
              pulmonary valve, aortic valve

Legend: RA: right atrium
              TV: tricuspid valve
              PV: pulmonary valve
              AV: Aortic valve
              RV: right ventricle

Fig. 4.3 Mid-esophageal right ventricular inflow–outflow view

4.3.1.3 Mid-Esophageal Right Ventricular Inflow–Outflow View

The next view obtained at the level of the AV is the mid-esophageal right ventricular inflow–outflow view. One starts at the mid-esophageal AV short axis and, without moving the probe, changes the rotation of the imaging angle to approximately 60–90°. The desired imaging plane will visualize the tricuspid valve, the right ventricular outflow tract, and the proximal pulmonary artery (Fig. 4.3).

The primary diagnostic goals of this view are to gauge the right ventricular chamber and pulmonary artery size and to evaluate the pulmonary valve. This view is often superior to the mid-esophageal four-chamber view for Doppler interrogation of the tricuspid valve.

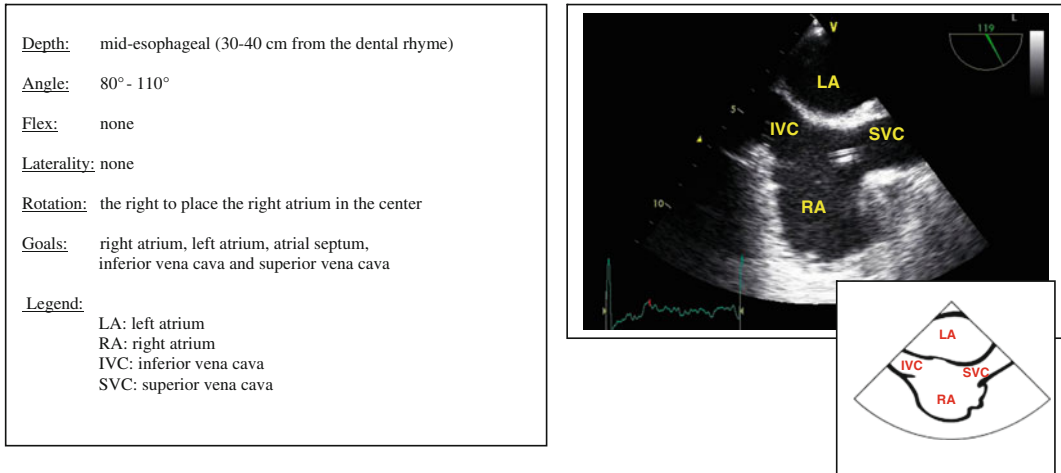### 4.3.1.4 Mid-Esophageal Bicaval View

The mid-esophageal bicaval view is then obtained by turning the probe further to the patient's right. This image is often best with 5–15° less rotation than in the mid-esophageal AV long-axis view. The key structures in this view are the left atrium, right atrium, superior vena cava, intra-atrial septum, and right atrial appendage (Fig. 4.4).

The primary diagnostic goals of this view are to examine for atrial chamber enlargements and the presence of a patent foramen ovale or an atrial septal defect, and to detect intra-atrial air. If the integrity of the intraatrial septum is questioned, CFD imaging or bubble contrast imaging should be performed.
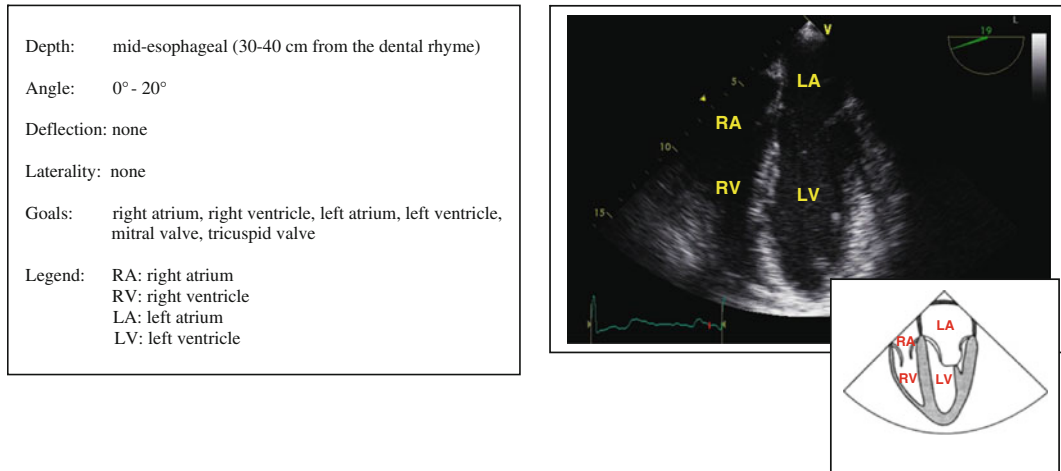
4.3.2 Mid-Esophageal Mitral Valve Level

4.3.2.1 Mid-Esophageal Four-Chamber View

After completion of the mid-esophageal bicaval view, the imaging angle is returned to 0° and the TEE probe is advanced to the mitral valve level. In the transverse plane, the mid-esophageal four-chamber view is obtained. This view allows visualization of all the chambers of the heart. The image rotation is approximately 0–10° with some posterior flexion of the probe. The key structures to observe are the left atrium, the LV, the right atrium, the right ventricle, the mitral and tricuspid valves, and the septal and lateral walls of the myocardium. If a portion of the left ventricular outflow tract and AV is displayed (called the five-chamber view), retroflexion of the probe and slight advancement or rotation of

Depth: mid-esophageal (30-40 cm from the dental rhyme)

Angle: 80° - 110°

Flex: none

Laterality: none

Rotation: the right to place the right atrium in the center

Goals: right atrium, left atrium, atrial septum,
            inferior vena cava and superior vena cava

Legend:
            LA: left atrium
            RA: right atrium
            IVC: inferior vena cava
            SVC: superior vena cava

Fig. 4.4 Mid-esophageal bicaval view

Depth: mid-esophageal (30-40 cm from the dental rhyme)

Angle: 0° - 20°

Deflection: none

Laterality: none

Goals: right atrium, right ventricle, left atrium, left ventricle,
            mitral valve, tricuspid valve

Legend: RA: right atrium
            RV: right ventricle
            LA: left atrium
            LV: left ventricle

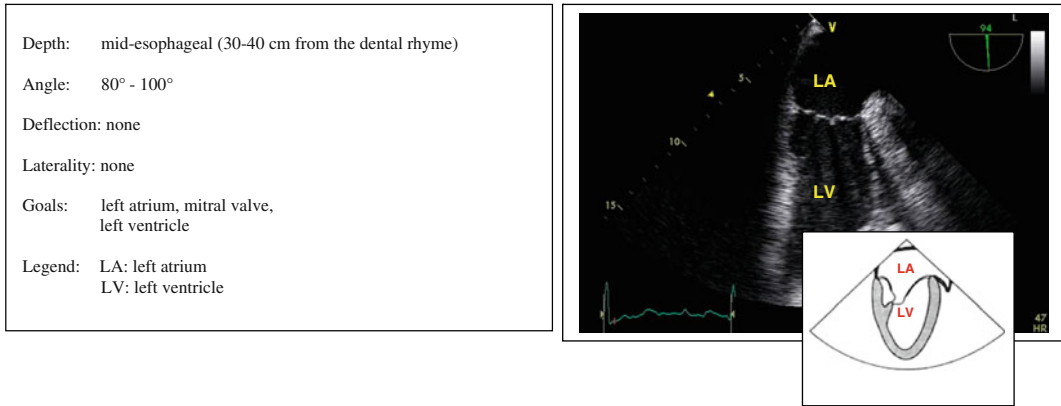**Fig. 4.5** Mid-esophageal four-chamber view

the imaging plane to 5–10° should produce the mid-esophageal four-chamber view (Fig. 4.5).

The mid-esophageal four-chamber view is one of the most diagnostically valuable views in TEE. The diagnostic goals of this view include evaluation of chamber size and function, valvular function (both mitral and tricuspid), biventricular interdependence, and regional motion of the septal and lateral walls of the LV. An additional important use of this view is to look for intraventricular air following cardiopulmonary bypass. After
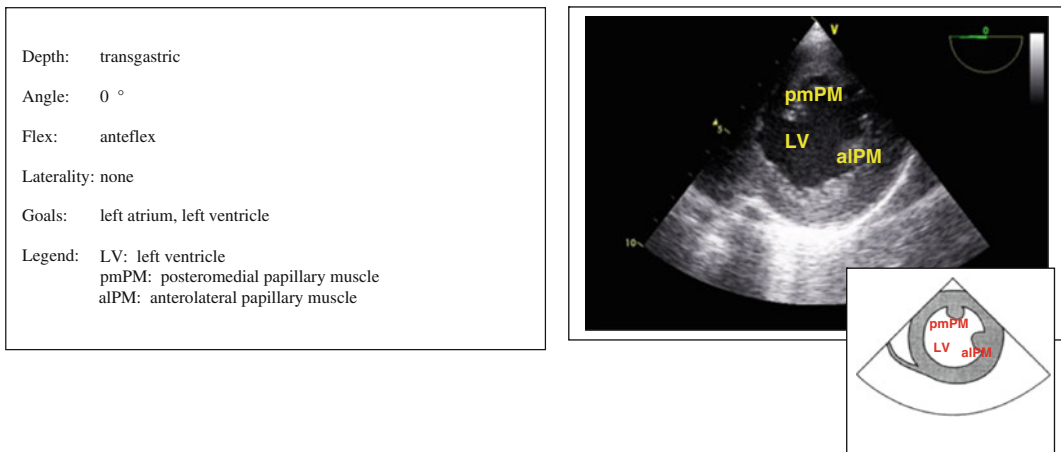
two-dimensional interrogation of this view, CFD imaging should be applied to the mitral and tricuspid valves to detect valvular insufficiency and stenosis.

4.3.2.2 Mid-Esophageal Two-Chamber View

From the mid-esophageal four-chamber view, the imaging angle is rotated to approximately 60° to 90° to obtain the mid-esophageal two-chamber view. This view is characterized by the

Depth:	mid-esophageal (30-40 cm from the dental rhyme)
Angle:	80° - 100°
Deflection: none	
Laterality: none	
Goals:	left atrium, mitral valve, left ventricle
Legend:	LA: left atrium LV: left ventricle

Fig. 4.6 Mid-esophageal two-chamber view

Depth:	transgastric
Angle:	0 °
Flex:	anteflex
Laterality: none	
Goals:	left atrium, left ventricle
Legend:	LV: left ventricle pmPM: posteromedial papillary muscle alPM: anterolateral papillary muscle

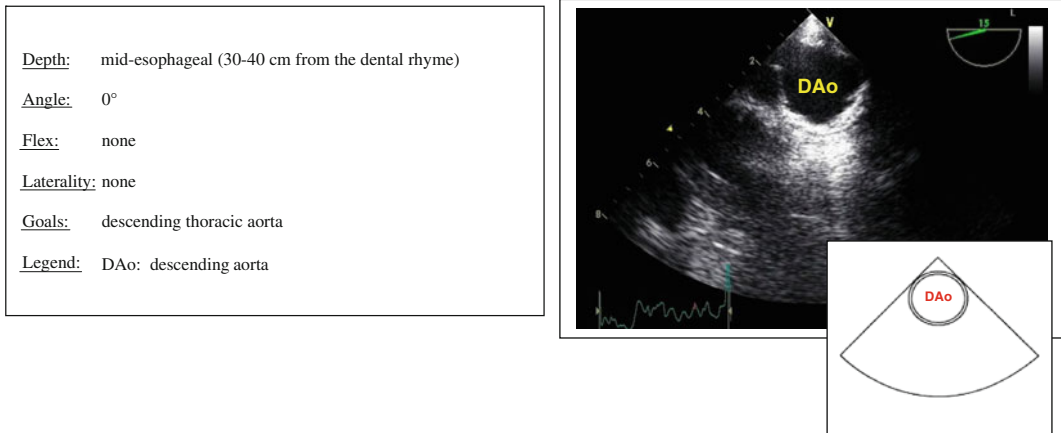**Fig. 4.7** Transgastric mid-papillary short-axis view

presence of the left atrial appendage and the absence of right-sided heart structures, and it allows visualization of the anterior and inferior walls of the LV. Occasionally, turning the probe shaft to the right will improve chamber alignment and visualization of the true left ventricular apex. Ventricular thrombus or hypokinesis at the apex is often best appreciated in this view (Fig. 4.6).

The primary goals of this view are to evaluate left ventricular function (especially the apex) and anterior and inferior regional wall motion.

It can also be used to look for thrombus of the left ventricular apex and left atrial appendage.

4.3.3 Transgastric Level: Transgastric Mid-Papillary Short-Axis View

After completion of the interrogation of the heart at the aortic and mitral valve levels, the imaging plane is returned to 0° and the probe is advanced into the stomach to obtain the transgastric views. The first is the transgastric mid short-axis view. The probe is then anteflexed and withdrawn until

Depth:	mid-esophageal (30-40 cm from the dental rhyme)
Angle:	0°
Flex:	none
Laterality:	none
Goals:	descending thoracic aorta
Legend:	DAo: descending aorta

Fig. 4.8 Descending aortic short-axis view

contact is made with the wall of the stomach. The key structures to visualize are the left ventricular walls and cavity in addition to the posteromedial and anterolateral papillary muscles. A true short-axis cross section of the LV is confirmed when the two papillary muscles are approximately of equal size. Fine-tuning this image may be difficult (Fig. 4.7).

The primary diagnostic goals of this view are assessment of left ventricular systolic function, left ventricular volume, and regional wall motion.

4.3.4   Aortic Examination

4.3.4.1   Descending Aortic Short-Axis View

After completion of the preliminary evaluation of the heart, the aorta is examined. From the transgastric two-chamber view, the imaging angle is rotated to 0° and the probe shaft is turned to the patient's left and slightly withdrawn until a transverse view of the descending aorta is obtained (the descending aortic short-axis view). Key factors in imaging the aorta are its small size and its proximity to the TEE probe head in the esophagus. Consequently, the following maneuvers are necessary to optimize aortic imaging. First, the image depth in reduced to enlarge the displayed aortic image. Then, the

frequency of the transducer can be increased to enhance resolution. The aorta is then visualized along its course as the probe is slowly withdrawn. When the aorta begins to appear elongated, the level of the aortic arch has been reached (Fig. 4.8).

4.3.4.2   Upper Esophageal Aortic Arch Short-Axis View

From the level of the aortic arch, the imaging angle is turned to 90° to obtain the upper esophageal aortic arch short-axis view. Small left and right turns of the probe shaft will allow the arch to be interrogated for calcification, enlargement, and foreign bodies. The origins of the great vessels may be at approximately three o'clock in the short axis of the aortic arch. The origin of the left subclavian artery is visualized in this view.

4.3.4.3   Descending Aortic Long-Axis View

From the upper esophageal aortic arch short-axis view with the imaging plane maintained at 90°, the probe is advanced to obtain the longitudinal view of the descending aorta (the descending aortic long-axis view). Again, as the probe is advanced, small left and right turns of the probe permit better interrogation of the aortic walls.
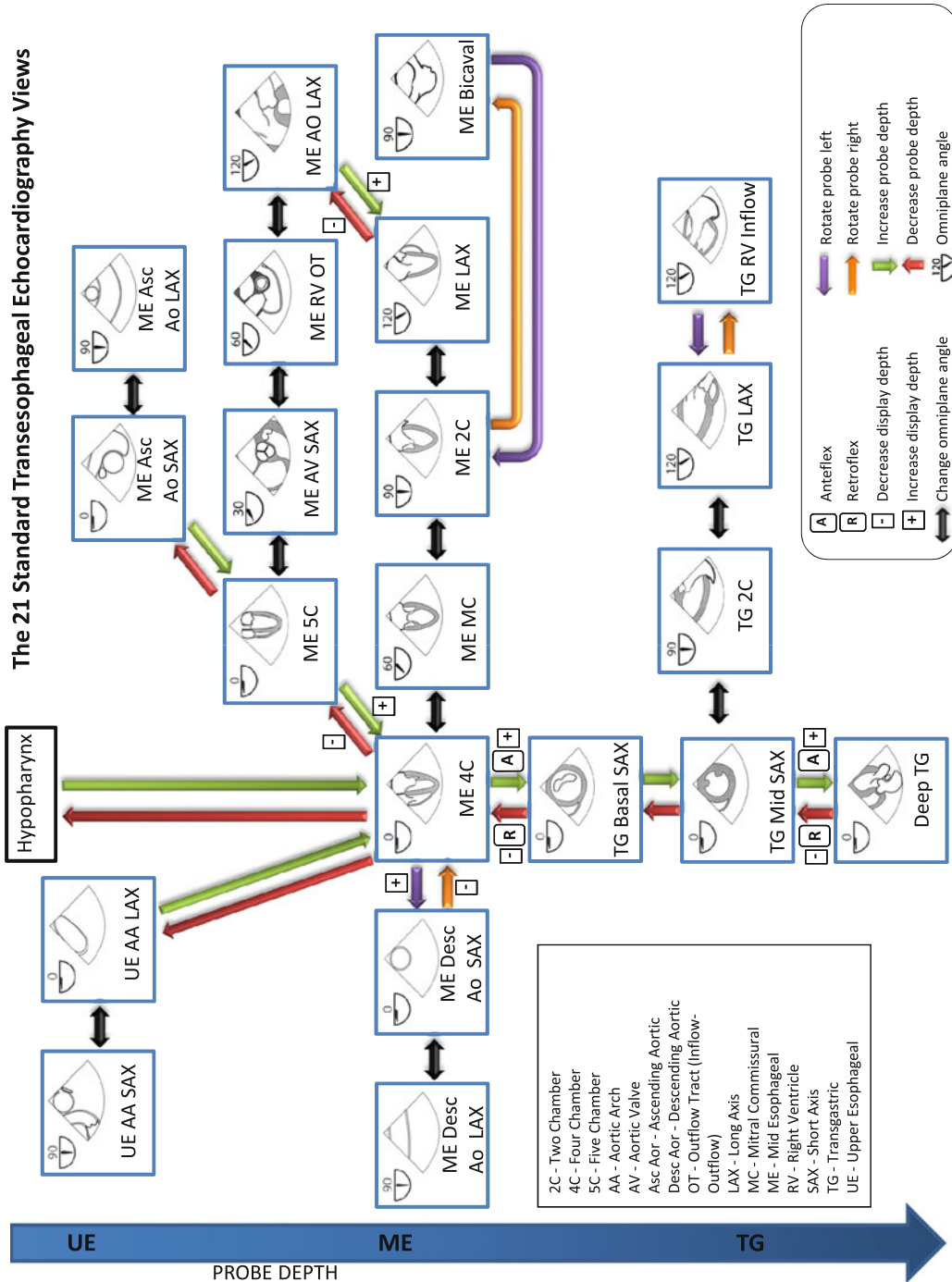
The 21 Standard Transesophageal Echocardiography Views

Fig. 4.9 The 21 standard transesophageal echocardiography views

4.4 Summary

To help understand the relationships between the various echocardiographic sections, Fig. 4.9 summarizes all standard views and movements of the transesophageal probe to move from one view to another.

Further Reading

Miller JP, Lambert SA, Shapiro WA et al (2001) The adequacy of basic intraoperative transesophageal echocardiography performed by experienced anesthesiologists. Anesth Analg 92:1103–1110

Shanewise JS, Cheung AT, Aronson S et al (1999) ASE/SCA guidelines for performing a comprehensive intraoperative multiplane transesophageal echocardiographic examination: recommendations of the American Society of Echocardiography Council for Intraoperative Echocardiography and the Society of Cardiovascular Anesthesiologists Task Force for Certification in Perioperative Transesophageal Echocardiography. Anesth Analg 89:870–884

Stevenson JG (1999) Adherence to physician training guidelines for pediatric transesophageal echocardiography affects the outcome of patients undergoing repair of congenital cardiac defects. J Am Soc Echocardiogr 12:165–172

Thys DM, Abel M, Bollen BA et al. (1996) Practice guidelines for perioperative transesophageal echocardiography. A report by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists Task Force on Transesophageal Echocardiography. Anesthesiology 84:986–1006

Ungerleider RM, Kisslo JA, Greeley WJ et al (1995) Intraoperative echocardiography during congenital heart operations: experience from 1,000 cases. Ann Thorac Surg 60:S539–S542