Annual CRASH TEE review 2010

Maximum CME: 7.5 hrs

Signup: $10

Part I: TEE for the general anesthesiologists (Monday 16:30-19:00)

Topics:		
	1. Basic views	Dr Weitzel
	2. TEE in hemodynamic monitoring	Dr Seres
	3. Case presentations	Drs Weitzel and Seres

Objectives:
1. Basic knowledge about the TEE probe, positioning the probe in the patient and get the basic views.
2. Basic knowledge about image and Doppler modalities. Using of different modalities for hemodynamic monitoring.
3. Examples of clinical scenarios where TEE can make a difference in the general OR.

At the end of the review, participants should be able to:
1. Understand how to manipulate the TEE probe. Recognize basic TEE views.
2. Understand the role of different image and Doppler modalities in hemodynamic monitoring.
3. Imagine scenarios where the TEE can be used in the general OR.

Part II: Advanced TEE (Tuesday 16:30-19:00)

Topics:		
	1. LV Systolic function	Dr Seres
	2. LV Diastolic function	Dr Seres
	3. Evaluation of mitral valve diseases	Dr Nasrallah

Objectives:
1. Evaluation of LV systolic function using the TEE. Understanding the importance of the measured parameters in different heart diseases.
2. Evaluation of LV diastolic function using the TEE. Evaluating the diastolic function in different heart diseases.
3. Using the TEE for anatomic and functional analysis of mitral valve diseases.

At the end of the review, participants should be able to:
1. Recognize systolic dysfunction and grade the severity.
2. Recognize different types of diastolic dysfunction.
3. Recognize altered mitral valve anatomy and function.

PART III: Advanced TEE (Wednesday 7:00-9:30)

Topics:	1.Evaluation of aortic valve diseases	Dr Puskas
	2. Evaluation of RV function	Dr Puskas
	3. Congenital heart diseases	Dr Nasrallah

Objectives:
1. Evaluation of the anatomic and functional status of the aortic valve by using TEE.
2. Evaluation of right ventricular function in different heart diseases using the TEE.
3. Using the TEE for anatomic and functional analysis of congenital heart diseases.

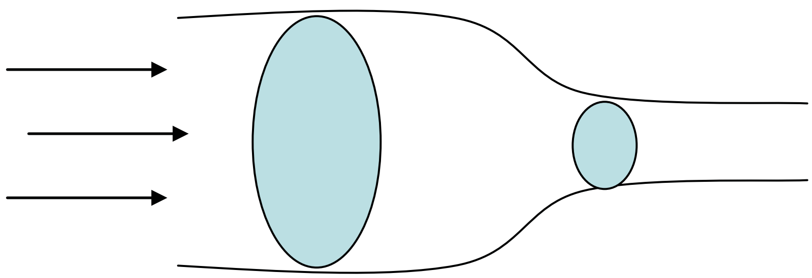
At the end of the review, participants should be able to:
1. Recognize aortic valve abnormalities and grade them.
2. Recognize and measure the severity of RV dysfunction.
3. Recognize the most frequent adult congenital abnormalities.

Continuity Equation

Tamas Seres, MD
UCHSC

The continuity equation based on assuming a constant flow of fluid through a conduit. If there is a stenosis in the conduit, the velocity of fluid will increase at the site of stenosis to keep the continuity of flow. Flow (cm^3/sec) in a conduit is the product of cross-sectional area (CSA) of the conduit (cm^2) and the velocity of the fluid (cm/sec). Continuity of flow is an important principle to evaluate areas with unknown size such as areas of AS, MS or regurgitant areas of AI or MR. The figure below represents the flow in the left ventricular outflow track (LVOT) and at the level of aortic stenosis (AS).

CSA_{LVOT} > CSA_{AS}



V_{LVOT} < V_{AS}

Flow through LVOT = Flow through AS

$CSA_{LVOT} \times V_{LVOT} = CSA_{AS} \times V_{AS}$

LVOT : Left Ventricular Outflow Track
AS: Aortic Stenosis
CSA: cross-sectional area
V: velocity

Cross-sectional area (CSA) of LVOT:

CSA can be calculated from the diameter of the studied part of the conduit. For example the diameter (d) of the LVOT can be measured using the LV long axis view:

$CSA_{LVOT} = d^2 \times 0.785$

$Area = (d/2)^2 \times \pi$

$Area = d^2 \times \pi/4$

$\pi/4 = 0.785$

$\text{Area} = d^2 \times 0.785$

d = diameter of LVOT

Measurement of V_{LVOT}:

The velocity of the flow at the level of the measurement of CSA_{LVOT} is determined by using PWD in the LV deep transgastric or transgastric long axis view.

Measurement of V_{AS}:

The velocity of the flow through the stenotic aortic valve is measured by using CWD. In this way the maximum velocity is measured through the smallest area in the direction of the measurement. The deep transgastric view and the transgastric long axis view can be used to perform the measurement.

Measurement of CSA_{AS}:

From the measurement of CSA_{LVOT}, V_{LVOT} and V_{AS} the stenotic area of the aortic valve (CSA_{AS}) can be calculated by using the flow continuity equation.

Flow Continuity:

Flow = area x velocity (ml/s)

$$CSA_{LVOT} \times V_{LVOT} = CSA_{AS} \times V_{AS}$$

$$CSA_{AS} = CSA_{LVOT} \times V_{LVOT} / V_{AS}$$

The alternative way to calculate the CSA_{AS} is based on the fact that the volume during a certain cardiac circle is also constant at different cross-sectional areas. For example during the systole the stroke volume (SV) is a product of CSA (cm^2) and velocity time integral (VTI) (cm).

Velocity Time Integral: The blood flow and velocity are phasic in the circulation because of the change throughout the cardiac cycle. A Doppler spectrum of the velocity of blood through a valve will yield a curve that has velocity (cm/s) on the *y* axis and time (s) on the *x* axis. When this curve is integrated, it yields a velocity-time integral (VTI) in units of centimeter (cm/sec x sec = cm). It indicates the distance the blood travels during a certain cardiac circle. The product of VTI (cm) and CSA (cm^2) will yield the stroke volume (cm^3).

The SV through the LVOT area equals the SV through the AS area. The VTI_{LVOT} and the VTI_{AS} can be determined using the Doppler spectrum of the velocity of blood through the LVOT and the AS area based on PWD or CWD measurement, respectively.

Volume Continuity:

Volume = area x VTI (ml)

$$CSA_{LVOT} \times VTI_{LVOT} = CSA_{AS} \times VTI_{AS}$$

$$CSA_{AS} = CSA_{LVOT} \times VTI_{LVOT} / VTI_{AS}$$

Summary for Clinical Practice:

V_{LVOT} and VTI_{LVOT} are measured by PWD at the level of the measurement of d_{LVOT}.
V_{AS} and VTI_{AS} are determined at the site of the stenosis by CWD.
A known area, CSA_{LVOT}, is used to calculate an unknown area CSA_{AS} by the continuity equation.

MS area can be calculated by the continuity equation. The V_{MS} or VTI_{MS} is measured by CWD aligned through the MV in ME 4 chamber view. The MV area (MVA) can be computed as follows:

Flow continuity:

$MVA = CSA_{LVOT} \times V_{LVOT}/V_{MS}$

Volume continuity:

$MVA = CSA_{LVOT} \times VTI_{LVOT}/VTI_{MS}$

Proximal Isovelocity Surface Area (PISA)

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If the molecules of a fluid move within a large cavity toward a small orifice the velocity increases and the velocity profile is hemispherical with the cavity of the hemisphere facing the orifice. The velocity over the surface of the hemisphere is the same (isovelocity), and because the hemisphere is proximal to the orifice, the surface area is known as proximal isovelocity surface area (PISA).
The flow toward a small orifice can be studied by color Doppler with the scale set. When the accelerated velocity exceeds the Nyquist limit (maximum value on the velocity scale), aliasing will take place and a semicircular shell of contrasting colors will cap the orifice. The semicircular shell is a hemisphere in three dimensions and its surface area can be calculated.

PISA surface area (hemisphere) = $2 \times r^2 \times \pi$

r: the distance from the orifice to PISA.

The velocity of the flow at PISA is the maximum velocity on the velocity scale of the color Doppler spectrum or the aliasing velocity (V_{al}). The flow at PISA:

Flow at the PISA = PISA x V_{al}

Flow at the orifice = $CSA_{orifice} \times V_{orifice}$

$V_{orifice}$: The flow velocity through the orifice can be measured by CWD. Continuous wave Doppler measures the maximum velocity at the smallest area in the direction of the measurement.

Flow continuity:

Flow at the PISA = Flow at the orifice

$PISA \times V_{al} = CSA_{orifice} \times V_{orifice}$

$CSA_{orifice} = PISA \times V_{al} / V_{orifice}$

Summary for Clinical Paractice:

Using color flow Doppler and continuous wave Doppler a narrow area at MR or MS can be measured. Color Doppler is used to measure the flow at the PISA where the flow velocity is the aliasing velocity which is the maximum velocity on the color Doppler scale. The velocity at the orifice can be determined by continuous wave Doppler. The orifice area can be calculated by the continuity equation.

Example:

Calculation of EROA in MR:

The orifice area of mitral regurgitation is the effective regurgitant orifice area (EROA). The EROA is a volume independent parameter of the severity of MR. Calculation of EROA of the MR with PISA based on the continuity equation.

PISA radius = 0.96 cm Velocity at PISA (V_{al}) = 49 cm/s

PISA flow:

The figure shows a color Doppler study of mitral regurgitation. The transition line between blue and red represents the proximal isovelocity area (PISA) where the velocity is known exactly as the maximum velocity of the color scale (49 cm/s).
The flow can be calculated through the PISA area:

$\text{Flow} = \text{PISA} \times V_{al}$

$\text{PISA} = 2 \times \pi \times r^2$

$r = 0.96$ cm

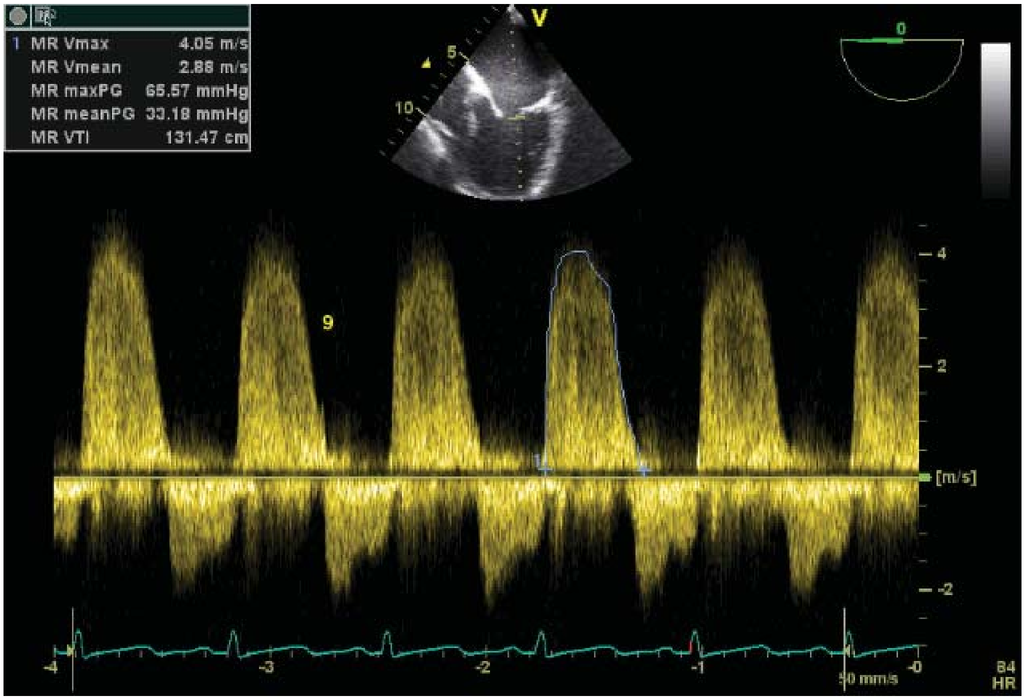
$\text{PISA} = 5.78\ \text{cm}^2$

$V_{al} = 49$ cm/s

Flow at PISA = 49 cm/s x 5.78 cm^2 = 283 cm^3/s

Velocity through the MR orifice:

The maximum velocity (V_{MR}) through the MR orifice can be measured by CWD.



V_{MR} (Maximum velocity at the EROA) = 405 cm/s
VTI_{MR} (Velocity time integral of the MR) = 131.5 cm

Calculation of EROA:

Using the flow continuity equation:

Flow at PISA = Flow at EROA

PISA x V_{al} = V_{MR} x EROA

EROA = Flow at PISA/V_{MR}

Flow at PISA = 283 cm^3/s

EROA = 283 cm^3/s/405 cm/s = 0.69 cm^2

Severe MR: EROA $\geq$ 0.4 cm^2

Calculation of Regurgitant Volume (RV):

Knowing the EROA and the VTI_{MR} the regurgitant volume (RV) can be calculated:

$RV = EROA \times VTI_{MR}$

$EROA = 0.69\ cm^2$

$VTI_{MR} = 131.5\ cm$

$RV = 0.69 \times 131.5 = 90\ cm^3$

Severe MR: $RV \geq 60\ cm^3$

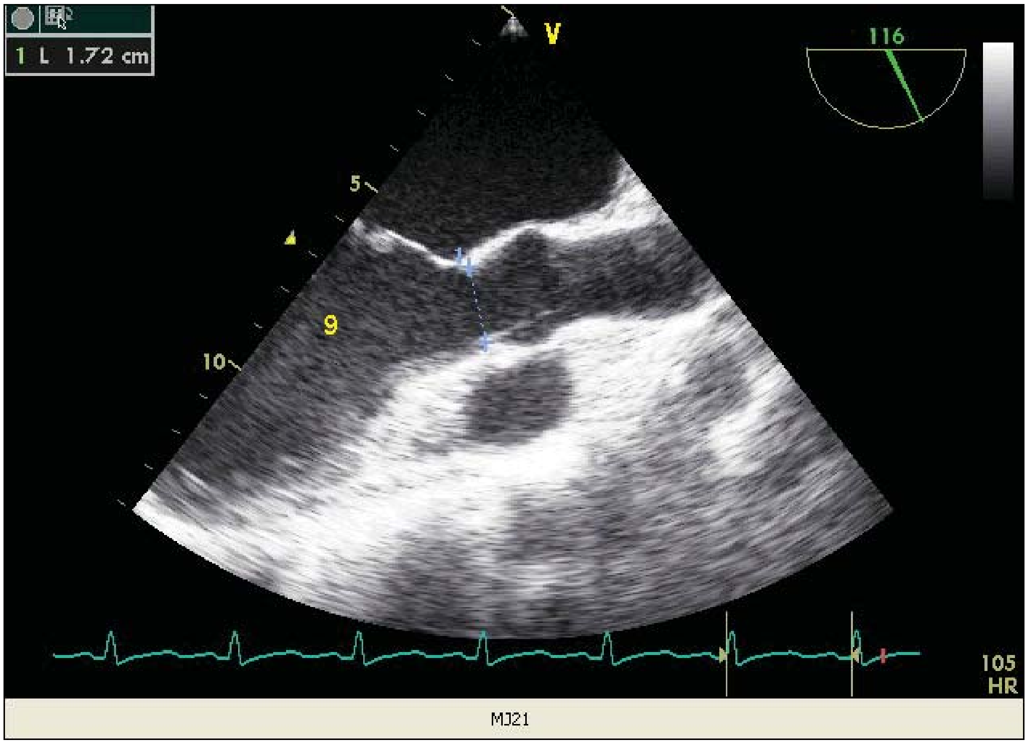
Calculation of Regurgitant Fraction (RF):

$RF = RV / SV + RV$

$SV = CSA_{AV} \times VTI_{AV}$

RV = regurgitant volume
SV: stroke volume
CSA_{AV} : cross-sectional area of the aortic valve

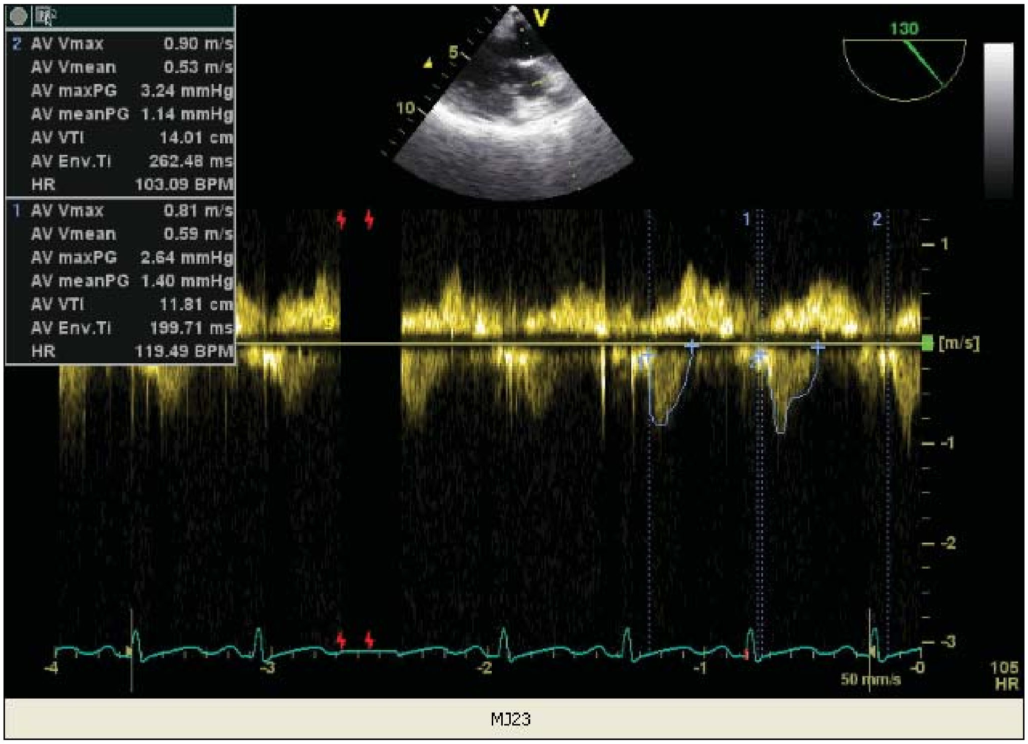
$CSA_{AV} = d^2 \times 0.785$



d= 1.72 cm

$CSA_{AV} = 1.72^2 \times 0.785 = 2.3 \text{ cm}^2$

VTI_{AV} can be measured as the area under the velocity curve of the aortic flow using either PWD or CWD:



VTI_{AV} = 13 cm (from 2 measurements)

SV = 2.3 cm^2 x 13 cm = 30 cm^3

Regurgitant Fraction (RF):

RF = RV/(RV + SV) x 100

RF (%) = 90/(90 + 30) x 100 = 75 %

Severe MR: RF ≥ 50 %

TEE in Hemodynamic Monitoring

Tamas Seres, MD, PhD
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TEE in Hemodynamic Monitoring

- TEE can rapidly provide a comprehensive array of hemodynamic variables.
- This is of particular importance in the OR and critical care setting, where patients are often obtunded and mechanically ventilated.

Indications for TEE in the critically ill

- In a review of 83 TEE performed in the critical care setting:
  - unexpected findings in 25% of patients
    - Change in management (17%)
    - Referral for invasive examination in 22%
    - Surgical intervention was performed based on TEE without further examination in 16%.

Foster, E et al. J Am Soc Echocardiogr 1992; 5:368.

Indications for TEE in the critically ill

- Suspicion of significant valve disease
- Prosthetic dysfunction
- Hypotension
- Suspicion of pulmonary embolism
- Investigating cardiac embolic source
- Suspected right or left ventricular dysfunction
- Situations conducive to mediastinal or thoracic bleeding
- Suspicion of hypoxia arising from an intracardiac shunt
- Chest pain indicative of dissection of the aorta
- Severe chest trauma
- Myocardial infarction with shock
- Cardiopulmonary resuscitation

TEE in Hemodynamic Monitoring

- Hemodynamic variables that are derived from TEE that can be estimated include:
  - Cardiac output
  - Left ventricular filling pressure
  - Temporal distribution of left ventricular filling
  - Chamber preload
  - Atrial interaction
  - Pulmonary pressure

Cardiac Output

- Doppler-derived pulmonary artery, aortic, or mitral flow signals can be used to calculate stroke volume, based on the principle that the velocity time integral (VTI) of blood flow multiplied by the cross-sectional area (CSA) at any of these conduits (cm^2) estimates the cardiac stroke volume.
- The product of stroke volume and heart rate is cardiac output.

Cardiac Output

- The VTI is the actual area under the velocity-time curve.
- Doppler signal is velocity (distance/time), the area under the velocity-time curve is distance/time x time or distance.
- Thus the velocity time integral is referred to as the stroke distance which is the distance traveled by the sampled volume within each heart beat.

Cardiac Output

- Stroke distance is normally 13 to 15 cm for the pulmonary artery and 18 to 20 cm for the aorta.
- This method eliminates the error introduced by estimating the cross-sectional area of the vessel and holds constant over a broad range of body surface areas.

Lim, DC et al. J Am Soc Echo 1993; 6:S34.

Cardiac Output

- Although cardiac output by thermodilution is not an ideal reference standard, the pulsed-wave Doppler method was able to follow directional changes in that parameter.

Cardiac Output

- Aortic blood flow cannot be accurately measured from the esophageal views because of poor ultrasound beam alignment for Doppler signals.
- Deep transgastric view aligns the left ventricular outflow tract with the transducer to obtain accurate flow signals and permits accurate determination of the cardiac output.

Darmon, PL et al. Anesthesiology 1994; 80:796.

Left Ventricular and Atrial Filling Pressures

- Doppler mitral inflow velocity
- Pulmonary venous flow patterns
- Continuous-wave Doppler of mitral regurgitation

Doppler mitral inflow velocity

- Doppler demonstration of the velocity profile of left ventricular transmitral inflow is the most informative method of assessing left ventricular filling.

Doppler mitral inflow velocity

- Important diagnostic parameters derived from the mitral inflow signals include:
  - E or early diastolic wave
  - A or late systolic wave
  - E/A ratio
  - Deceleration time of early filling curve (DT)
  - Isovolumic relaxation time (IVRT).

Doppler mitral inflow velocity

- Although there is considerable variability, two predominant patterns of flow have been recognized that reflect the two major categories of diastolic dysfunction:
  - Impaired left ventricular relaxation
  - Decreased left ventricular compliance

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- E/A ratio is <0.8
- DT > 200
- IVRT >100

Impaired left ventricular relaxation

- This form of diastolic dysfunction occurs in:
  - – 1. Ischemic heart disease
  - – 2. Hypertension
  - – 3. Normal aging

Decreased left ventricular compliance

- Diminished left ventricular compliance is characterized by a "restrictive flow" pattern:
  - E/A >2
  - DT <160 ms
  - IVRT < 60

Decreased left ventricular compliance

- This pattern occurs in patients with:
  - 1. Restrictive cardiomyopathies such as amyloid heart disease
  - 2. Elevated filling pressures associated with a variety of myopathic conditions

Left Ventricular and Atrial Filling Pressures

- The diastolic filling pattern does not always reflect these two circumscribed categories because it is influenced by a variety of other factors:
  - Loading conditions
  - Heart rate
  - Pericardial restraint
  - Left atrial pressure and compliance
  - Right and left ventricular interaction
  - Intrinsic properties of left atrial and left ventricular muscle
  - Presence or absence of mitral regurgitation
  - Patient age

Left Ventricular and Atrial Filling Pressures

- Changes in loading conditions during cardiac surgery have been shown to influence filling patterns.
- With an increase in intravascular volume, a rise in early diastolic filling velocity is seen, most likely due to an increased left atrial to left ventricular pressure gradient.

Nishimura, RA et al. Circulation 1990; 81:1488.

Left Ventricular and Atrial Filling Pressures

- An increase in left atrial pressure due to ischemia may be associated with an increase in early diastolic filling velocities and normalization from relaxation abnormality called pseudonormalization.

Kuecherer, HF et al. Circulation 1990; 82:1127.

Left Ventricular and Atrial Filling Pressures

- Hypovolemia or preload reduction (eg, nitrates) may cause a decrease in early filling velocity mimicking impaired relaxation.

Pulmonary venous flow

- The interpretation of the mitral inflow pattern is greatly enhanced when the pattern of pulmonary venous Doppler signal is examined.
- TEE has contributed substantially to our understanding of this hemodynamic parameter.

Pulmonary venous flow

- TEE from the base of the heart demonstrates the entrance of the four pulmonary veins into the left atrium.
- The left upper pulmonary vein flow is close to and parallel to the direction of the interrogating beam.

Pulmonary venous flow

- Flow in the pulmonary veins is triphasic:
  - Systolic phase, S wave
  - Early diastolic phase, D wave
  - Atrial contraction, A reversal or Ar wave

Pulmonary venous flow

- The systolic phase is predominant, accounting for more than 55 percent of total flow integral representing systolic atrial filling.
- The second phase occurs in early diastole and is approximately 40 percent of the total representing early diastolic atrial emptying.

Pulmonary venous flow

- The third phase is a small retrograde flow into the pulmonary vein in late diastole and results from atrial contraction.

Nishimura, RA et al. Circulation 1990; 81:1488.

Pulmonary venous flow

- Variables measured from pulmonary venous flow velocity tracings include:
  - S/D ratio
  - Ar peak velocity
  - Ar duration

Pulmonary venous flow

- In conditions when left ventricular filling pressures are elevated:
  - 1. S/D <1
  - 2. Ar >0.35 m/s
  - 3. Ar – A > 30 ms

Rossvoll, O et al. J Am Coll Cardiol 1993; 21:1687.

Pulmonary venous flow

- In severe mitral regurgitation, systolic flow reversal has been described as one of the signs of severity.

Klein, AL et al. J Am Coll Cardiol 1992; 20:1345.

Mitral regurgitation continuous-wave Doppler echocardiography

- Mitral regurgitation continuous-wave Doppler signals are also hemodynamically informative.
- The simplified Bernoulli equation, when applied to the peak systolic mitral regurgitation flow velocity, can be used to calculate the peak systolic gradient between the left atrium and the left ventricle:

  peak PG = 4 x V^2

Mitral regurgitation continuous-wave Doppler echocardiography

- This value theoretically exceeds systemic arterial pressure by a value equal to left atrial pressure:

  LA pressure = peak PG_{MR} – systolic BP

Mitral regurgitation continuous-wave Doppler echocardiography

- This measurement may be affected by several factors:
  - Ultrasound beam alignment with the mitral regurgitant jet
  - Gradient across the aortic valve.

Mitral regurgitation continuous-wave Doppler echocardiography

- The LA pressure values derived should be confirmed using independent noninvasive indices (mitral inflow and pulmonary vein flow pattern).

Mitral regurgitation continuous-wave Doppler echocardiography

- Other features of the mitral continuous-wave Doppler flow signal:
  - Density of the signal, which is roughly proportional to severity of regurgitation
  - The early systolic acceleration of the jet flow envelope, which is an expression of dP/dt (the change in pressure over time) or contractiltiy of the LV

The Left Ventricular and Atrial Chamber Sizes (Preload)

- Volume changes, ie, preload, affect the size and shape of the left heart chambers.

Hypovolemia

- In acute hypovolemia, most normal hearts become hyperdynamic and develop very small end-systolic volumes.
- The left atrium in hypovolemia becomes tubular, and it may be possible to see the entire chamber and the pulmonary veins in one image.

Hypovolemia

- A small hypercontractile left ventricle in the presence of a predominantly systolic pulmonary venous inflow pattern (S/D >1) and an A-wave dominant mitral inflow pattern (E/A<0.8) are consistent with hypovolemia.

Hypovolemia

- The right atrium, venae cavae, and hepatic veins become small, and respiratory collapse might be appreciated.

Hypotension

- Transesophageal echocardiography provides diagnostic and prognostic information safely and expeditiously in the setting of unexplained hypotension.
- An accurate assessment of intravascular volume is essential to the evaluation of hypotension.

Cardiogenic shock

- In hypotension due to cardiogenic shock, the left ventricular ejection fraction is severely reduced with or without segmental wall motion abnormalities.
- A diastolic predominant pulmonary venous flow pattern (S/D <1) and E-wave dominant mitral inflow pattern (E/A >2) reflect high filling pressures.

Pericardial tamponade

- Pericardial tamponade can usually be diagnosed by surface imaging with the notable exception of the postoperative cardiothoracic surgical patient.
- Loculated pericardial hematomas that impair cardiac filling are difficult to detect with transthoracic echocardiography.

Chan, KL. Am J Cardiol 1988; 62:1142.

Pulmonary embolism

- Massive pulmonary embolism that leads to acute right heart failure is often unrecognized as a cause of hypotension.
- Transesophageal echocardiographic findings consistent with this diagnosis include:
  - Emboli in transit, seen within the right heart chambers
  - Right chamber dilatation
  - Severely reduced right ventricular ejection fraction
  - Thromboembolus within the proximal pulmonary artery

  Wittlich, N et al. J Am Soc Echocardiogr 1992; 5:515.

Pulmonary embolism

- The finding of right ventricular systolic dysfunction alone is not specific for pulmonary embolism.
- This diagnosis needs to be differentiated from a right ventricular infarction, which is almost always associated with the findings of an inferoposterior myocardial infarction and may lead to hypotension.

Jugdutt, BI et al. Am Heart J 1984; 107:505.

Complications of myocardial infarction

- The cause of hemodynamic instability in the setting of acute myocardial infarction can often be elucidated noninvasively using TEE.
- In mechanically ventilated patients highly defined images of the endocardium by TEE are essential for accurate wall motion evaluation.

Complications of myocardial infarction

- TEE:
  - RWMA
  - MR
  - Papillary muscle rupture
  - VSD
  - Pseudoaneurysm
  - Intramyocardial hematoma

  Kranidis, A et al. J Heart Valve Dis 1993; 2:529.

  Topaz, O et al. Am J Med 1992; 93:683.

Complications of myocardial infarction

- These complications should be suspected when a postmyocardial infarction patient with low output is evaluated and unexpectedly found to have hyperdynamic left ventricular function.
- This paradox should initiate a search for papillary muscle rupture or acute ventricular septal defect.

Hypervolemia

- In hypervolemia, as seen in congestive heart failure, especially if chronic, the left ventricle assumes a spherical state as it dilates.
- This appearance is strikingly different from the ellipsoid shape of the healthy heart.
- Filling pressures cannot be determined from inspecting the ventricles and atria thus observations of the Doppler data provide information about filling pressures.

Intraatrial septal motion

- The behavior of the interatrial septum is a particularly important clue to the left ventricular filling pressure.
- Observations made on ventilated patients showed that in the euvolemic or hypovolemic state, the interatrial septum, normally curved to the right, will reverse curvature at end expiration at both end-systole and end-diastole

Kusumoto, FM et al. J Am Coll Cardiol 1993; 21:721.

Intraatrial septal motion

- The cause of the rapid reversal in curvature has been documented with flow-directed catheters; it arises from a transient reversal in the pressure differential in such a way that right atrial pressure transiently exceeds left atrial pressure during the expiratory phase of the ventilator cycle.
- This occurs only when pressures (pulmonary capillary wedge and central venous pressure) are low and nearly equal.

Intraatrial septal motion

- If either atrium carries higher pressure, the atrial septum will remain bowed toward the lower pressure chamber.
- In mitral regurgitation, for example, the atrial septum bows from left to right, and this curvature is little affected by the respiratory cycle.

Intraatrial septal motion

- In tricuspid regurgitation or pulmonary hypertension the curvature goes from right to left.

TEE in CPR

TEE in CPR

- Transesophageal echocardiography is ideally suited for rapid evaluation of the etiology of arrest and the effectiveness of cardiopulmonary resuscitation.
- In one study, TEE was performed on 18 patients during cardiopulmonary arrest as they arrived in the emergency department; blind esophageal intubation was rapidly possible in 14, while 4 required laryngoscopy

Redberg, RF et al. Cardiol Clin 1993; 11:529.

TEE in CPR

- The diagnosis was established in 56 percent and included:
  - Acute myocardial infarction
  - Dilated or hypertrophic cardiomyopathy
- It remains unproven, however, if the rapid diagnosis afforded by transesophageal echocardiography in these patients improves outcome.

TEE in CPR

- Research using TEE has helped elucidate the mechanism of cardiopulmonary resuscitation.
- In 20 patients evaluated with transesophageal echocardiography during compressions, the chambers decreased in size, the mitral valve closed, and the aortic valve opened.

Redberg, RF et al. Circulation 1993; 88:534.

TEE in CPR

- These findings seem to show that the heart is acting like a pump, confirming the so-called cardiac pump theory.
- In a few patients, however, the thoracic pump theory was supported by observation of open aortic and mitral valve during compression.

CPR

- In one patient, the right side appeared to be a passive conduit (thoracic pump), whereas the left side was an active pump.
- Thus, both theories are probably correct, with the cardiac pump probably playing a role in the majority of patients.

END

Transesophageal Echocardiography Basic Views

Prairie Neeley Robinson MD, Nathaen Weitzel MD

Transesophageal Echocardiography

Intraoperative transesophageal echocardiography (TEE) is widely used in modern operating rooms as it provides valuable real time information to the surgical team. The TEE allows intraoperative decisions to be made based on data collected throughout the procedure instead of waiting until after the case to evaluate surgical outcomes. Outcomes have been shown to improve secondary to intraoperative TEE evaluation specifically in cardiac valvular surgery (1), which has promoted the routine use in most cardiac cases today. The anesthesiologist performs the TEE at most institutions intraoperatively and may perform exams in emergency situations in non-cardiac operating rooms or locations such as the intensive care unit. Therefore, it is useful for all anesthesiologists to have basic knowledge of the TEE and the intraoperative exam.

1) **TEE Exam Basics:** A TEE exam is performed by placing the TEE probe into the esophagus.

   a) **Placement:** Consider placing an orogastric tube first to suction the gastric contents; then use a lubricant jelly and a mouth/bite guard when placing the probe.
   b) **Relative contraindications:** Patient history of: mediastinal radiation, dysphagia, recent upper gastrointestinal surgery or bleeding. Known esophageal pathology is also a relative contraindication including: stricture, varices, tumor, diverticulum or esophagitis.

2) **TEE Views:**
   The basic TEE exam consists of 20 views adapted from Shanewise JS, et al (2) **(Figure 1).** These are the basic views used by anesthesiologists to evaluate the heart in the operating room. Not every view is utilized in every patient, but it is useful to know the structures present and how to obtain each view. Each of the 20 views will be described in this chapter as well as how to obtain the view. The views will be discussed as they are found cephalad to caudad in the esophagus. There are markings of the depth in centimeters on the TEE probe. The depth is usually measured at the patient's incisors.

Transesophageal Echocardiography Basic Views

Prairie Neeley Robinson MD, Nathaen Weitzel MD

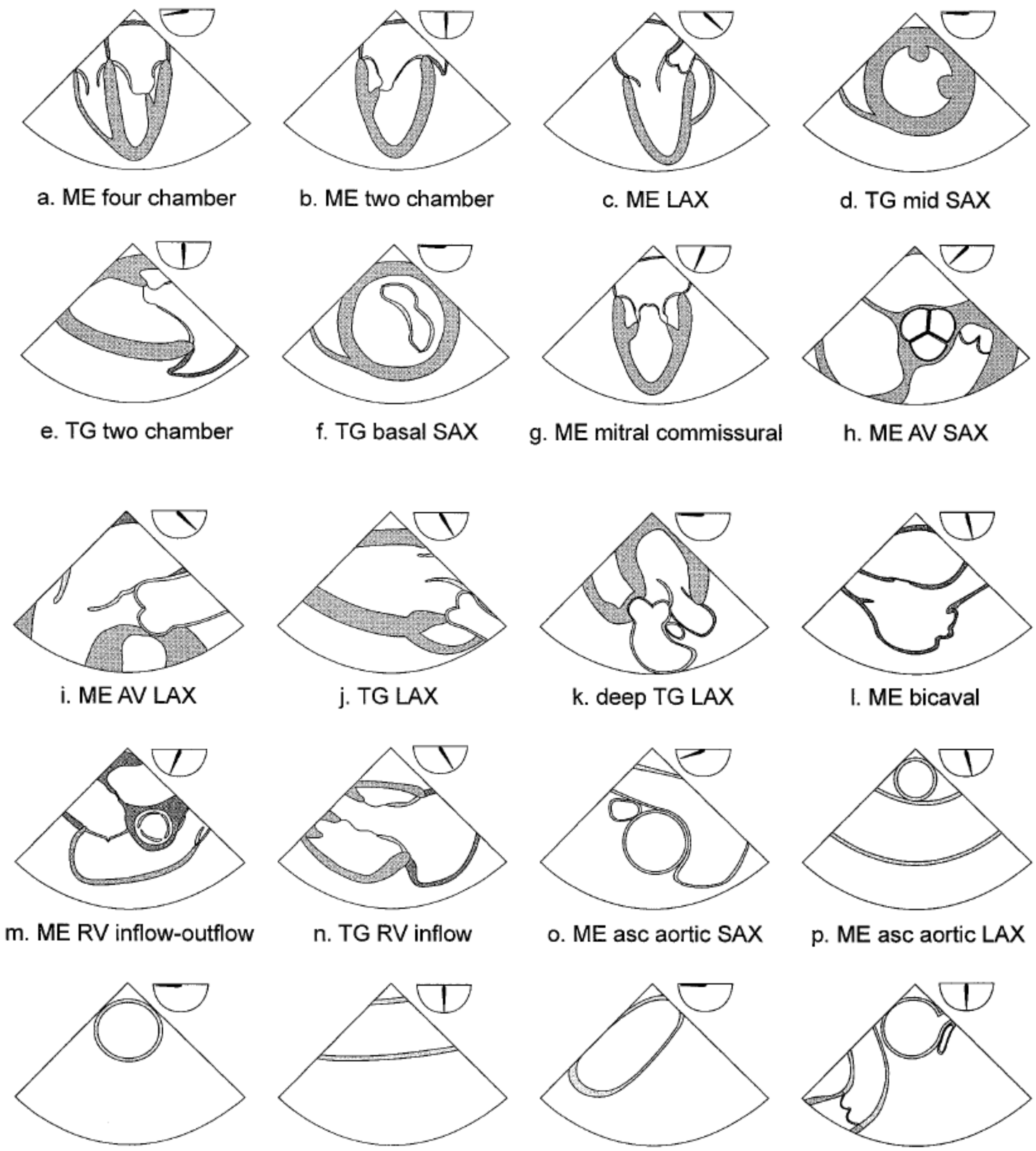


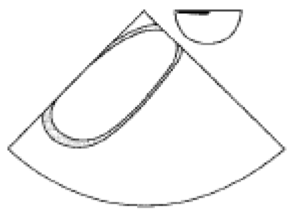
Figure 1. 20 views of the recommended comprehensive TEE exam.
(Shanewise JS, Cheung AT, Aronson S, et al. ASE/SCA Guidelines for performing a comprehensive intraoperative multiplane transesophageal echocardiography examination. Anes Anal 1999;89:870-84)

Transesophageal Echocardiography Basic Views

Prairie Neeley Robinson MD, Nathaen Weitzel MD

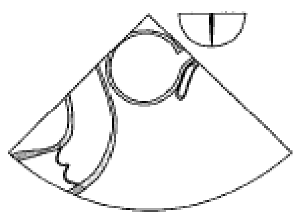
Upper Esophageal 20-25cm

Aortic Arch LAX 0°



The long axis (LAX) view of the aortic arch. It is typically found after imaging the descending thoracic aorta. The probe is withdrawn and the thoracic aorta is followed superiorly until the arch is in view. This view is useful to look for aortic pathology including atherosclerotic plaques, mobile plaques, calcification and dissections.

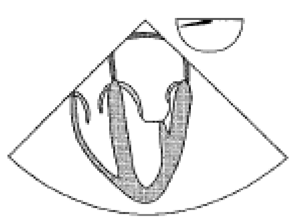
Aortic Arch SAX 90°



The short axis (SAX) view of the aortic arch. It is found similarly to the above view of the arch in long axis. Once the long axis is in view, rotate the angle to 90° to obtain the SAX view. The aortic arch is seen along with the subclavian artery. The pulmonary valve and main pulmonary artery are seen in long axis. The aorta is evaluated for pathology in this view similarly to the long axis aortic arch view above.

Mid Esophageal 30-40cm

Four Chamber 0-20°



The four chamber view is often considered the "home base" view of the TEE exam. To obtain this view once the four chambers are visualized, retroflex the probe slightly and rotate the angle to 0-20°. The four chamber view is used to evaluate the ventricular size, wall motion, masses, and systolic function of each chamber. Atrial size and structure can be examined along with evaluation of the tricuspid (TV) and mitral valve (MV).

Transesophageal Echocardiography Basic Views

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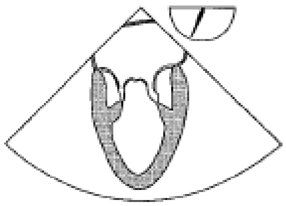
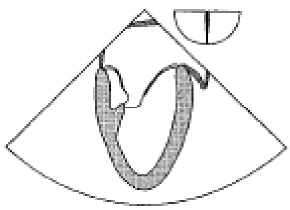
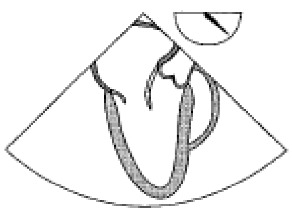
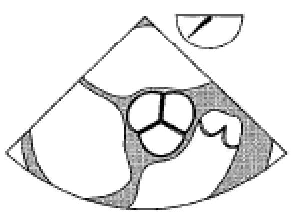
Mitral Commissural 60-80° 	The commissural view of the mitral valve. The leaflets visualized from left to right: **P3, A2, P1**. To obtain this view from the four chamber view above, rotate the angle to 60-80°. Utilize this view to evaluate the mitral valve leaflets, their motion, and to measure the commissural distance / annular dilatation.
Two Chamber 80-100° 	The two chamber view of the left atrium and left ventricle is obtained by rotating the angle to 80-100° until the right side of the heart disappears. Utilize this view to evaluate the mitral valve leaflets, and the anterior and inferior walls of the left ventricle. The left atrium is also examined in this view for evidence of thrombus.
LV Long Axis 120-160° 	The midesophageal long axis view (ME LAX) is obtained by rotating the angle to 120-160^{o} in the ME plane. The left ventricle outflow tract (LVOT) should come into view. The aortic valve and proximal ascending aorta are seen in this view. Utilize this view to evaluate for systolic anterior motion of the mitral valve and to evaluate the anteroseptal and posterior walls of the left ventricle.
AV SAX 30-50° 	The aortic valve short axis view (AV SAX) is obtained in the ME plane usually at 30-50^{o}. Adjust the probe depth until the AV is centered in screen. In this view all three cusps of the AV can be visualized. The noncoronary cusp is adjacent to the interatrial septum, the right coronary cusp is anterior, and the remaining cusp is posterior. The right and left coronary arteries can often be visualized superior to their corresponding cusp. Utilize this view to evaluate the aortic valve cusps for prolapse, calcification, restriction, and for aortic insufficiency.

Transesophageal Echocardiography Basic Views

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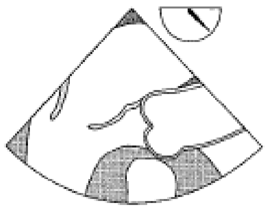
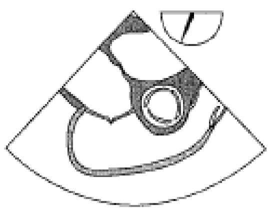
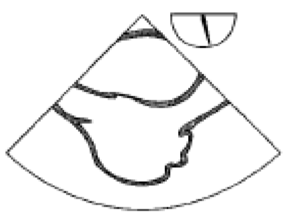
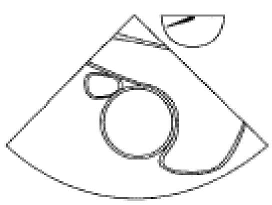
AV LAX 120-150° 	The aortic valve long axis view (AV LAX) can be obtained by starting from the AV SAX view and rotating the angle to 120-150^o. Utilize this view to examine the aortic valve movement, prolapse, restriction, calcification, and for aortic insufficiency using color flow Doppler. In addition, this view is used to measure the annulus, sinus and ascending aorta.
RV Inflow-Outflow 60-90° 	This is the right ventricle (RV) inflow-outflow view. To obtain this view, start at the four chamber view and rotate the probe to the right until the tricuspid valve (TV) is in the center of the screen. Then rotate the angle to 60-90 to see the pulmonic valve (PV) and the main pulmonary artery. The right ventricular outflow tract (RVOT) is well visualized. Utilize this view to evaluate the TV and PV
Bicaval 80-110° 	To obtain the midesophageal bicaval view, start at the four chamber view and **rotate** the probe to the right, centering on the right atrium (RA). Then increase the angle to 80-110. Utilize this view to evaluate the RA, the inferior vena cava (left) and the superior vena cava (right). This view is also useful to evaluate for atrial septal defects (ASD). A bubble study can be performed while in this view to look for the ASD.
Asc Ao SAX 0-60° 	To obtain the midesophageal ascending aortic short axis view (Asc Ao SAX), locate the ascending aorta in the center of the screen, and advance or withdraw the probe to examine different levels of the aorta. The main PA and right PA and the SVC are also visualized here.

Transesophageal Echocardiography Basic Views

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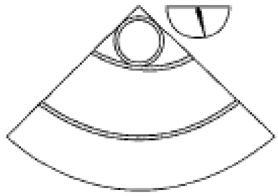
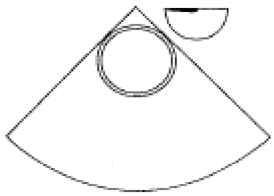
Asc Ao LAX 100-150°



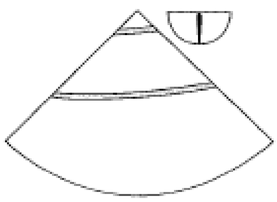
The midesophageal ascending aortic long axis view (Asc Ao LAX) is obtained by adjusting the multiplane angle to 100-150° from the Asc Ao SAX view. Utilize this view to examine the aorta in long axis as well as the right pulmonary artery in short axis.

Desc Ao SAX 0°



To obtain the descending aortic short axis view (Desc Ao SAX), begin with the four chamber view and turn the probe left ~ 90° until the aorta comes into view. The length of the thoracic aorta can be examined by advancing and withdrawing the probe.

Desc Ao LAX 90°



To obtain the descending aortic long axis view (Desc Ao LAX) start with the Desc Ao SAX view and adjust the multiplane angle to 90°. Utilize this view to complement the SAX evaluation of the descending aorta.

Transesophageal Echocardiography Basic Views

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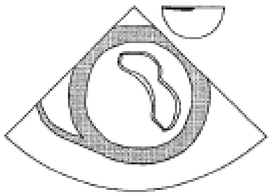
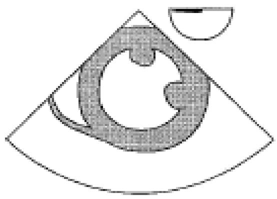
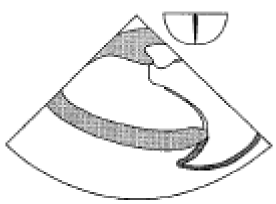
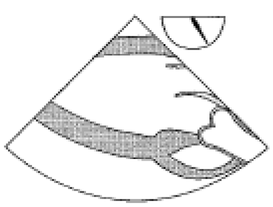
Transgastric 40-45cm

TG Basal MV SAX **0-20°** 	The transgastic views are obtained by advancing the probe into the stomach and strongly anteflexing the tip. The basal mitral valve short axis view (Basal MV SAX) is located superior / proximal to the Mid SAX view and corresponds to the basal segments of the left ventricle. Utilize this view to evaluate the MV.
TG Mid SAX **0-20°** 	The transgastric mid short axis view (TG Mid SAX) is obtained by advancing the probe from the ME plane or TG Basal view until the papillary muscles are visualized. Anteflexion is typically required. Utilize this view to evaluate global ventricular function, monitor regional wall motion abnormalities, and to assess volume status (preload) of the LV.
TG Two chamber **80-100°** 	This is the transgastric two chamber view. To obtain this view from the TG Mid SAX view, adjust the multiplane angle to between 80-100°. Utilize this view to evaluate the mitral valve, chordae tendinae, MV leaflets, along with the anterior (bottom) and inferior (top) left ventricular walls
LV long axis 90-120° 	This is the transgastric left ventricular long axis view. To obtain this view from the above image, further advance the multiplane angle to 120°. Utilize this view to evaluate the AV and LVOT, especially to take measure gradients through the AV.

Transesophageal Echocardiography Basic Views

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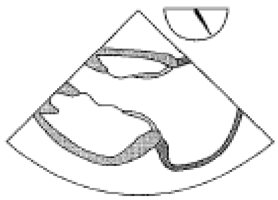
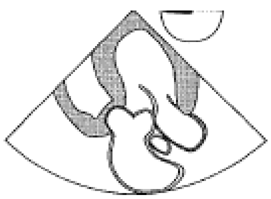
RV Inflow 100-120°



This is the right ventricular (RV) inflow view. To obtain this view rotate the probe to the right from the mid short axis view. Utilize this view to examine the right atrium, right ventricle, tricuspid valve and papillary muscle.

Deep Transgastric 45-50cm

Deep TG LAX 0-20°



This is the deep transgastric long axis view (TG LAX). To obtain this view, advance the probe deep into the stomach and maximally anteflex the probe. Then slowly withdraw the probe until it contacts the stomach wall. Utilize this view to interrogate the aortic valve and left ventricular outflow tract, again like the **LV long axis,** a useful view for the measurement of aortic valve gradients.

The twenty views above are important for every anesthesiologist to understand and be able to recognize cardiac structures. TEE is an excellent tool to evaluate cardiac function and pathology in the OR as well outside the OR.

References:

1. Marymont J, Murphy GS. Intraoperative monitoring with transesophageal echocardiography: indications, risks, and training. Anesthesiol Clin 2006;24:737-53.
2. Shanewise JS, Cheung AT, Aronson S et al. ASE/SCA guidelines for performing a comprehensive intraoperative multiplane transesophageal echocardiography 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 1999;89:870-84.