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UNIVERSITY OF TORONTO

Comprehensive TEE Exam & Introduction to Doppler Echocardiography

July 17, 2019

Department of Anesthesia and Pain Management- TGH, Toronto

EXPERT CONSENSUS STATEMENT

Basic Perioperative Transesophageal Echocardiography Examination: A Consensus Statement of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists

Scott T. Reeves, MD, FASE, Alan C. Finley, MD, Nikolaos J. Skubas, MD, FASE, Madhav Swaminathan, MD, FASE, William S. Whitley, MD, Kathryn E. Glas, MD, FASE, Rebecca T. Hahn, MD, FASE, Jack S. Shanewise, MD, FASE, Mark S. Adams, BS, RDCS, FASE, and Stanton K. Shernan, MD, FASE, for the Council on Perioperative Echocardiography of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists, *Charleston, South Carolina; New York, New York; Durham, North Carolina; Atlanta, Georgia; Boston, Massachusetts*

(J Am Soc Echocardiogr 2013;26:443-56.)

JASE May 2013

ASE GUIDELINES AND STANDARDS

Guidelines for Performing a Comprehensive Transesophageal Echocardiographic Examination: Recommendations from the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists

Rebecca T. Hahn, MD, FASE, Chair, Theodore Abraham, MD, FASE, Mark S. Adams, RDCS, FASE, Charles J. Bruce, MD, FASE, Kathryn E. Glas, MD, MBA, FASE, Roberto M. Lang, MD, FASE, Scott T. Reeves, MD, MBA, FASE, Jack S. Shanewise, MD, FASE, Samuel C. Siu, MD, FASE, William Stewart, MD, FASE, and Michael H. Picard, MD, FASE, *New York, New York; Baltimore, Maryland; Boston, Massachusetts; Rochester, Minnesota; Atlanta, Georgia; Chicago, Illinois; Charleston, South Carolina; London, Ontario, Canada; Cleveland, Ohio*

(J Am Soc Echocardiogr 2013;26:921-64.) **JASE September 2013**

GUIDELINES AND STANDARDS

Guidelines for Performing a Comprehensive Transesophageal Echocardiographic Examination in Children and All Patients with Congenital Heart Disease: Recommendations from the American Society of Echocardiography

Check for updates

Michael D. Puchalski, (Chair), MD, FASE, George K. Lui, MD, FASE, Wanda C. Miller-Hance, MD, FASE, Michael M. Brook, MD, FASE, Luciana T. Young, MD, FASE, Aarti Bhat, MD, FASE, David A. Roberson, MD, FASE, Laura Mercer-Rosa, MD, MSCE, Owen I. Miller, BMed (Hons), FRACP, David A. Parra, MD, FASE, Thomas Burch, MD, Hollie D. Carron, AAS, RDCS, ACS, FASE, and Pierre C. Wong, MD, *Salt Lake City, Utah; Stanford, San Francisco and Los Angeles, California; Houston, Texas; Seattle, Washington; Chicago, Illinois; Philadelphia, Pennsylvania; London, United Kingdom; Nashville, Tennessee; Boston, Massachusetts; and Kansas City, Missouri*

JASE February 2019

Indications of TEE

1. Diagnostic TEE: TEE performed to address a specific diagnostic question

2. Intraprocedural TEE
   a. Surgical-based procedure (Intraoperative TEE)
   b. Catheter-based procedure (Interventional TEE)

Table 4 General indications for TEE

General indication	Specific examples
1. Evaluation of cardiac and aortic structure and function in situations where the findings will alter management and TTE is non-diagnostic or TTE is deferred because there is a high probability that it will be non-diagnostic.	a. Detailed evaluation of the abnormalities in structures that are typically in the far field such as the aorta and the left atrial appendage. b. Evaluation of prosthetic heart valves. c. Evaluation of paravalvular abscesses (both native and prosthetic valves). d. Patients on ventilators. e. Patients with chest wall injuries. f. Patients with body habitus preventing adequate TTE imaging. g. Patients unable to move into left lateral decubitis position.
2. Intraoperative TEE.	a. All open heart (i.e., valvular) and thoracic aortic surgical procedures. b. Use in some coronary artery bypass graft surgeries. c. Noncardiac surgery when patients have known or suspected cardiovascular pathology which may impact outcomes.
3. Guidance of transcatheter procedures	a. Guiding management of catheter-based intracardiac procedures (including septal defect closure or atrial appendage obliteration, and transcatheter valve procedures).
4. Critically ill patients	a. Patients in whom diagnostic information is not obtainable by TTE and this information is expected to alter management.

General indications for TEE

Table 6 List of absolute and relative contraindications to transesophageal echocardiography

Absolute contraindications	Relative contraindications
• Perforated viscus • Esophageal stricture • Esophageal tumor • Esophageal perforation, laceration • Esophageal diverticulum • Active upper GI bleed	• History of radiation to neck and mediastinum • History of GI surgery • Recent upper GI bleed • Barrett's esophagus • History of dysphagia • Restriction of neck mobility (severe cervical arthritis, atlantoaxial joint disease) • Symptomatic hiatal hernia • Esophageal varices • Coagulopathy, thrombocytopenia • Active esophagitis • Active peptic ulcer disease

Absolute and relative contraindications to TEE

Table 7 List of complications reported with TEE and the incidence of these complications during diagnostic TEE and intraoperative TEE[7,24-31]

Complication	Diagnostic TEE	Intraoperative TEE
Overall complication rate	0.18-2.8% (refs 24,25)	0.2% (ref 7)
Mortality	<0.01-0.02% (refs 24,25,27)	0% (ref 7)
Major morbidity	0.2% (ref 27)	0-1.2% (refs 7,28,29)
Major bleeding	<0.01% (ref 24)	0.03-0.8% (refs 7,28)
Esophageal perforation	<0.01 (ref 24)	0-0.3% (refs 7,28,29)
Heart failure	0.05% (ref 28)	
Arrhythmia	0.06-0.3% (refs 7,28,30)	
Tracheal intubation	0.02% (ref 30)	
Endotracheal tube malposition		0.03% (ref 7)
Laryngospasm	0.14% (ref 27)	
Bronchospasm	0.06-0.07% (refs 24,30)	
Dysphagia	1.8 % (ref 31)	
Minor pharyngeal bleeding	0.01-0.2% (refs 24,25,27)	0.01% (ref 7)
Severe odynophagia		0.1% (ref 7)
Hoarseness	12% (ref 31)	
Lip injury	13% (ref 31)	
Dental injury	0.1% (ref 31)	0.03% (ref 7)

Complications reported with TEE and intraoperative TEE

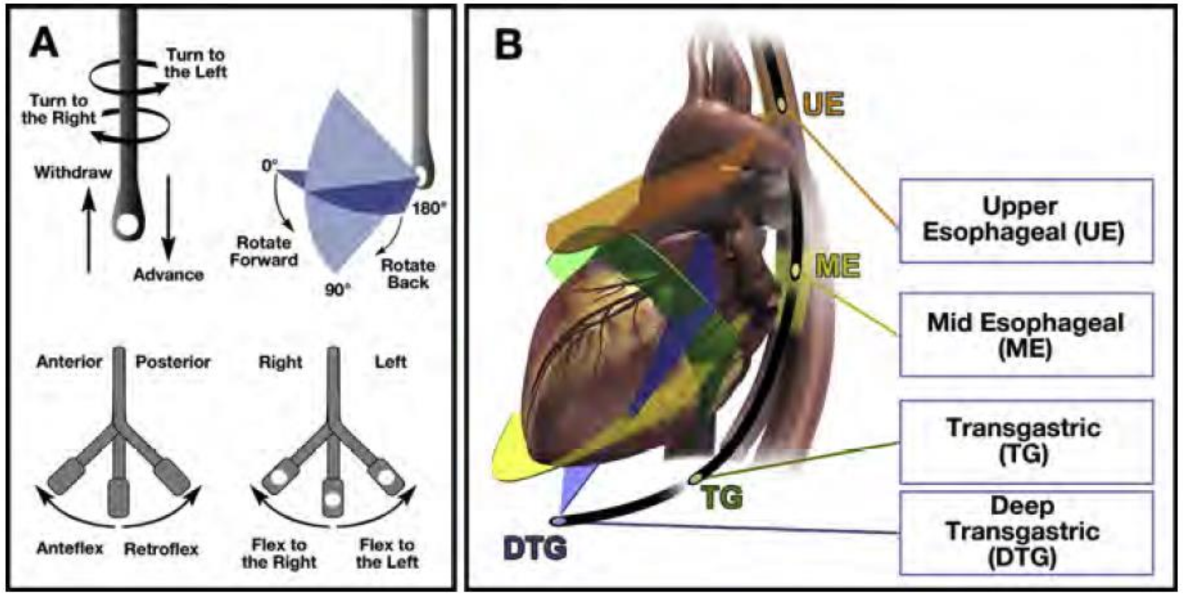
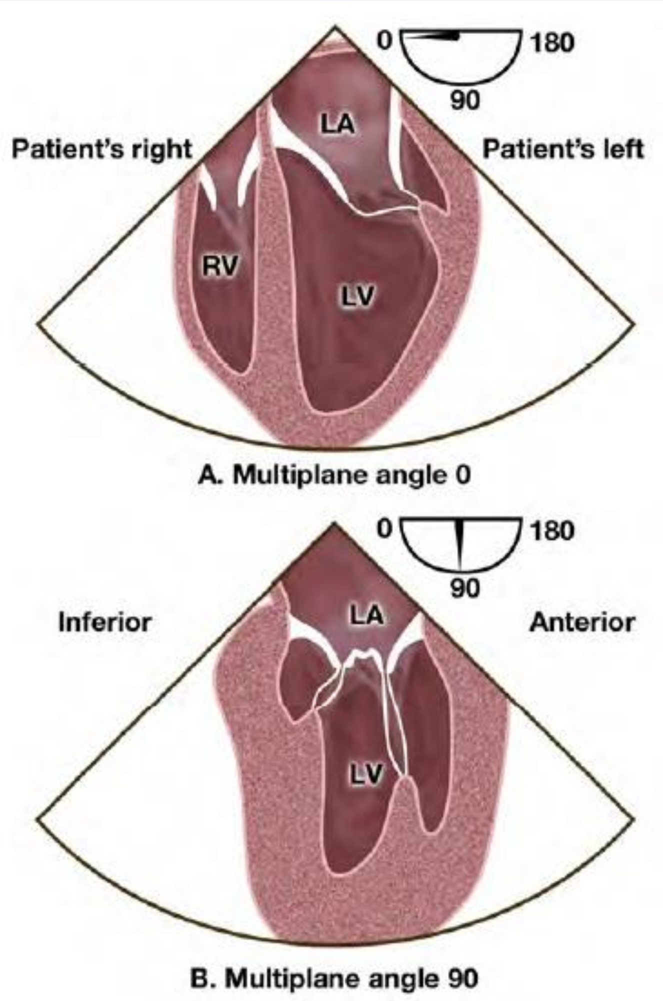


Figure 1 Terminology used to describe manipulation of the transesophageal echocardiographic probe during image acquisition. **(A)** Terminology used for the manipulation of the transesophageal echocardiographic probe. **(B)** Four standard transducer positions within the esophagus and stomach and the associated imaging planes.

Terminology in manipulation of TEE probe



Conventions of TEE image display

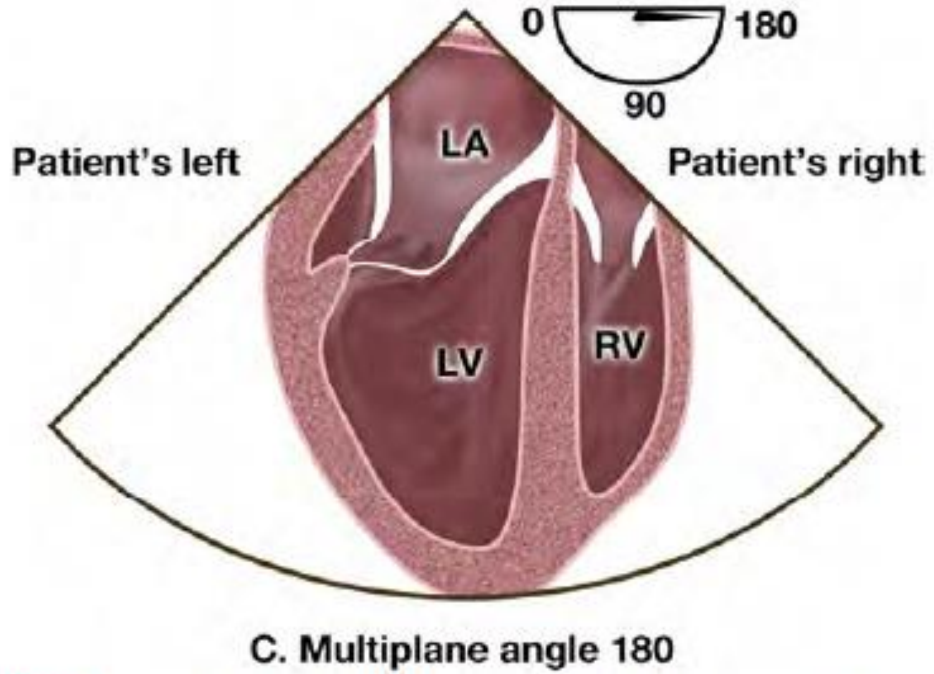
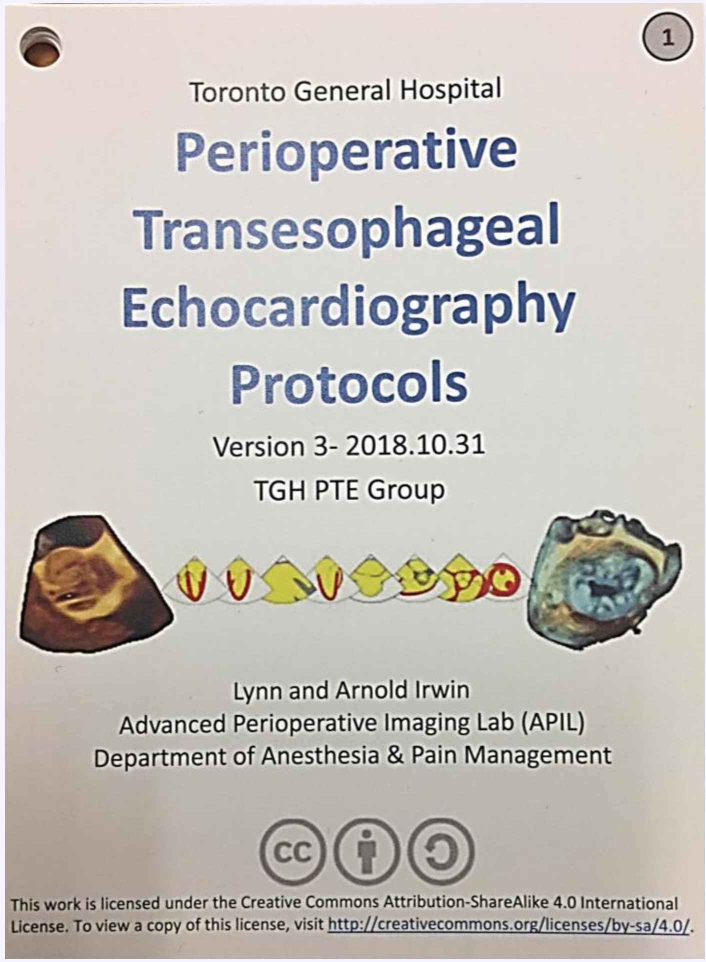
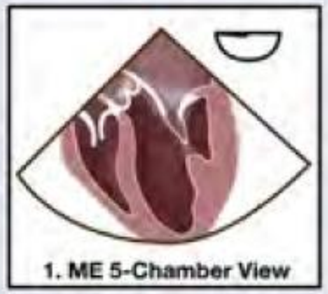
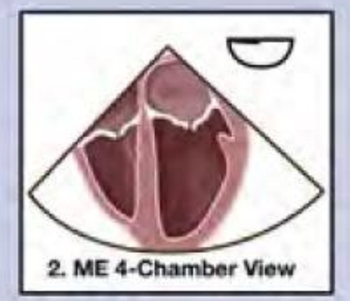


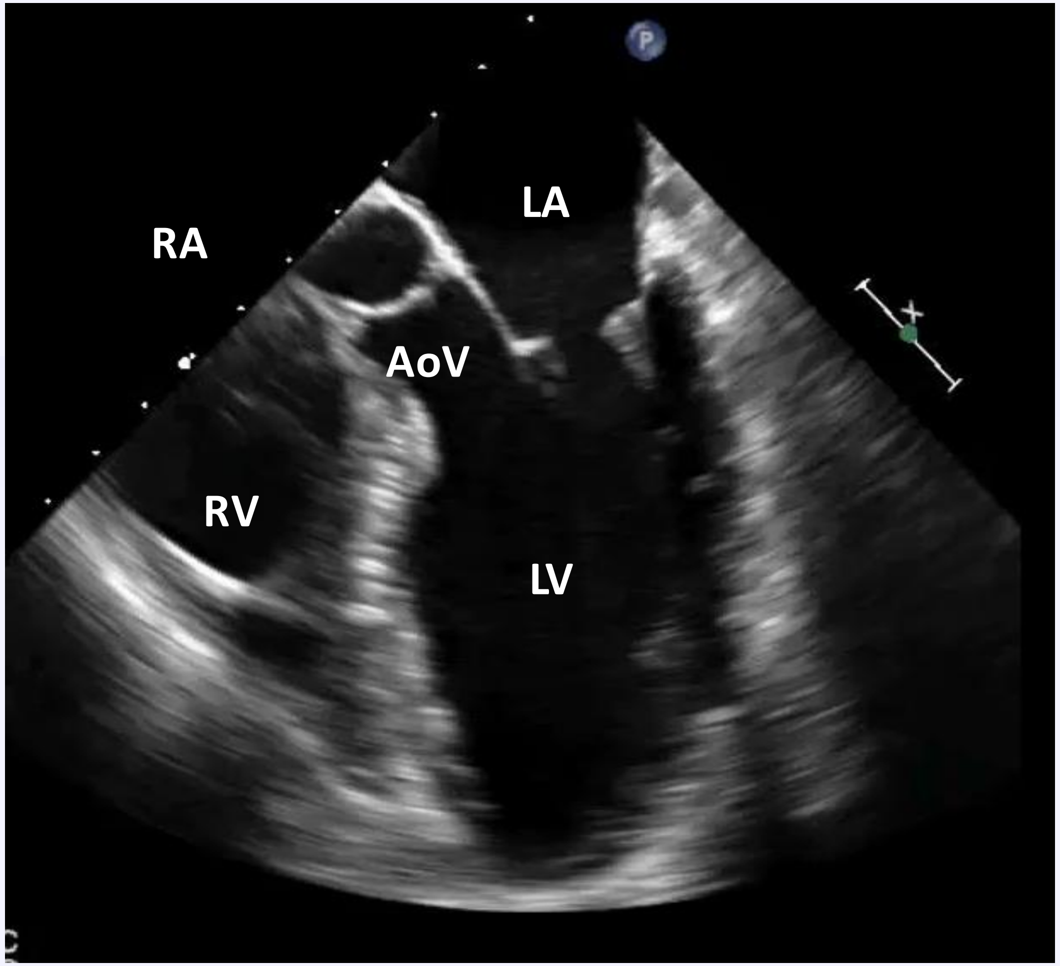
Figure 2 Conventions of 2D transesophageal echocardiographic image display. The transducer location and the near field (vertex) of the image sector are at the top of the display screen and far field at the bottom. **(A)** Image orientation at transducer angle 0°. **(B)** Image orientation at transducer angle 90°. **(C)** Image orientation at transducer angle 180°. *LA*, Left atrium; *LV*, left ventricle; *RV*, right ventricle. Modified from Shanewise *et al.*[6]

Conventions of TEE image display

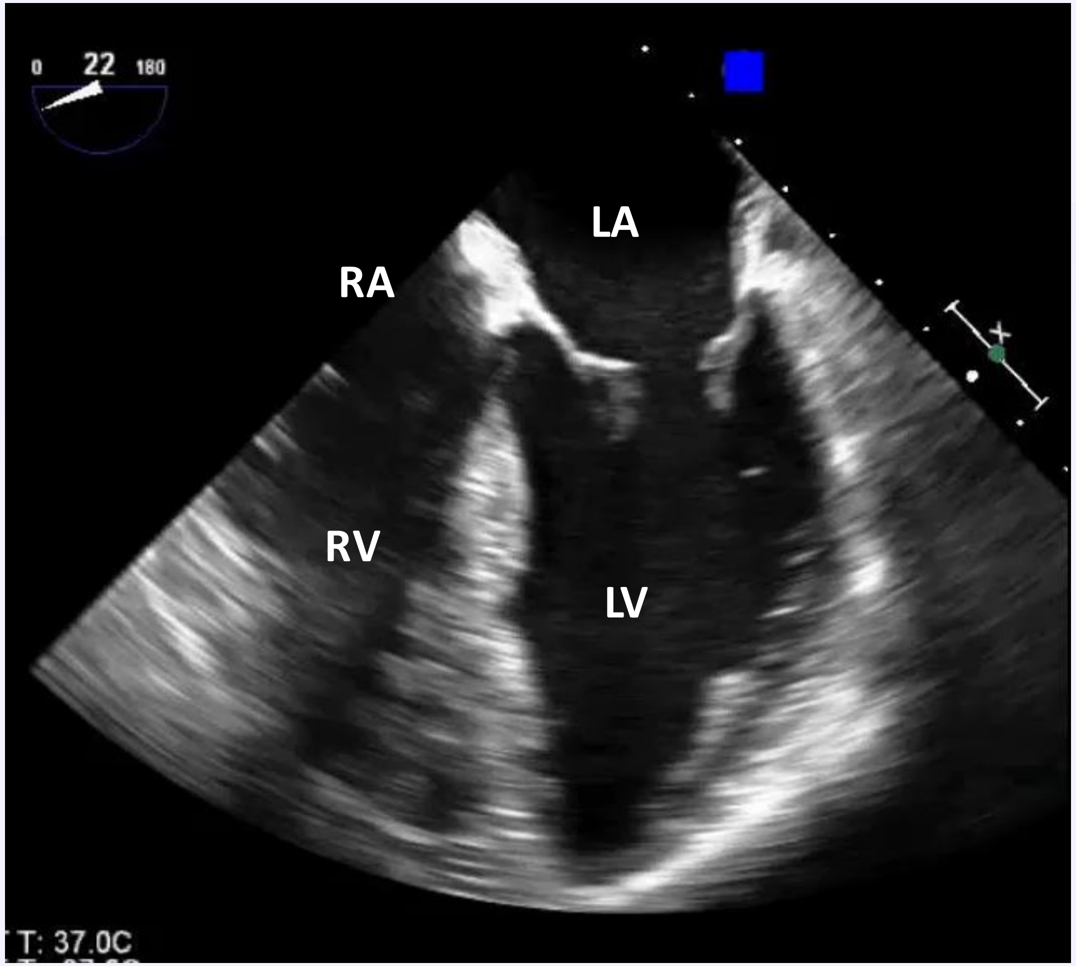
Table 10 Comprehensive transesophageal echocardiographic examination. The table lists the suggested 28 views included in a comprehensive transesophageal echocardiographic examination. Each view is shown as a 3D image, the corresponding imaging plane, and a 2D image. The acquisition protocol and the structures imaged in each view are listed in the subsequent columns



Imaging Plane	3D Model	2D TEE Image	Acquisition Protocol	Structures Imaged
Midesophageal Views				
			**Transducer Angle:** ~ 0 - 10^0 **Level:** Mid-esophageal **Maneuver** (from prior image): NA	Aortic valve LVOT Left atrium/Right atrium Left ventricle/Right ventricle/IVS Mitral valve (A_2A_1-P_1) Tricuspid valve
			**Transducer Angle:** ~ 0 - 10^0 **Level:** Mid-esophageal **Maneuver** (from prior image): Advance ± Retroflex	Left atrium/Right atrium IAS Left ventricle/Right ventricle/IVS Mitral valve (A_3A_2-P_2P_1) Tricuspid valve

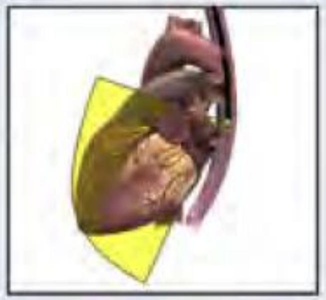


1- ME 5-Chamber View



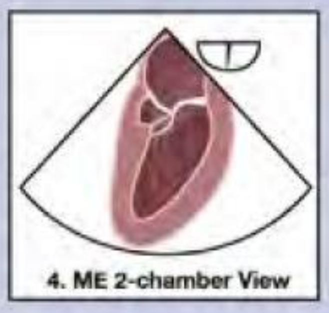
2- ME 4-Chamber View


3. ME Mitral Commissural View



Transducer Angle:
~ 50 - 70^{0}
Level: Mid-esophageal
Maneuver (from prior image): NA

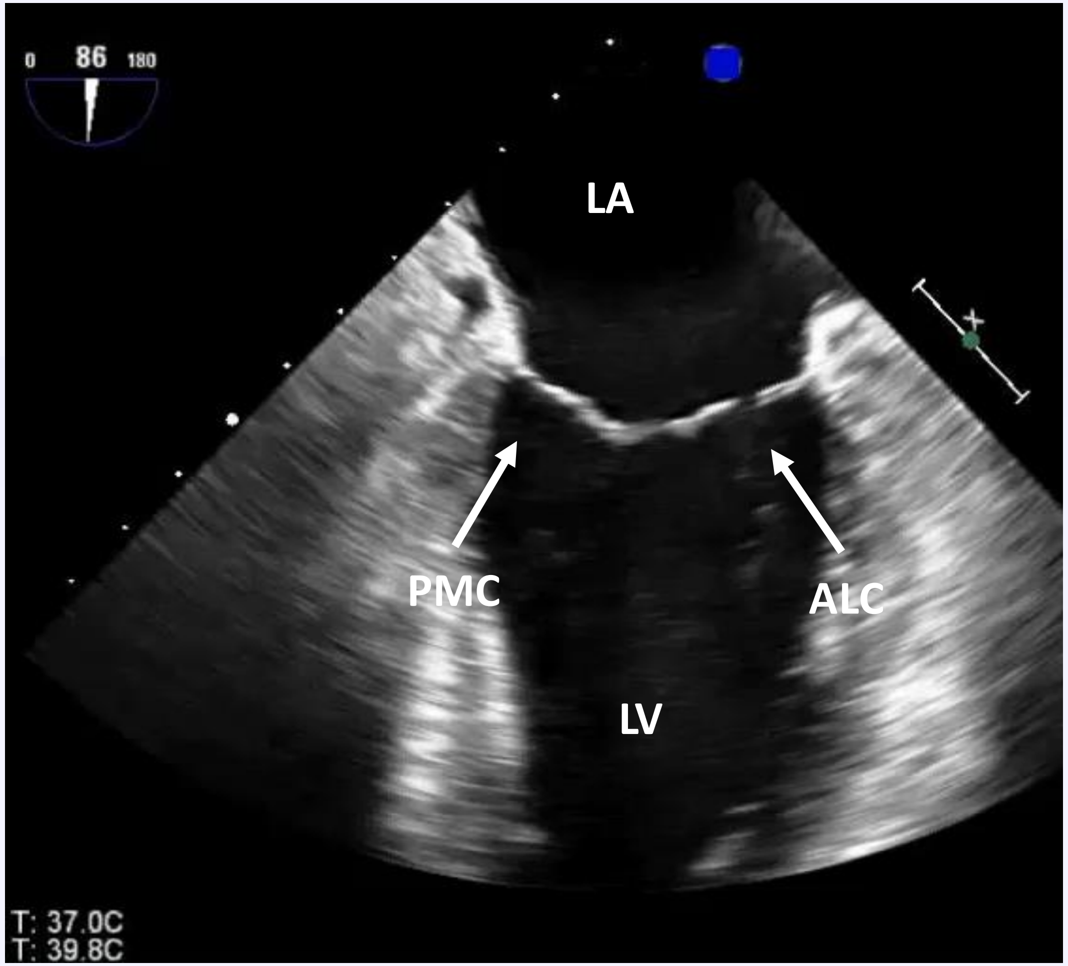
Left atrium
Coronary Sinus
Left ventricle
Mitral Valve (P_3- $A_3A_2A_1$ - P_1)
Papillary muscles
Chordae tendinae

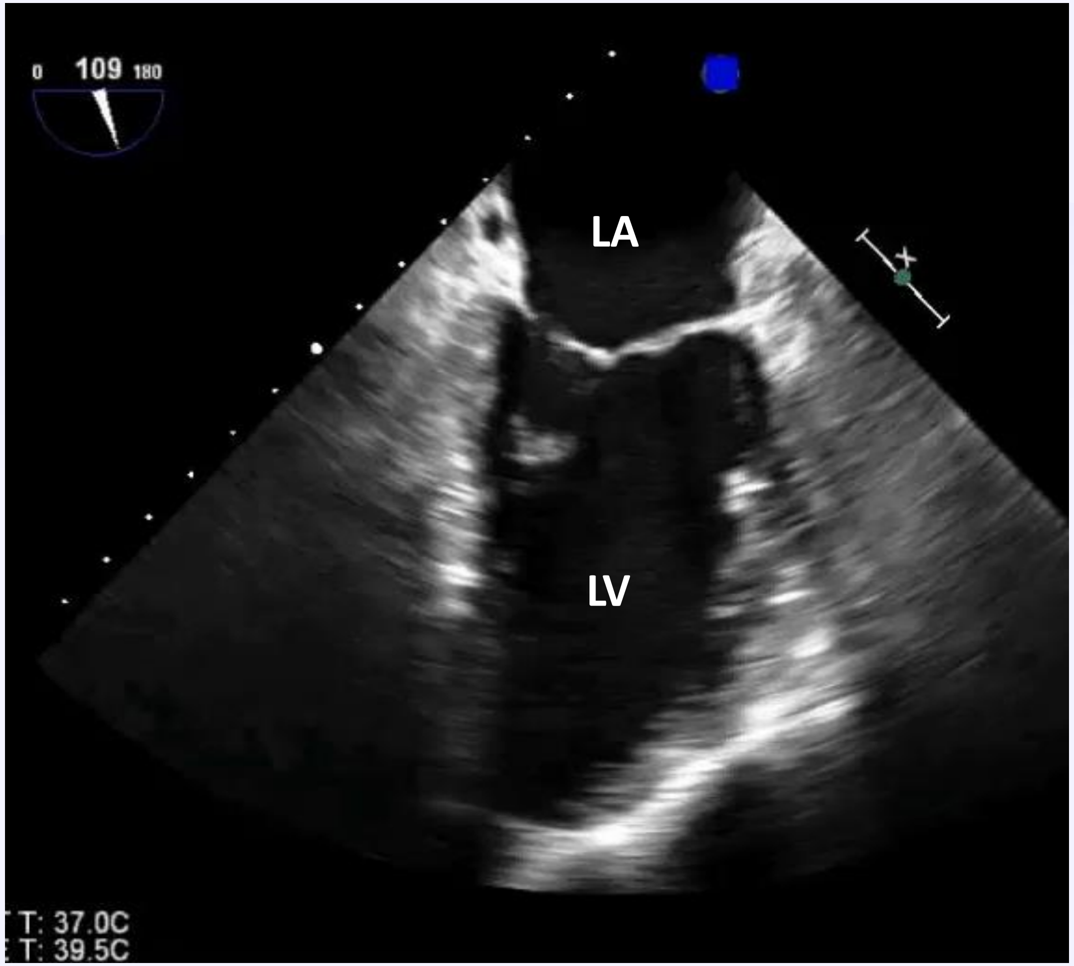

4. ME 2-chamber View

Transducer Angle:
~ 80 - 100^{0}
Level: Mid-esophageal
Maneuver (from prior image): NA

Left atrium
Coronary sinus
Left atrial appendage
Left ventricle
Mitral valve (P_3- $A_3A_2A_1$)

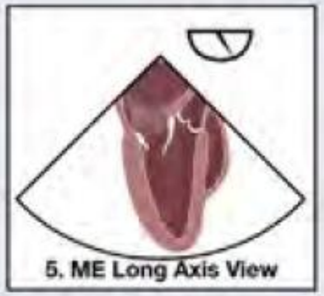
Correction: LAA?



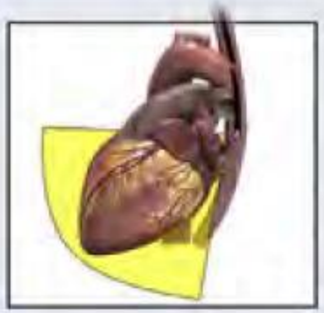


3- ME Mitral Commissural View

4- ME 2-Chamber View



5. ME Long Axis View



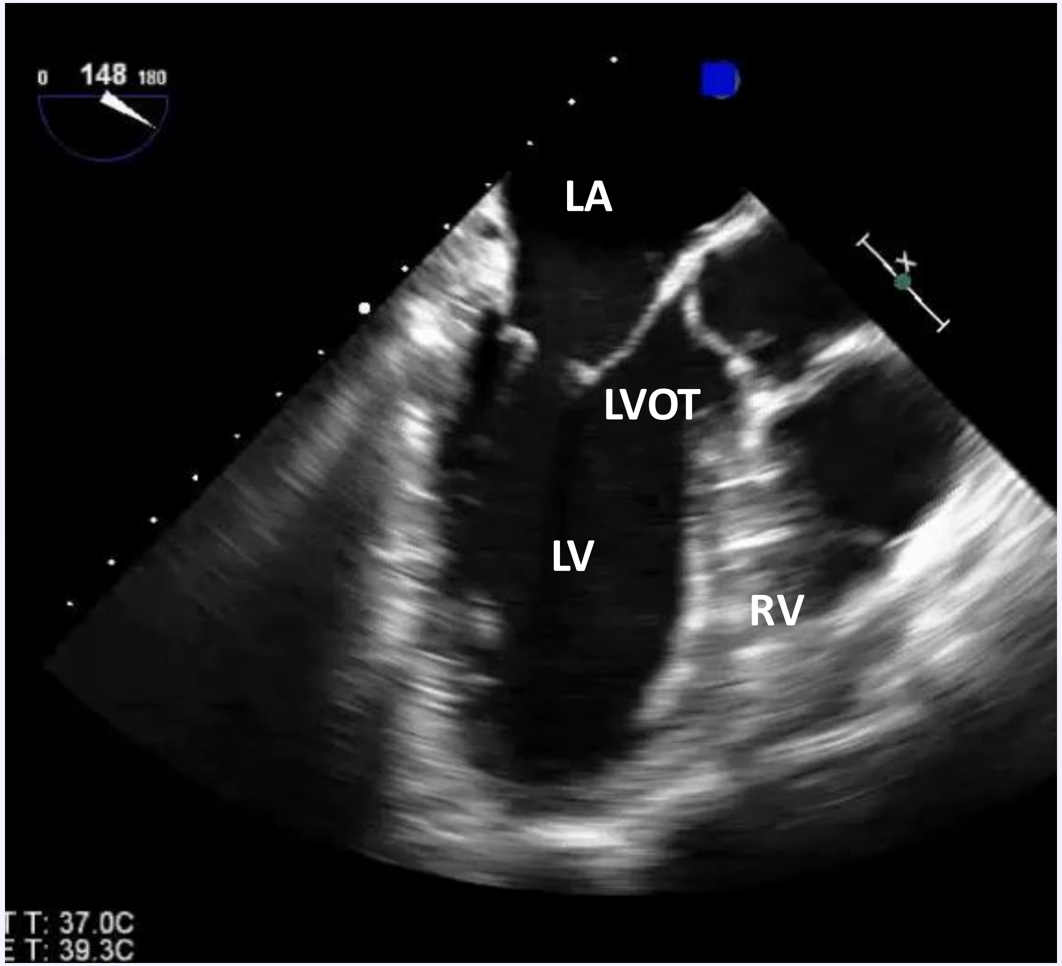
Transducer Angle: ~ 120 - 140^0
Level: Mid-esophageal
Maneuver (from prior image): NA

Left atrium
Left ventricle
LVOT
RVOT
Mitral valve (P_2- A_2)
Aortic valve
Proximal ascending aorta

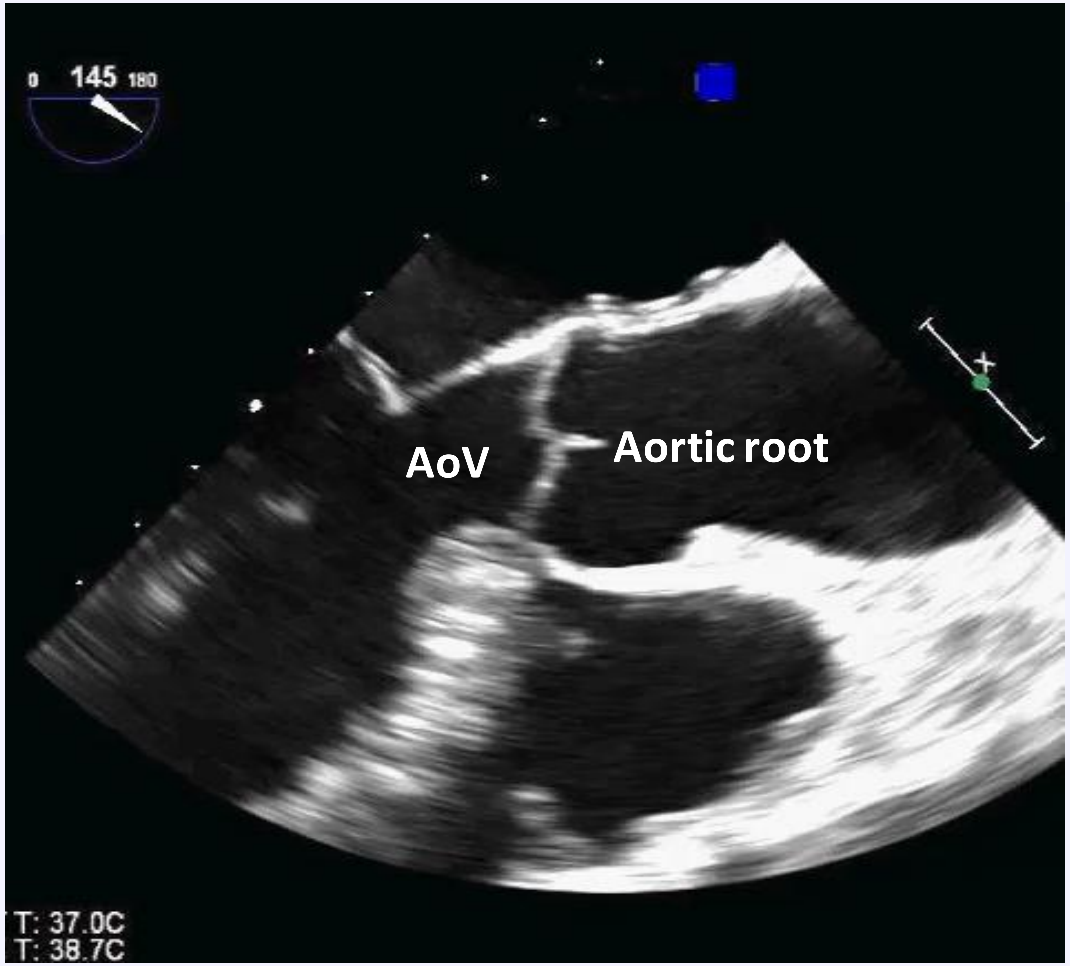
6. ME AV LAX View

Transducer Angle: ~ 120 - 140^0
Level: Mid-esophageal
Maneuver (from prior image): Withdrawl ± anteflex

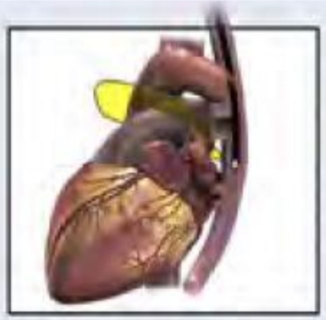
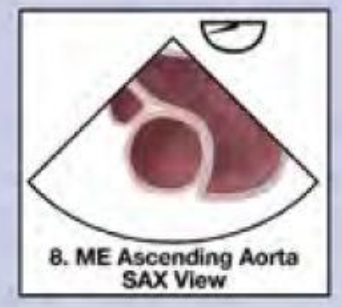
Left atrium
LVOT
RVOT
Mitral valve (A_2- P_2)
Aortic valve
Proximal ascending aorta



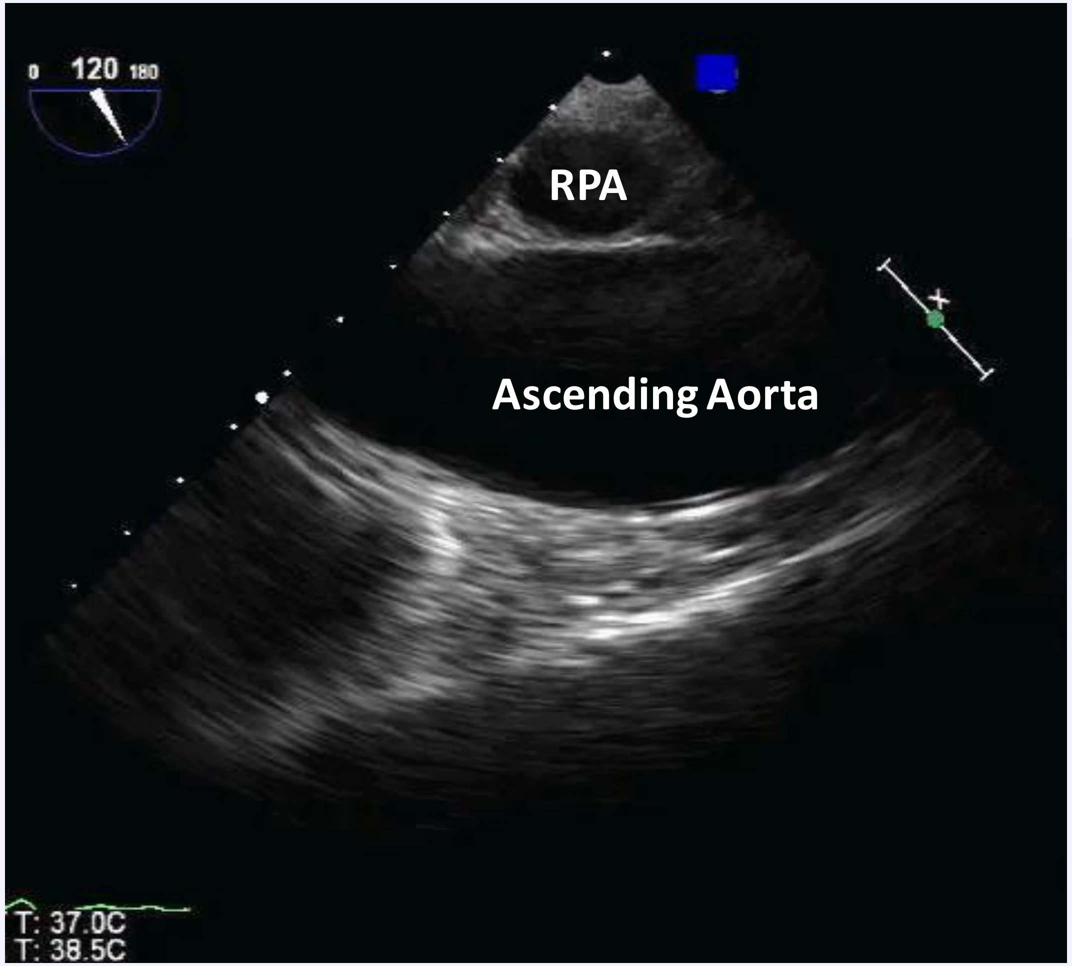
5- ME Long Axis View



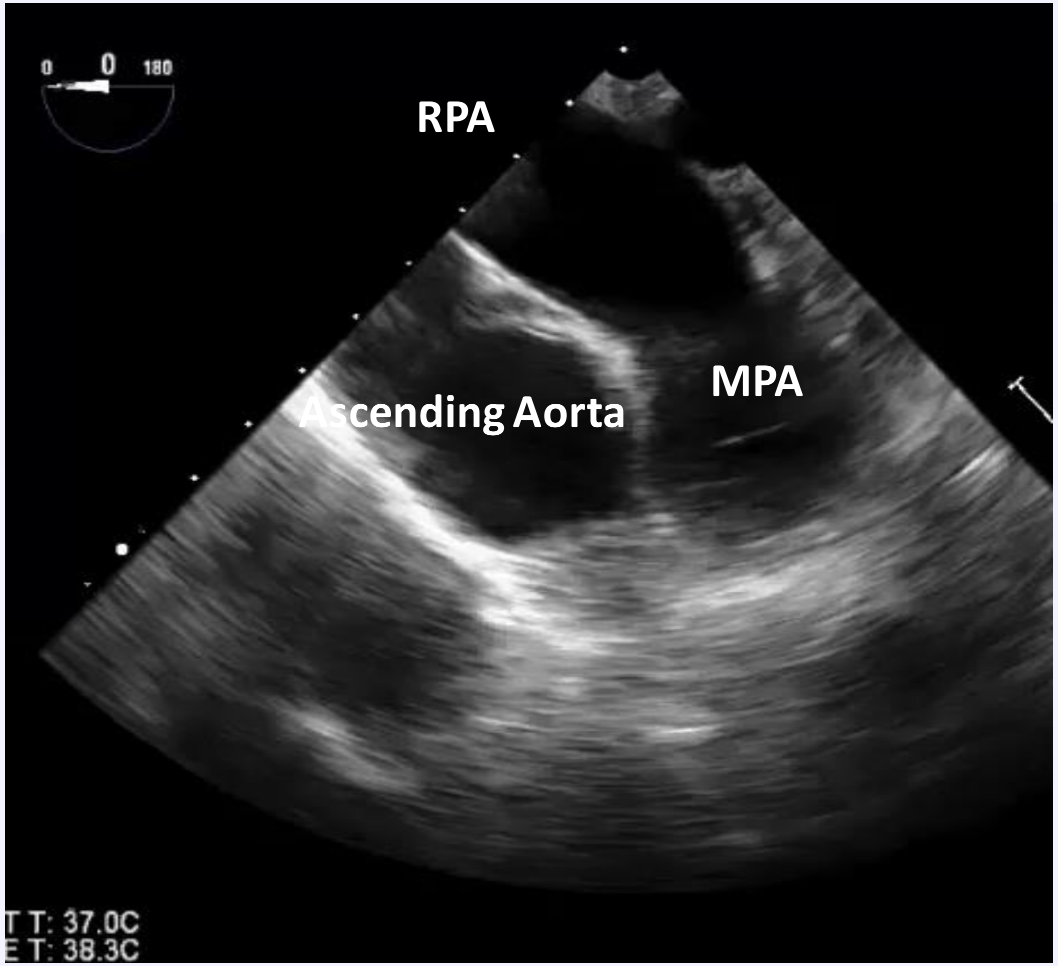
6- ME AV LAX View

			**Transducer Angle:** ~ 90 - 110^0 **Level:** Upper-Esophageal **Maneuver** (from prior image): Withdrawl	Mid-ascending aorta Right pulmonary artery
			**Transducer Angle:** ~ 0 - 30^0 **Level:** Upper-Esophageal **Maneuver** (from prior image): CW	Mid-ascending aorta (SAX) Main/bifurcation pulmonary artery Superior vena cava

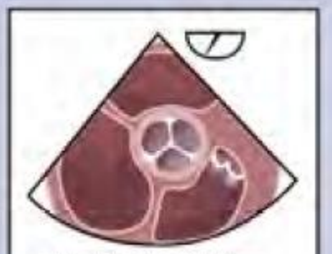
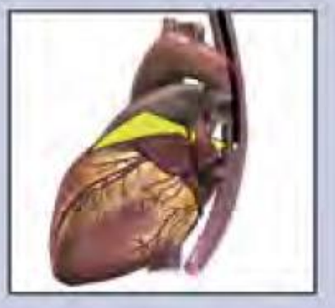
CW= Clockwise rotation of the probe



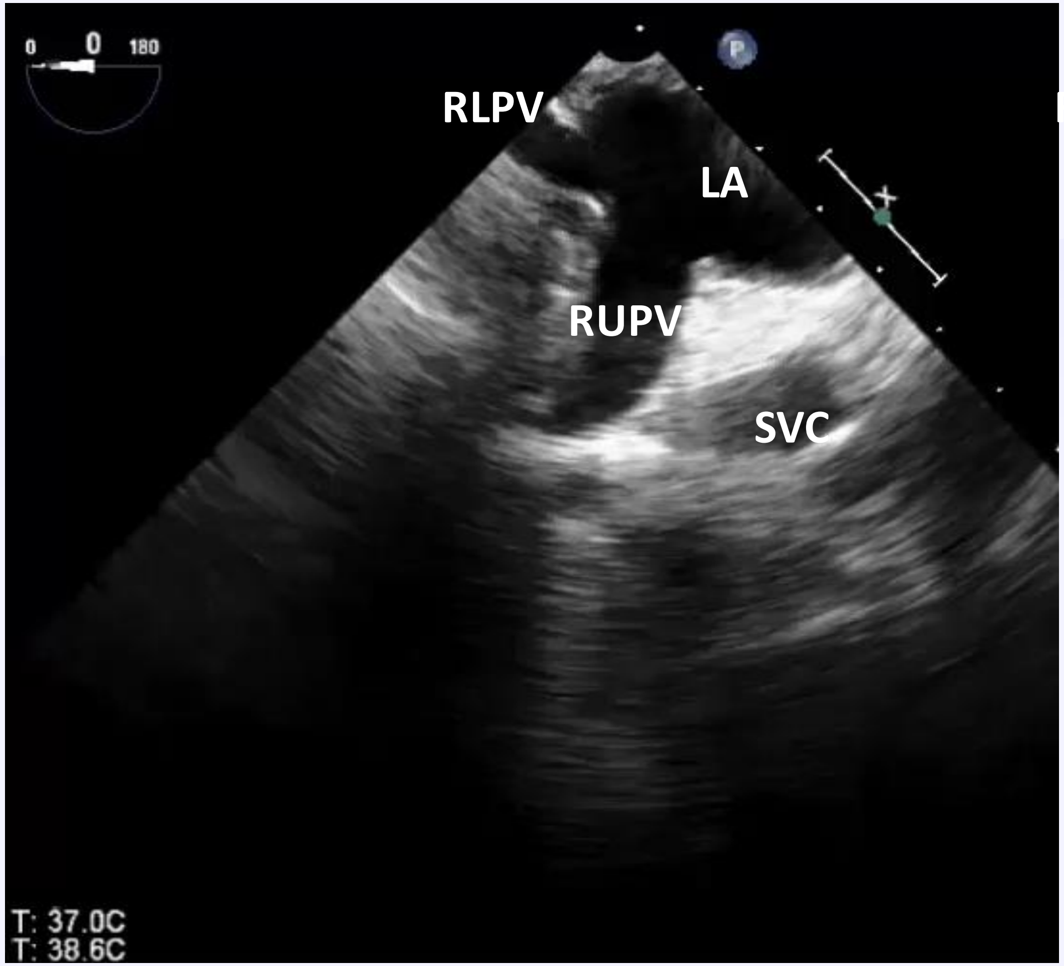
7- ME Ascending Aorta LAX View



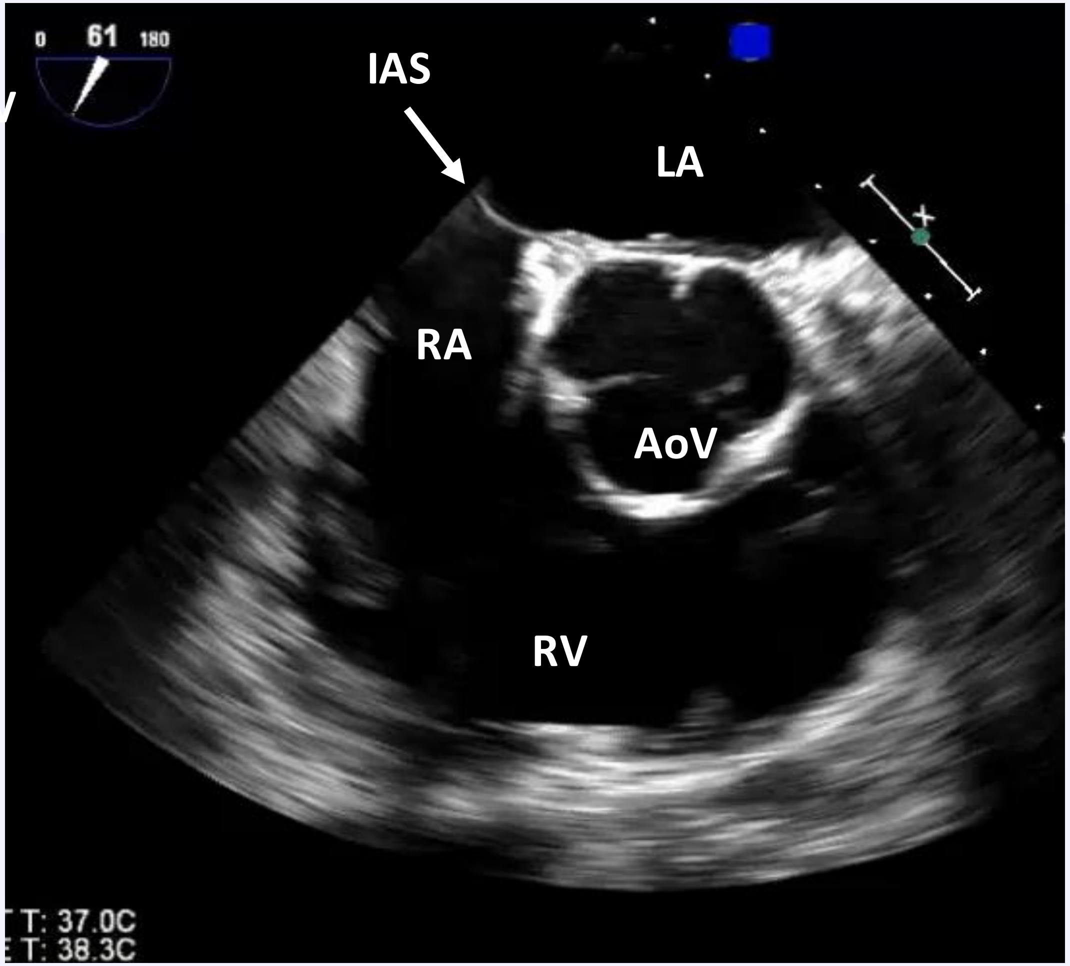
8- ME Ascending Aorta SAX View

 9. ME Right Pulmonary Vein View			**Transducer Angle:** ~ 0 - 30^0 **Level:** Upper-esophageal **Maneuver** (from prior image): CW, Advance	Mid-ascending aorta Superior vena cava Right pulmonary veins
 10. ME AV SAX View			**Transducer Angle:** ~ 25 - 45^0 **Level:** Mid-esophageal **Maneuver** (from prior image): CCW, Advance, Anteflex	Aortic valve Right atrium Left atrium Superior IAS RVOT Pulmonary Valve

CW = Clockwise rotation
CCW= Counterclockwise rotation of the probe



9- ME Right Pulmonary Veins View



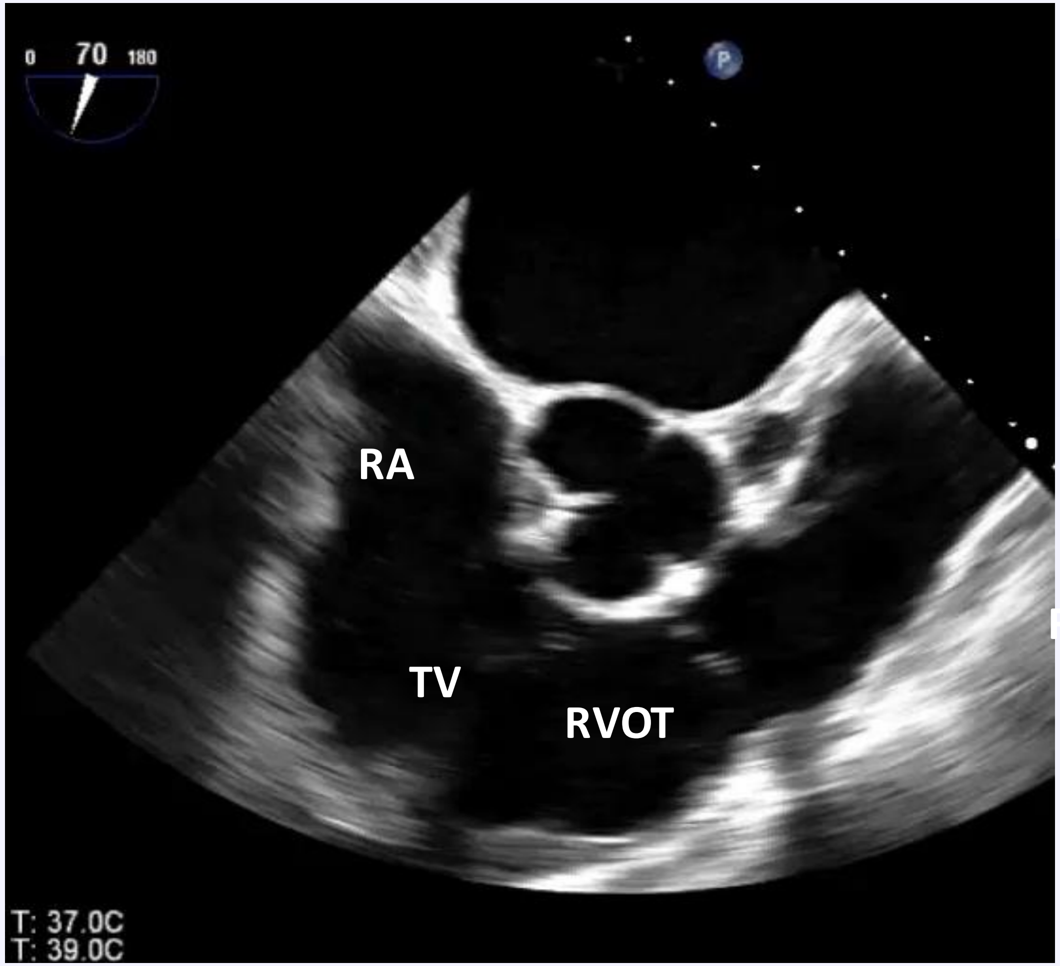
10- ME AV SAX View

Transducer Angle: ~ 50 - 70^0
Level: Mid-esophageal
Maneuver (from prior image): CW, Advance

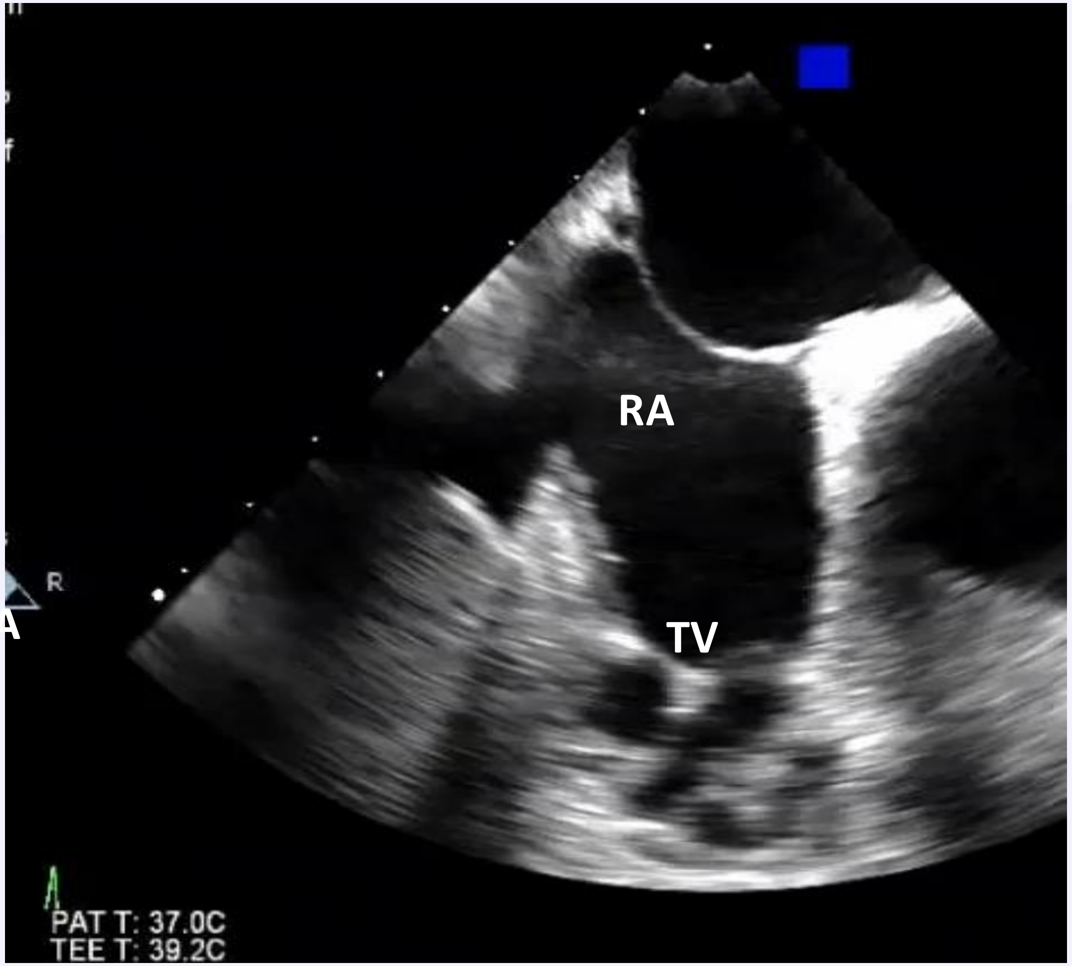
Aortic valve
Right atrium
Left atrium
Superior IAS
Tricuspid Valve
RVOT
Pulmonary Valve

Transducer Angle: ~ 50 - 70^0
Level: Mid-esophageal
Maneuver (from prior image): CW

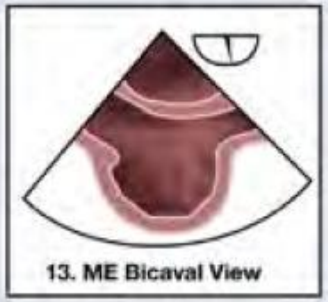
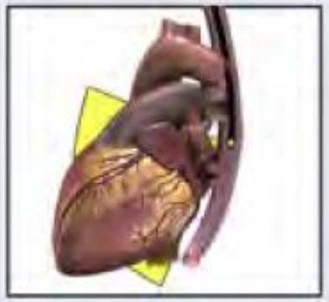
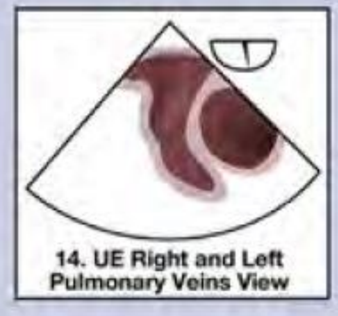
Right atrium
Left atrium
Mid-IAS
Tricuspid Valve
Superior vena cava
Inferior vena cava/coronary sinus



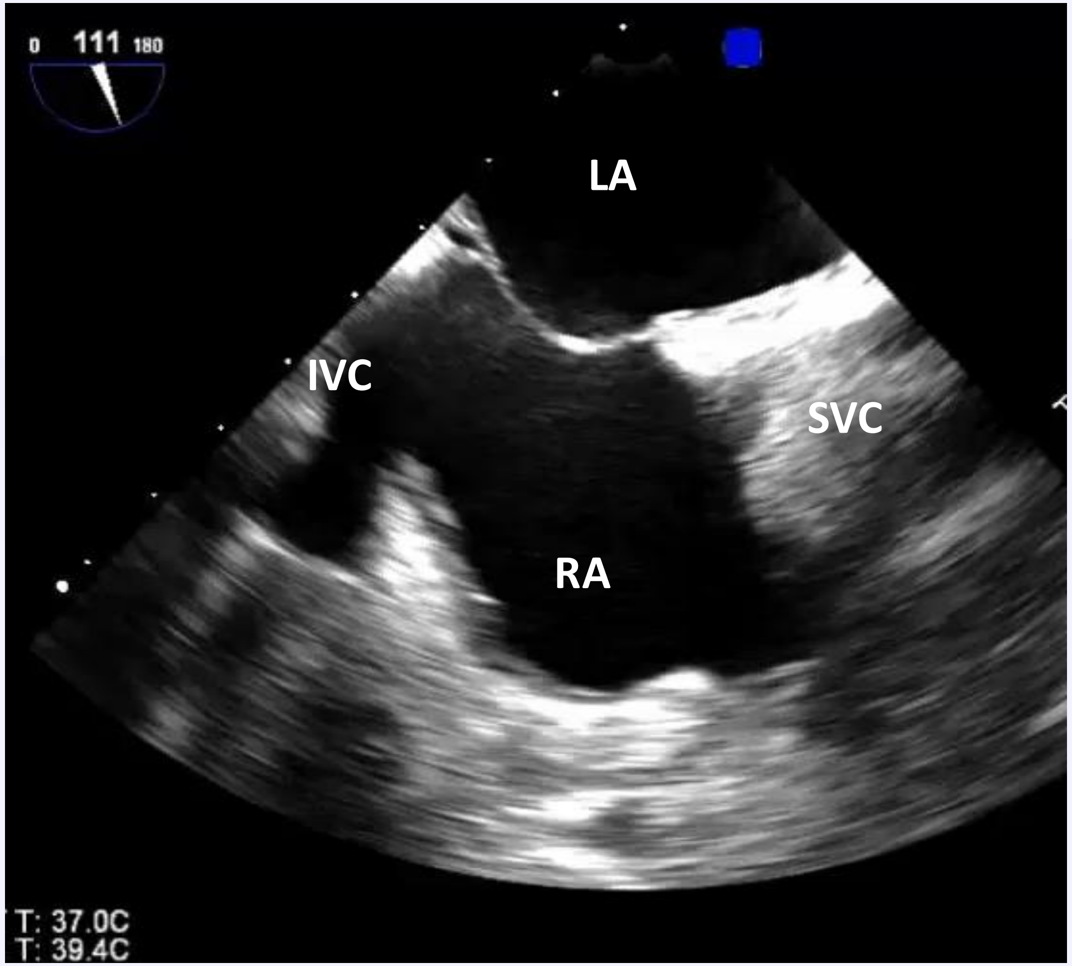
11- ME RV Inflow-Outflow View



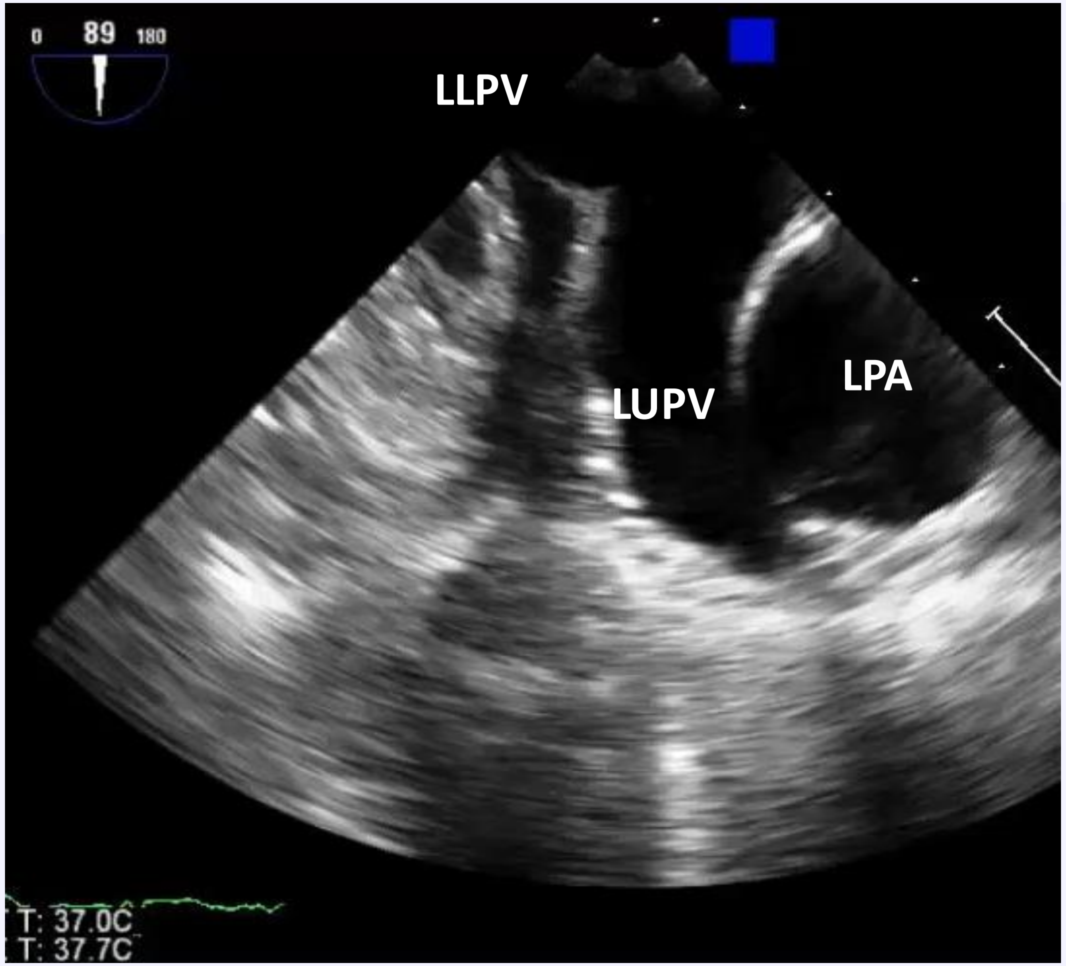
12- ME Modified Bicaval TV View

			**Transducer Angle:** ~90 - 110^{0} Level: Mid-esophageal **Maneuver** (from prior image): CW	Left atrium Right atrium/appendage IAS Superior vena cava Inferior vena cava
			**Transducer Angle:** ~ 90 - 110^{0} **Level:** Upper-esophageal **Maneuver** (from prior image): Withdraw, CW for the right veins, CCW for the left veins	Pulmonary vein (upper and lower) Pulmonary artery

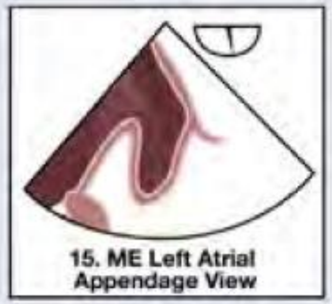
Correction: 14- ME Left Pulmonary Veins View



13- ME Bicaval View



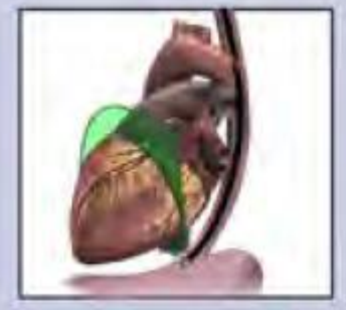
14- ME Left Pulmonary Veins View



Transducer Angle: ~90 - 110°
Level: Mid-esophageal
Maneuver (from prior image): Advance

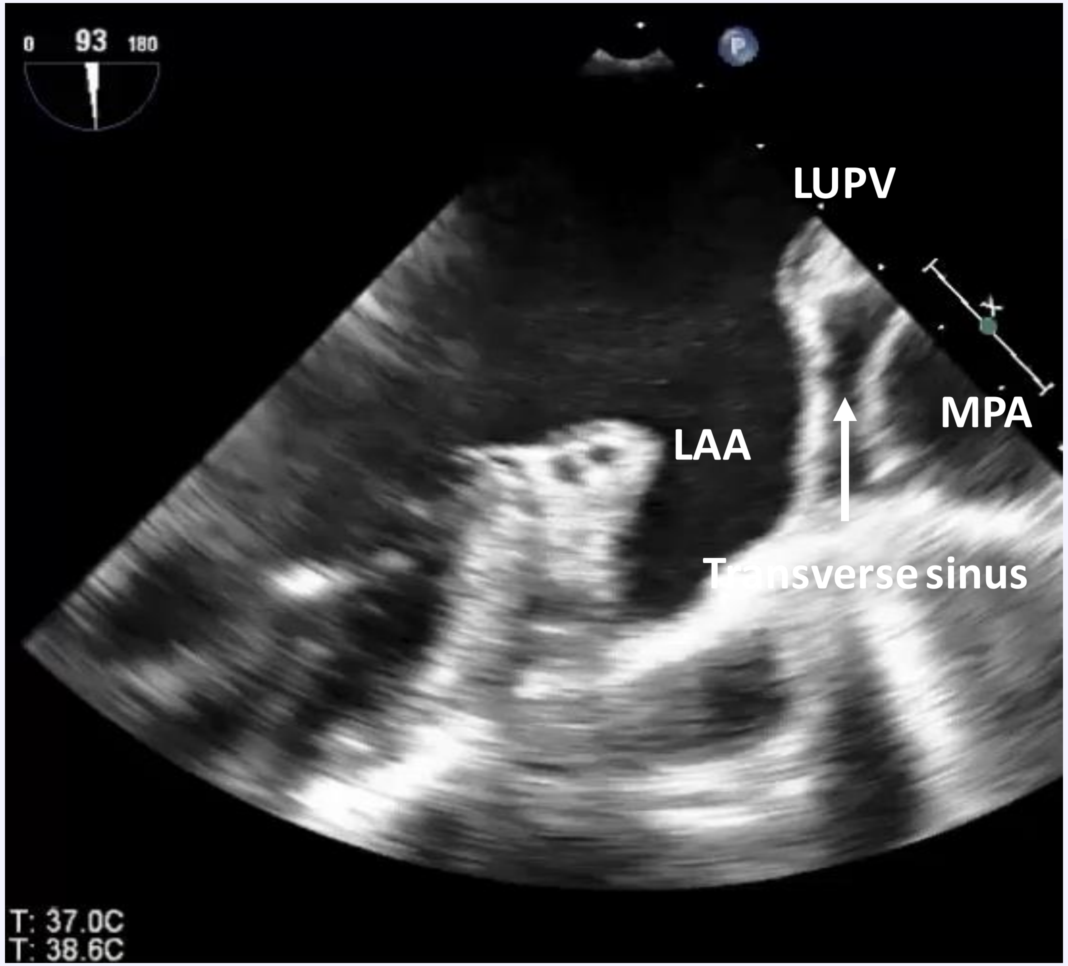
Left atrial appendage
Left upper pulmonary vein

Transgastric Views

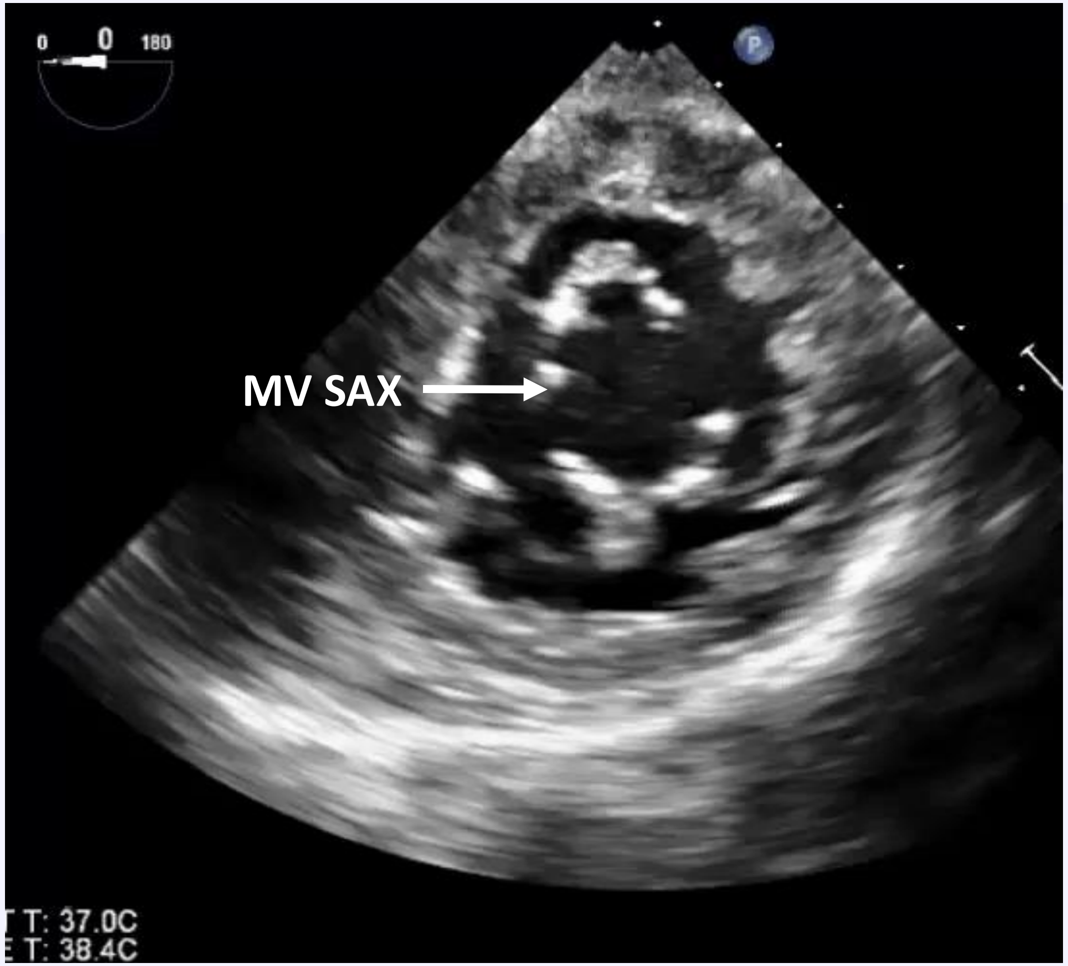


Transducer Angle: ~ 0 - 20°
Level: Transgastric
Maneuver (from prior image): Advance ± Anteflex

Left ventricle (base)
Right ventricle (base)
Mitral valve (SAX)
Tricuspid valve (short-axis)



15- ME Left Atrial Appendage View



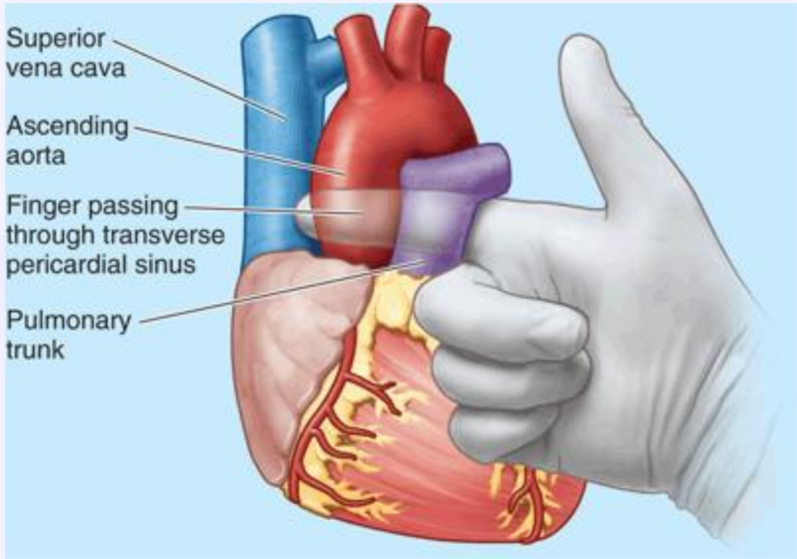
16- TG Basal SAX View

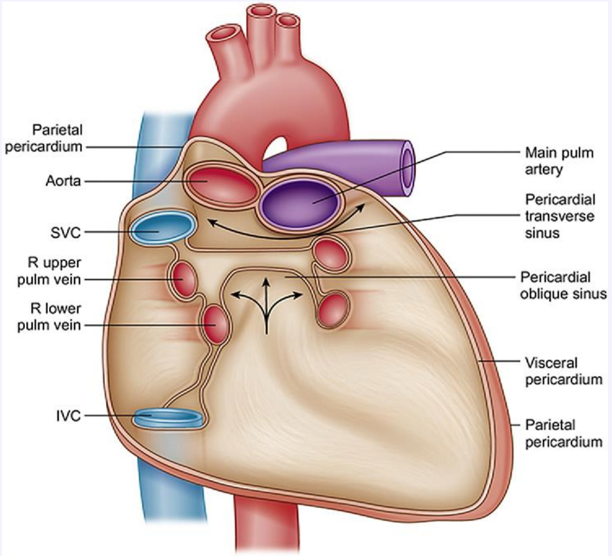
Sinuses of pericardium

- 2 sinuses in the serous pericardium are formed during development of the heart (Transverse & Oblique)

• Transverse sinus

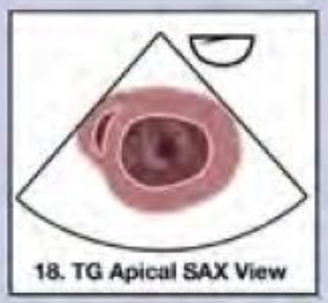
- A recess behind pulmonary trunk & ascending aorta
- <u>Boundaries:</u>
- **Ant:** Pulmonary trunk & ascending aorta.
- **Post**: SVC &Upper part of the 2 atria
- **Above:** Rt. Pulmonary artery
- **Below**: the 2 atria mainly Lt.





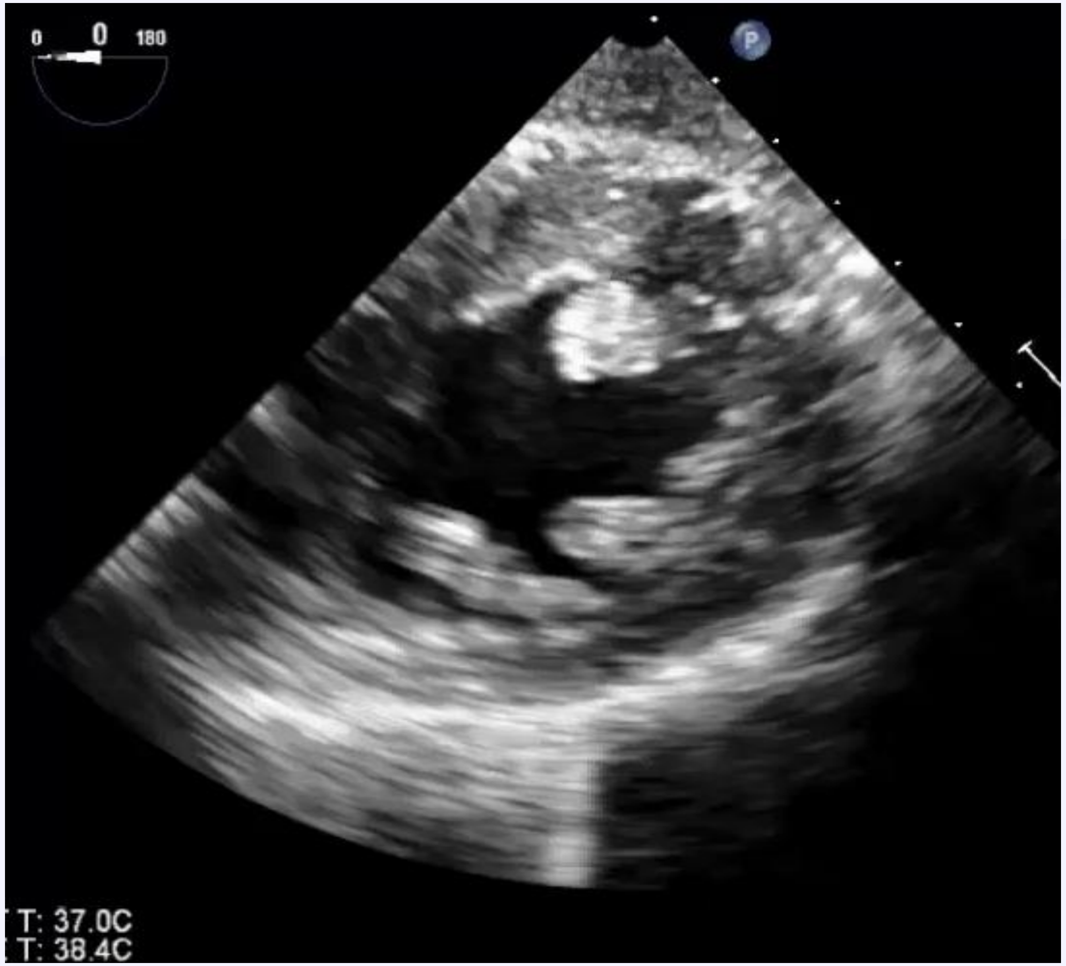
Transducer Angle:
~ $0 - 20^0$
Level: Transgastric
Maneuver (from prior image): Advance ± Anteflex

Left ventricle (mid)
Papillary muscles
Right ventricle (mid)



Transducer Angle:
~ $0 - 20^0$
Level: Transgastric
Maneuver (from prior image): Advance ± Anteflex

Left ventricle (apex)
Right ventricle (apex)



17- TG Mid Papillary SAX View

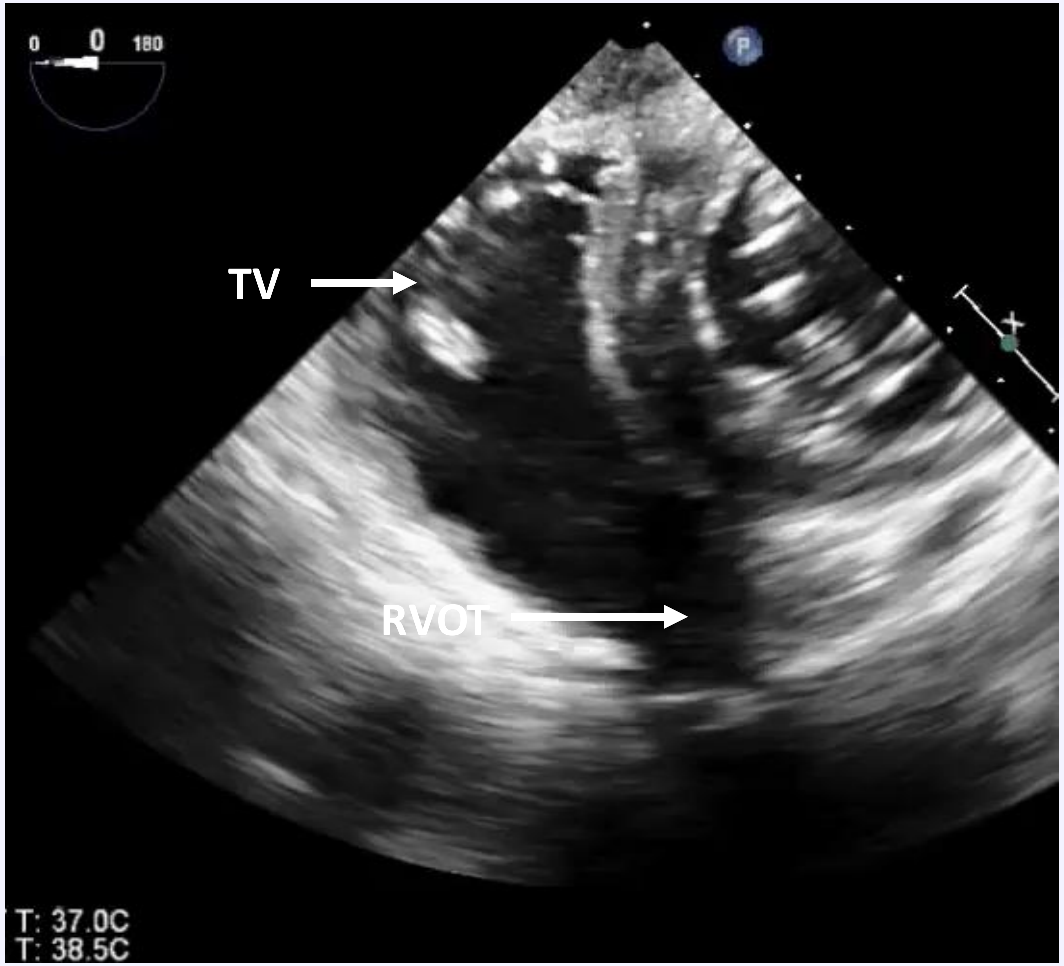
18- TG Apical SAX View

Transducer Angle: ~ 0 - 20^0
Level: Transgastric
Maneuver (from prior image): Anteflex

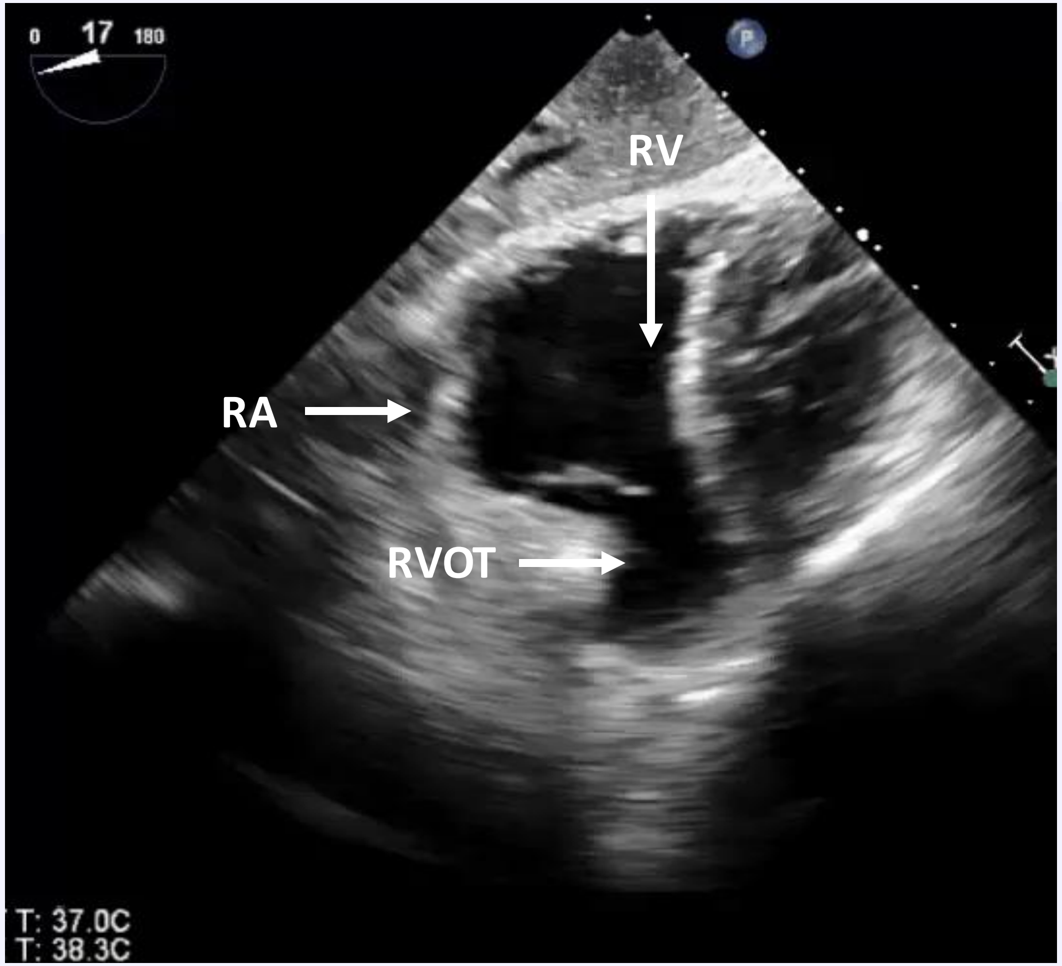
Left ventricle (mid)
Right ventricle (mid)
Right ventricular outflow tract
Tricuspid Valve (SAX)
Pulmonary Valve

Transducer Angle: ~ 0 - 20^0
Level: Transgastric
Maneuver (from prior image): Right-flex

Right atrium
Right ventricle
Right ventricular outflow tract
Pulmonary valve
Tricuspid Valve



19- TG RV Basal View



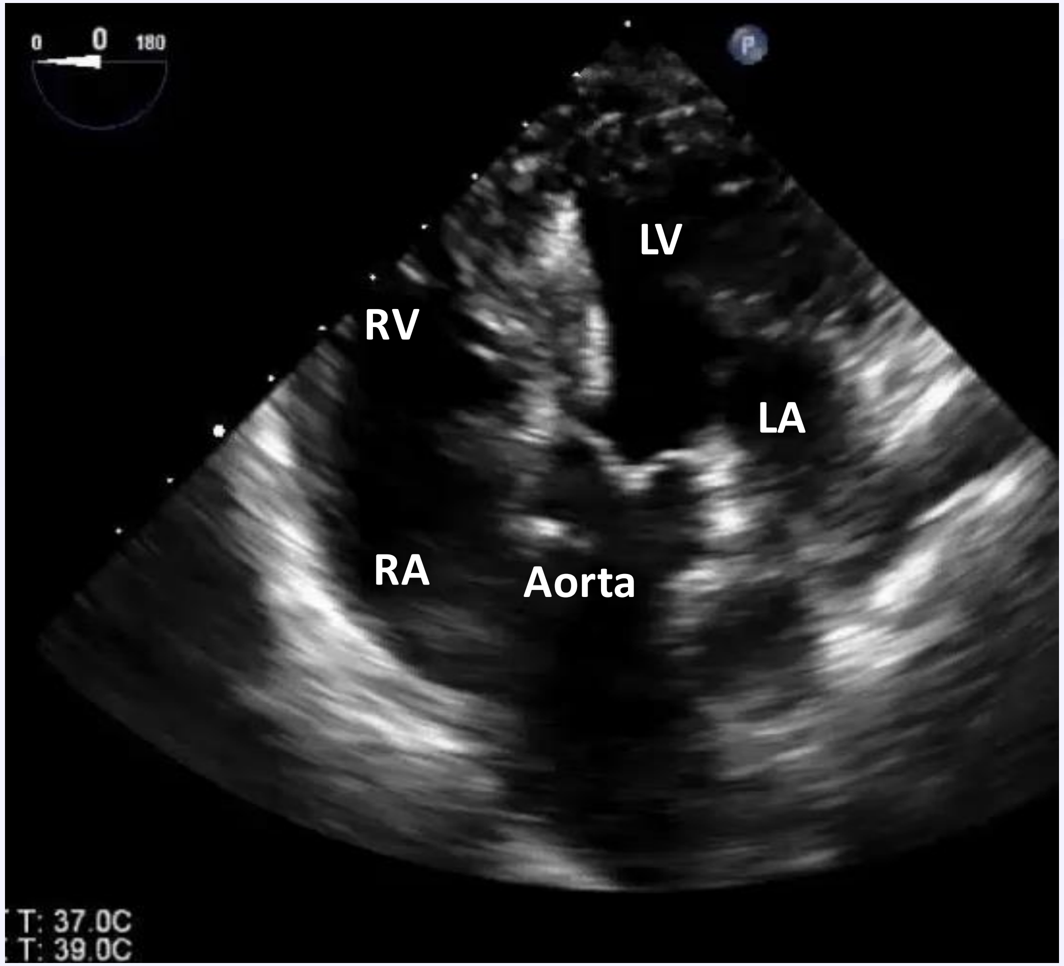
20- TG RV Inflow-Outflow View

Transducer Angle: ~ 0 - 20⁰
Level: Transgastric
Maneuver (from prior image): Left-flex, Advance, Anteflex

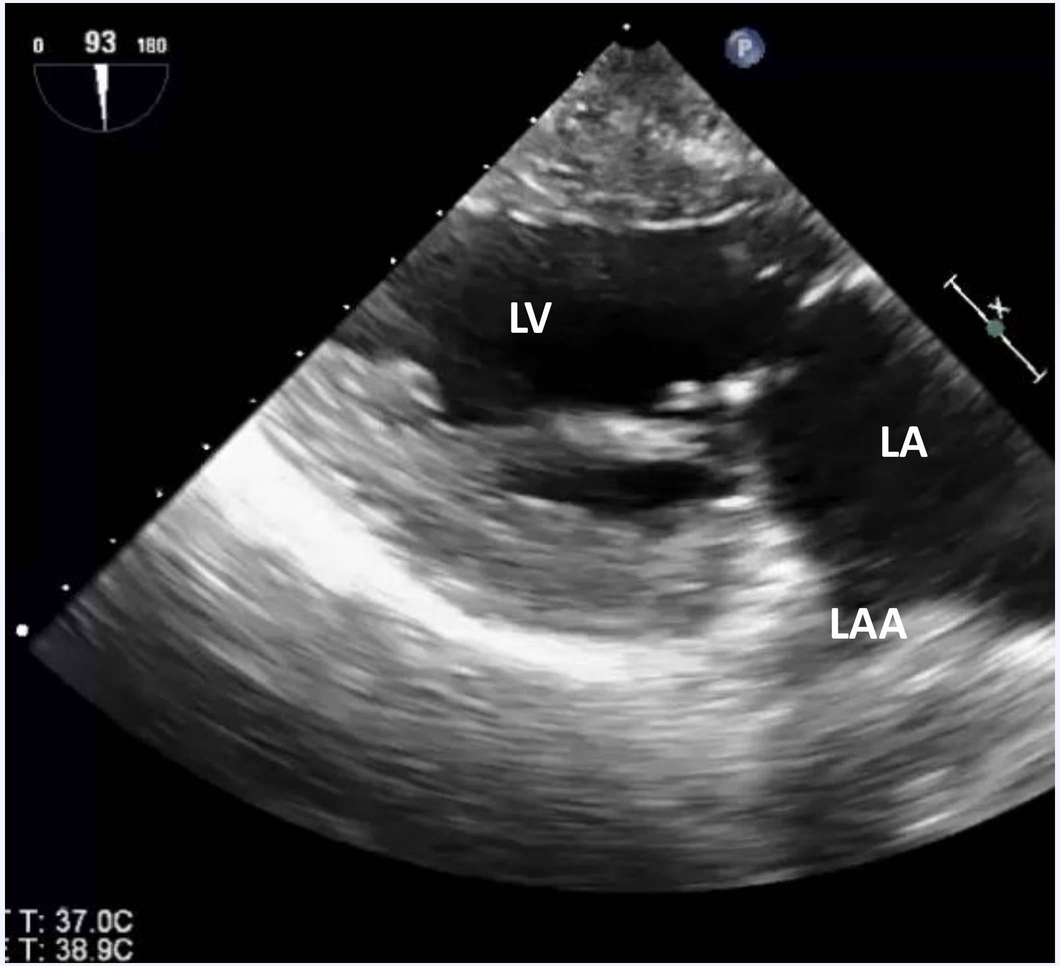
Left ventricle
Left ventricular outflow tract
Right ventricle
Aortic valve
Aortic root
Mitral Valve

Transducer Angle: ~ 90 - 110⁰
Level: Transgastric
Maneuver (from prior image): Neutral flexion, Withdraw

Left ventricle
Left atrium/appendage
Mitral valve

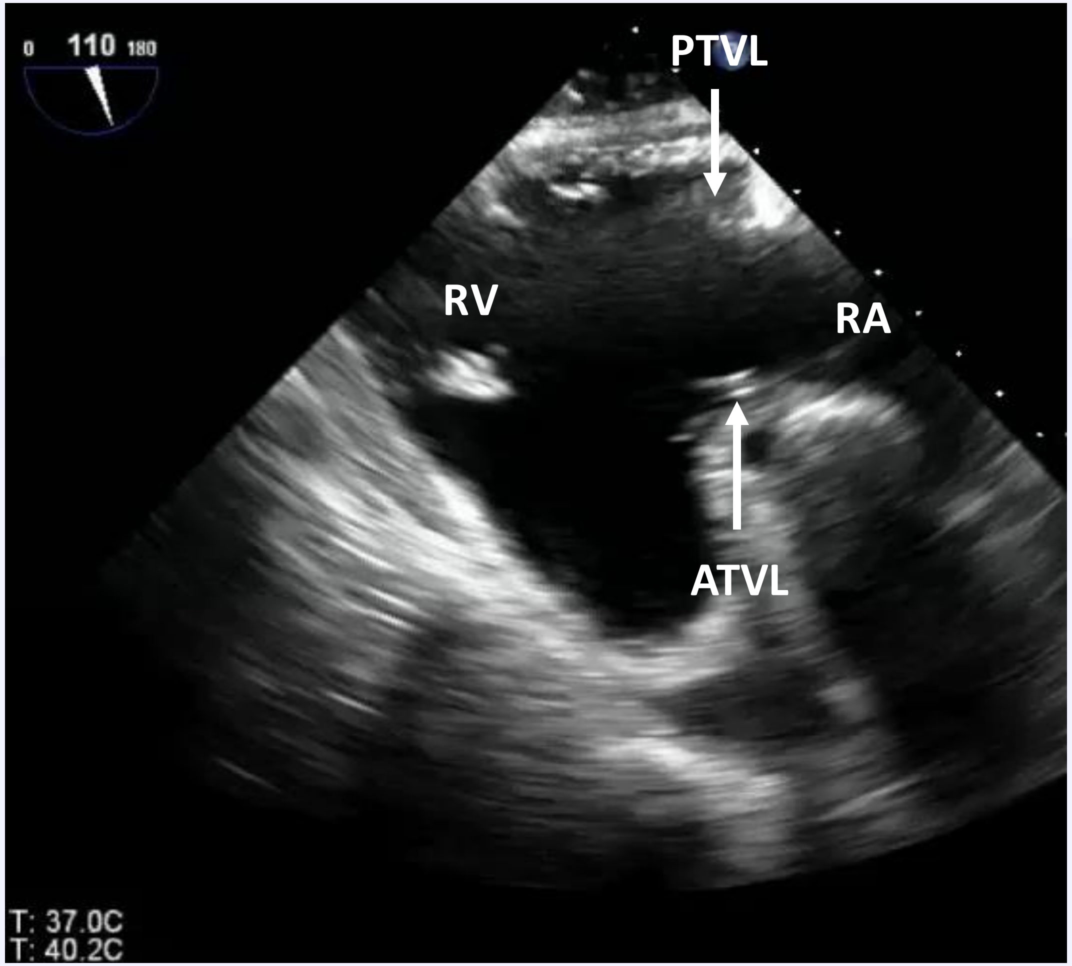


21- Deep TG 5-Chamber View

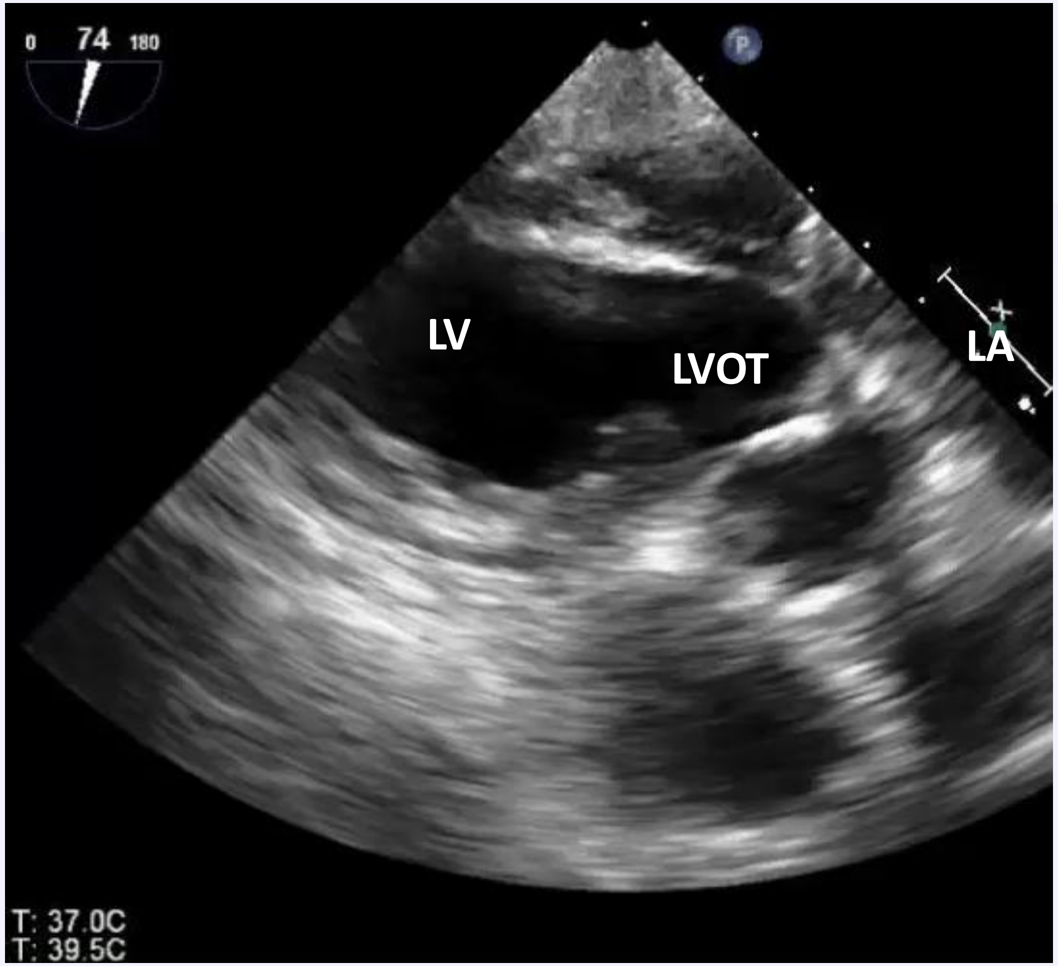


22- TG 2-Chamber View

24. TG LV LAX View

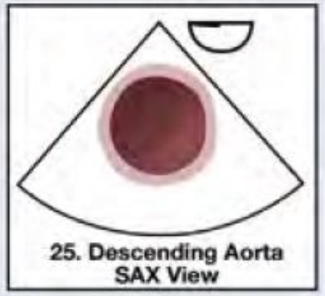


23- TG RV Inflow View



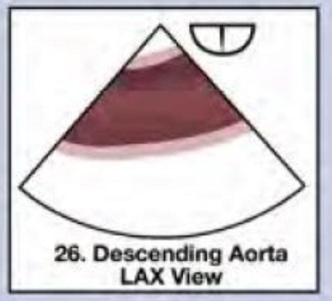
24- TG LAX View

Aortic Views



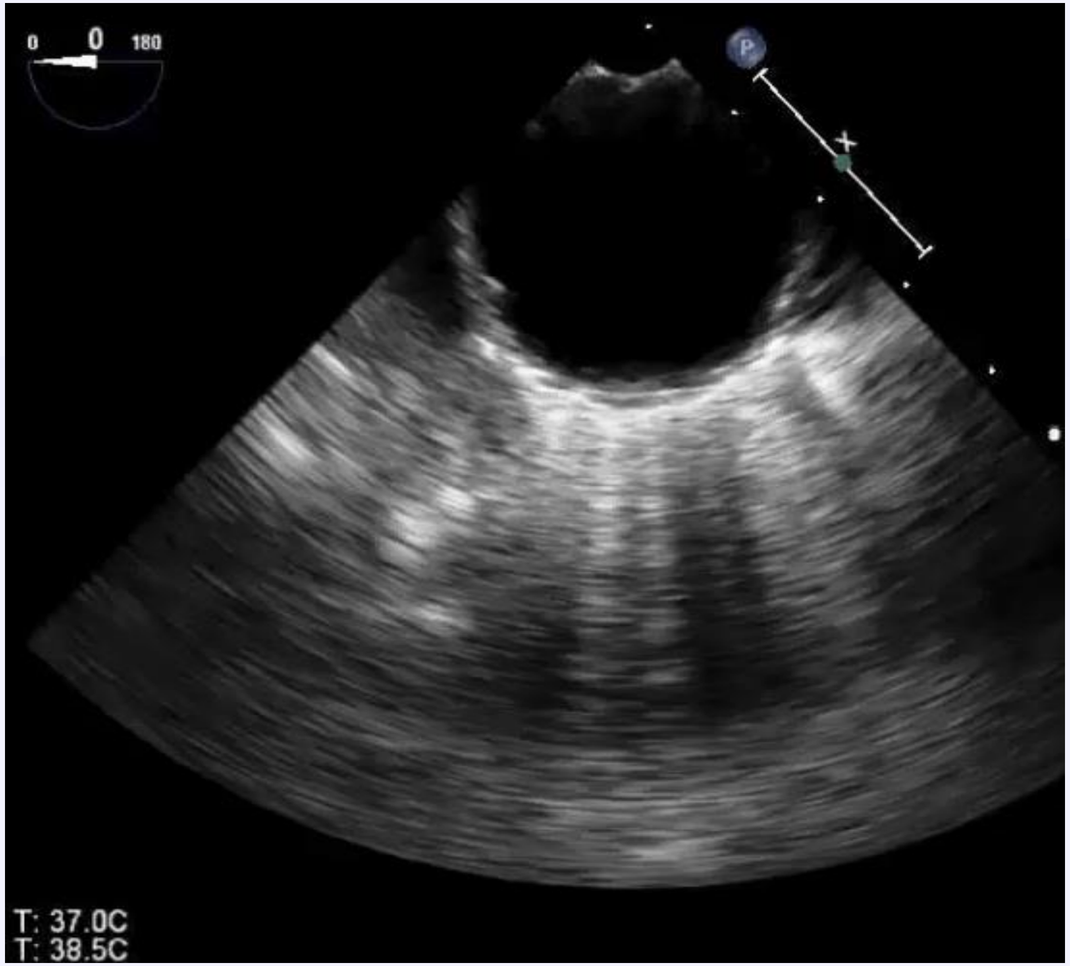
Transducer Angle:
~ 0 - 10^0
Level: Transgastric to Mid-esophageal
Maneuver (from prior image): Neutral flexion

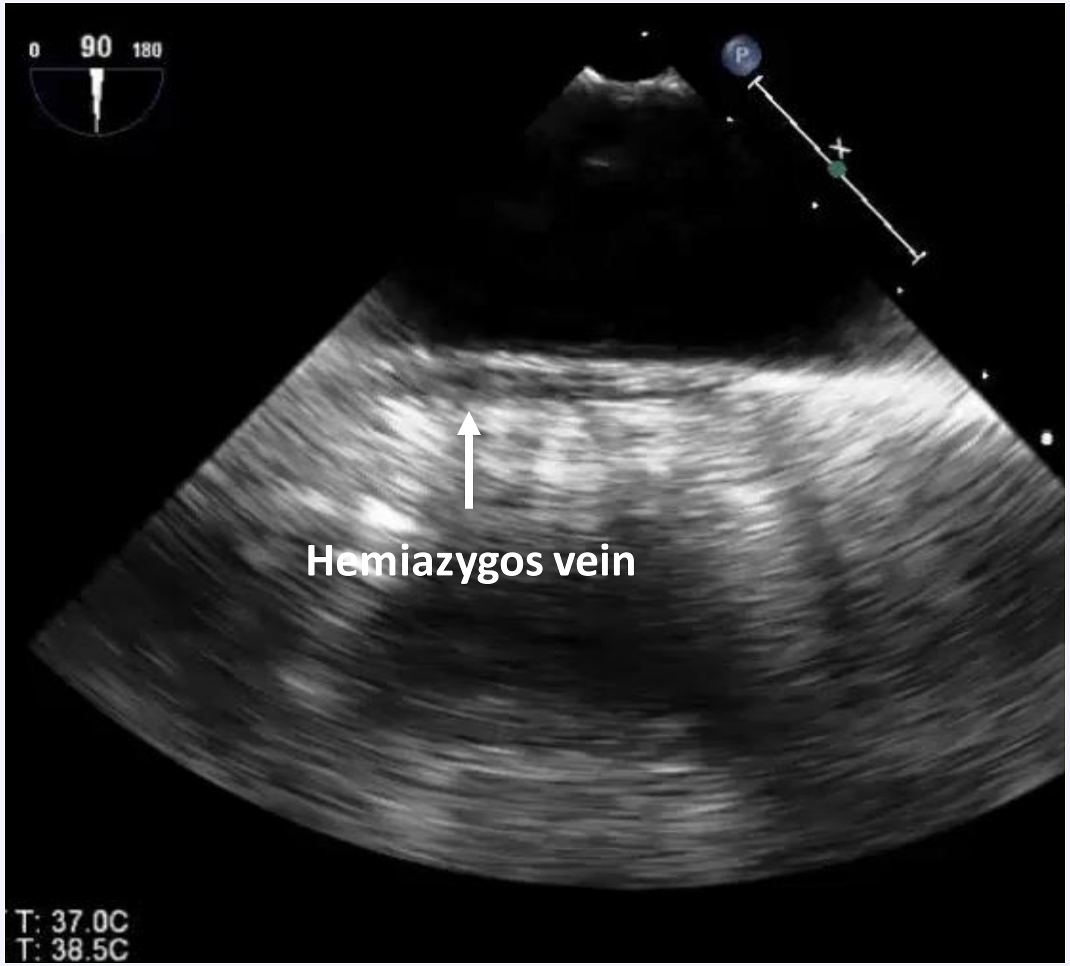
Descending aorta
Left thorax
Hemiazygous and Azygous veins
Intercostal arteries



Transducer Angle:
~ 90 - 100^0
Level: Transgastric to Mid-esophageal
Maneuver (from prior image): Neutral flexion

Descending aorta
Left thorax





25- Descending Aorta SAX View

26- Descending Aorta LAX View

Transducer Angle: ~ 0 - 10⁰
Level: Upper Esophageal
Maneuver (from prior image): Withdrawl

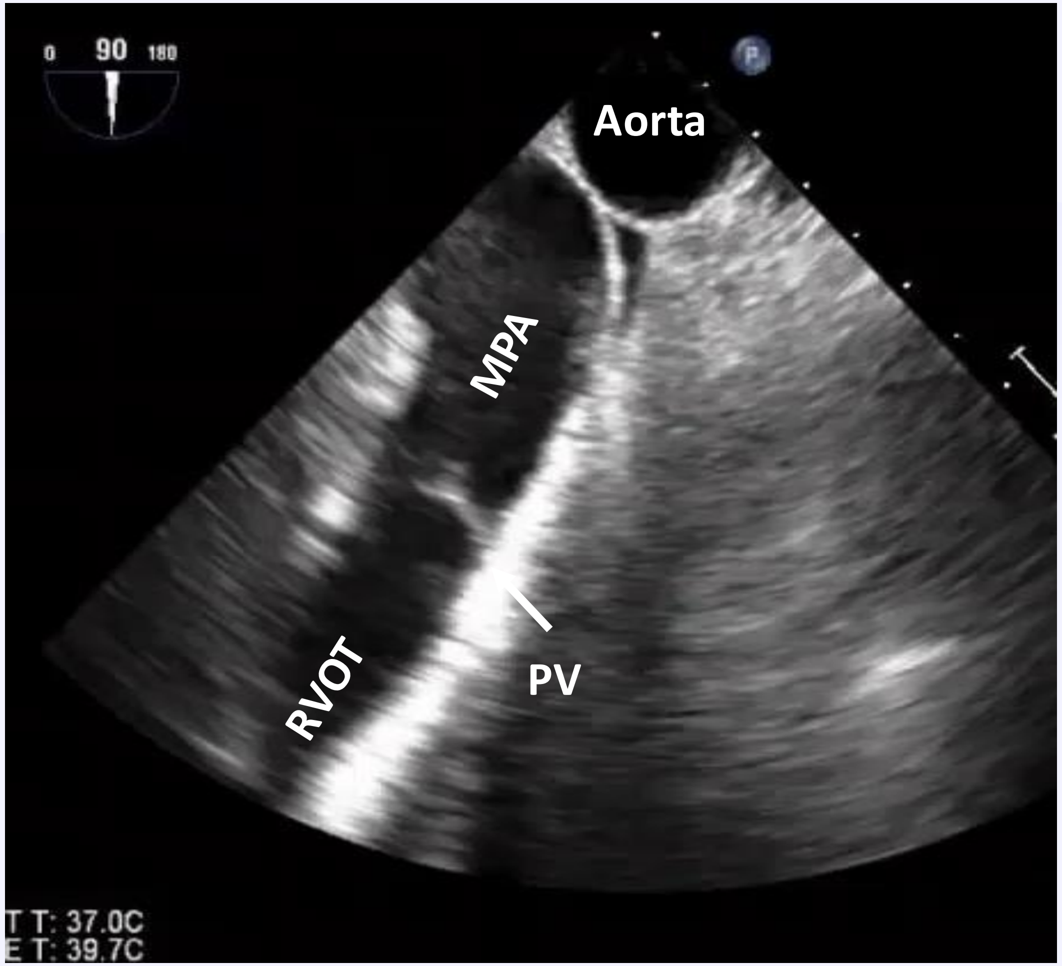
Aortic arch
Innominate vein
Mediastinal tissue

Transducer Angle: ~ 70 - 90⁰
Level: Transgastric to Mid-esophageal
Maneuver (from prior image): NA

Aortic arch
Innominate vein
Pulmonary artery
Pulmonary valve
Mediastinal tissue

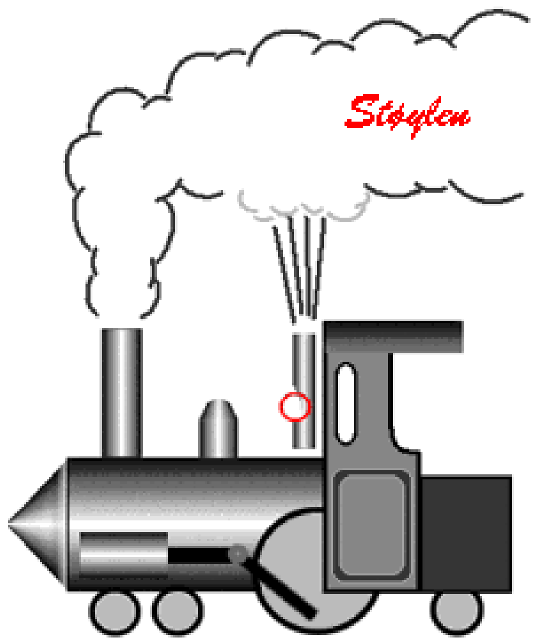
Correction: Level: Upper Esophageal

27- UE Aortic Arch LAX View



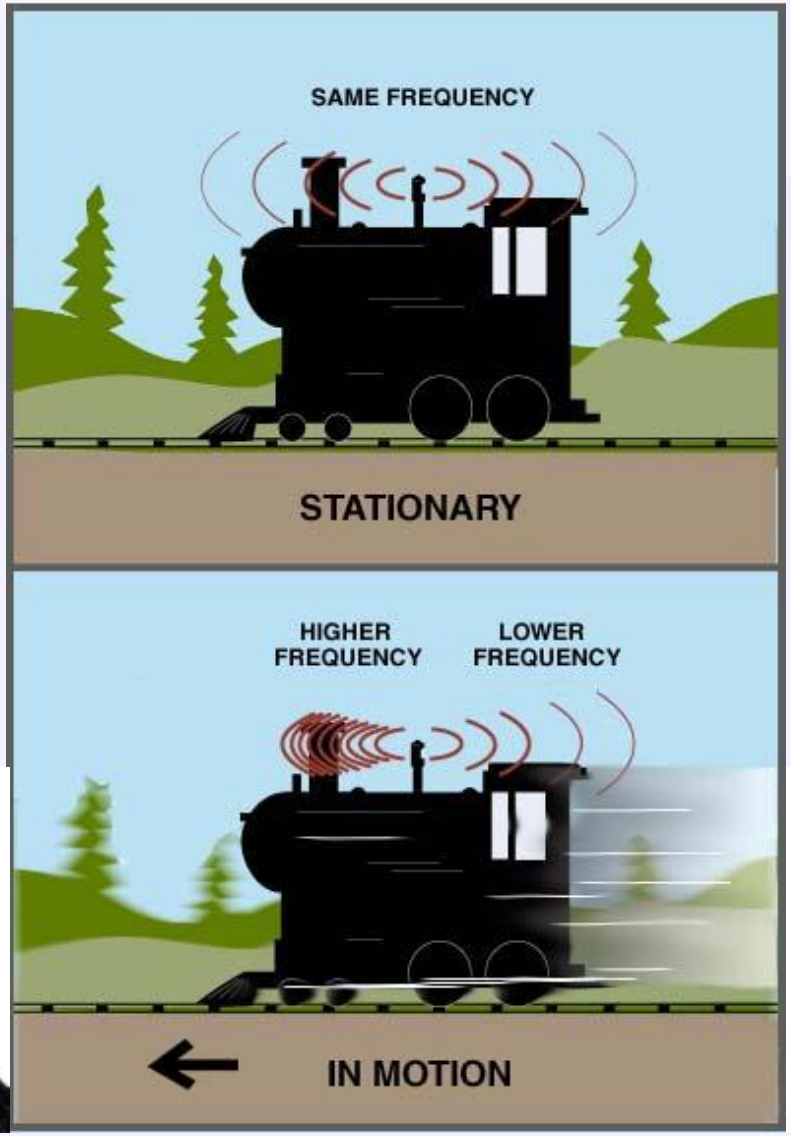
28- UE Aortic Arch SAX View

Introduction to Doppler Echocardiography

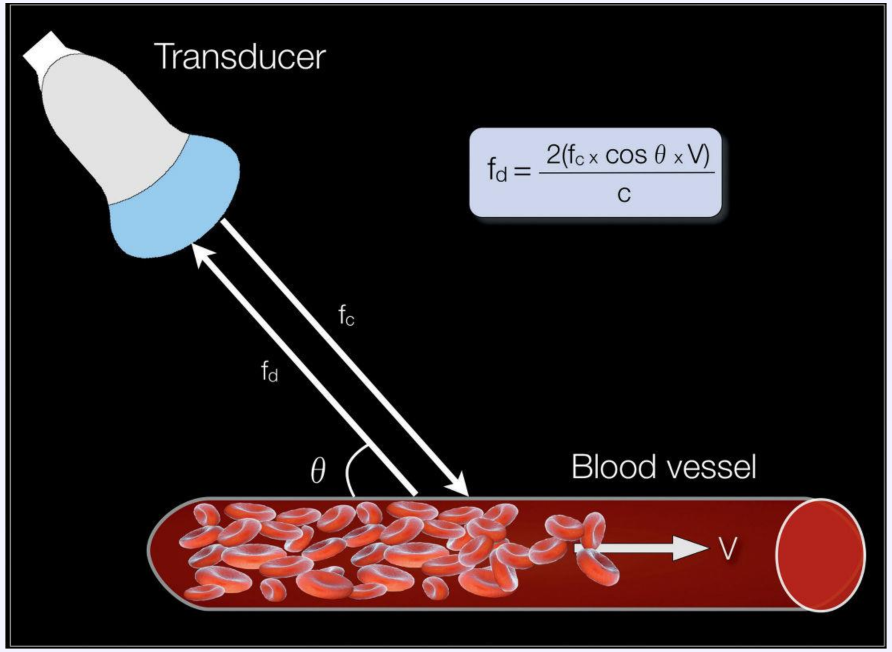


Christian Doppler
(1803- 1853)

Doppler phenomenon (1843): Changing of frequency of an emitted wave with the velocity of the emitter (source of sound) or the velocity of the observer (receiver of the sound or a moving target)



Observer:
Receiver of the sound



Doppler equation

$$v = \frac{\Delta f \times c}{2 f_0 \cos\theta}$$

θ = Angle of insonation of the ultrasound to the moving target

Measured velocity = real blood velocity X cos θ

Blood pool Doppler (conventional): High velocity, low amplitude wave
Tissue Doppler : Low velocity, high amplitude wave

Doppler echocardiography

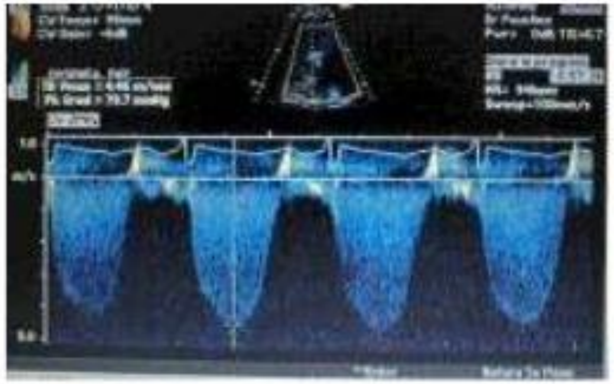
Spectral Doppler

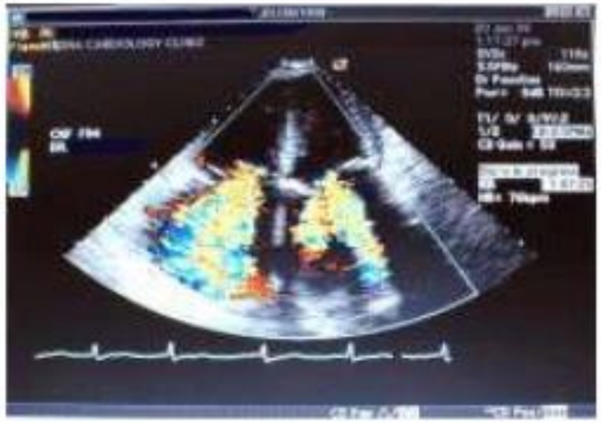
Doppler echocardiography is a method for detecting the direction and velocity of moving blood within the heart.

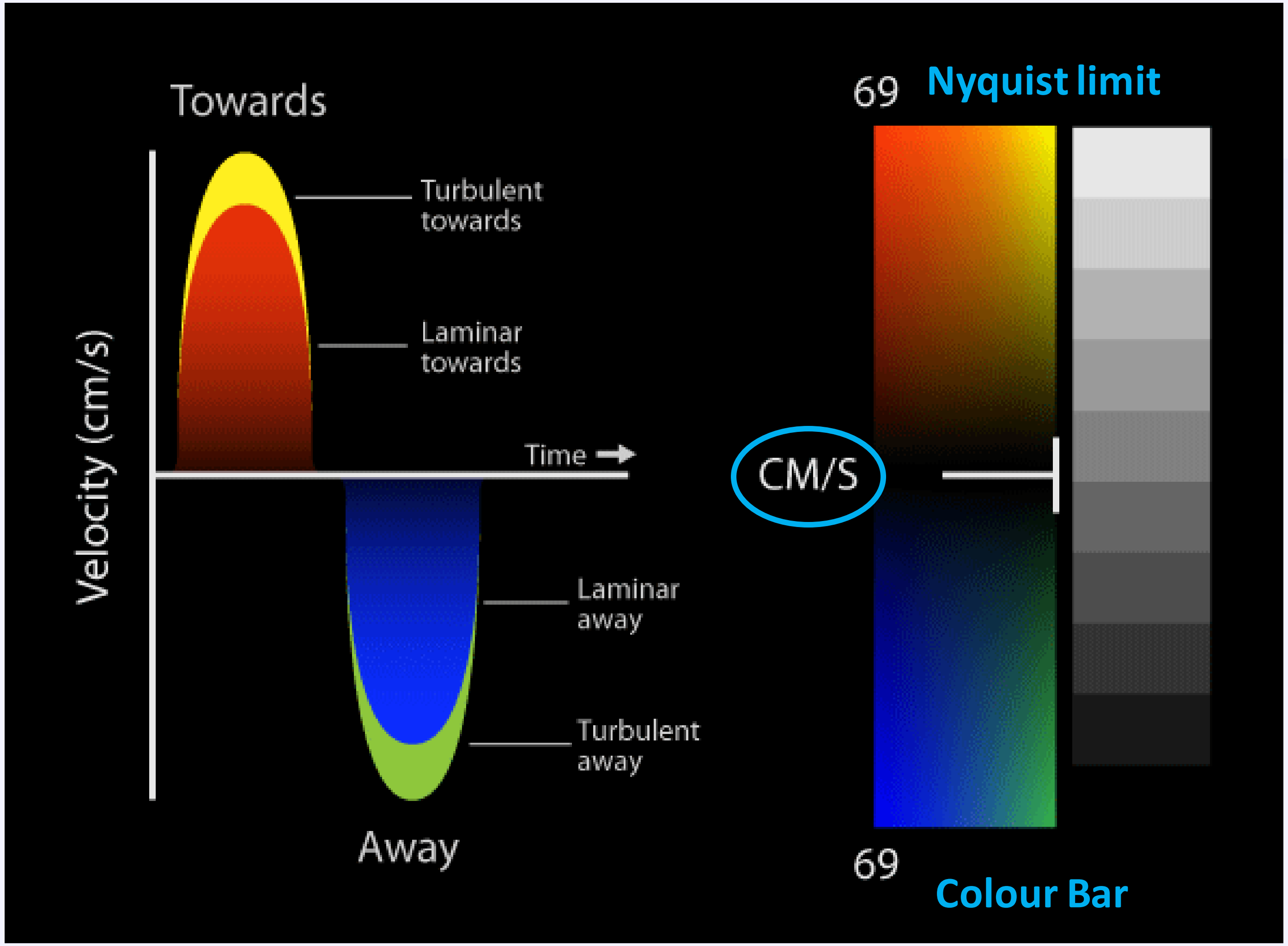
Pulsed Wave (PW) useful for low velocity flow e.g. MV flow

Continuous Wave (CW) useful for high velocity flow e.g aortic stenosis

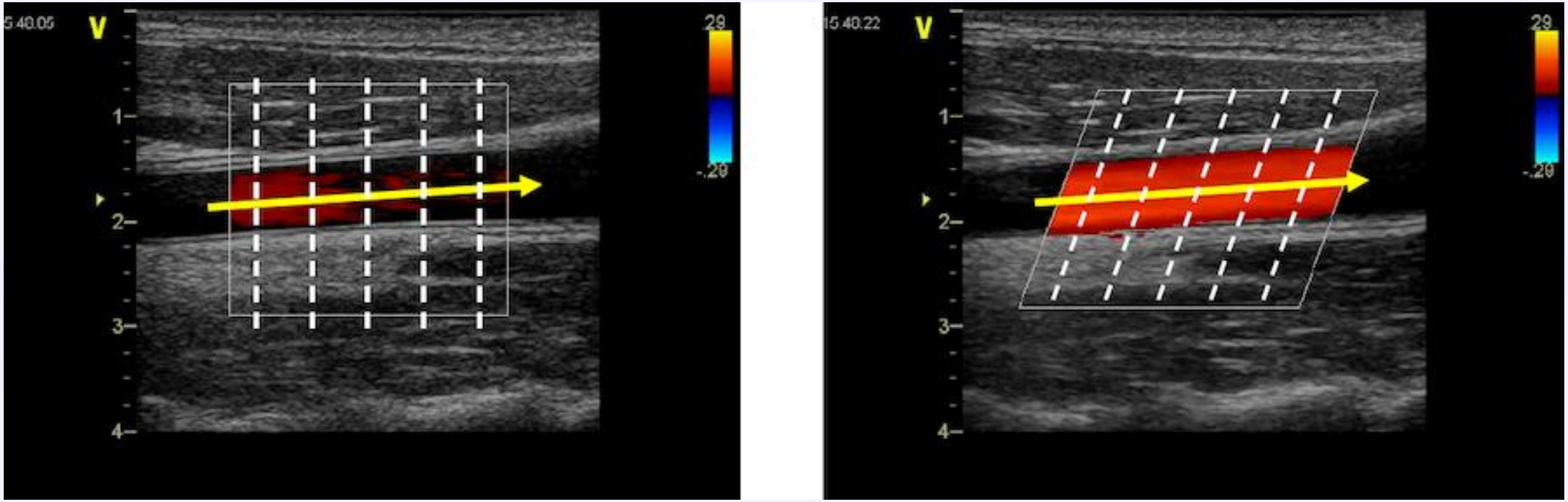
Color Flow (CF) Different colors are used to designate the direction of blood flow. Red is flow toward, and **blue** is flow away from the transducer **(BART)** with turbulent flow shown as a mosaic pattern.



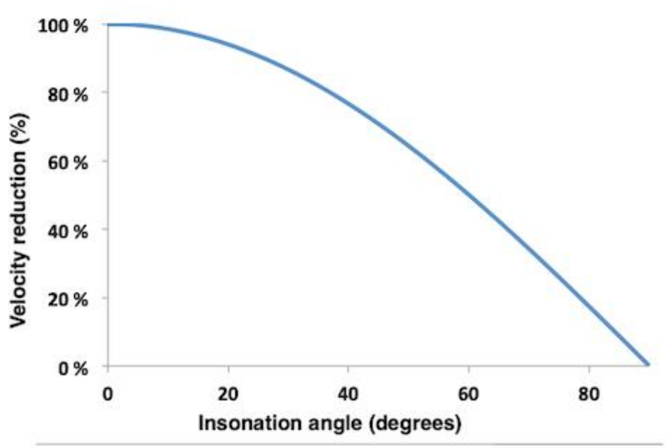


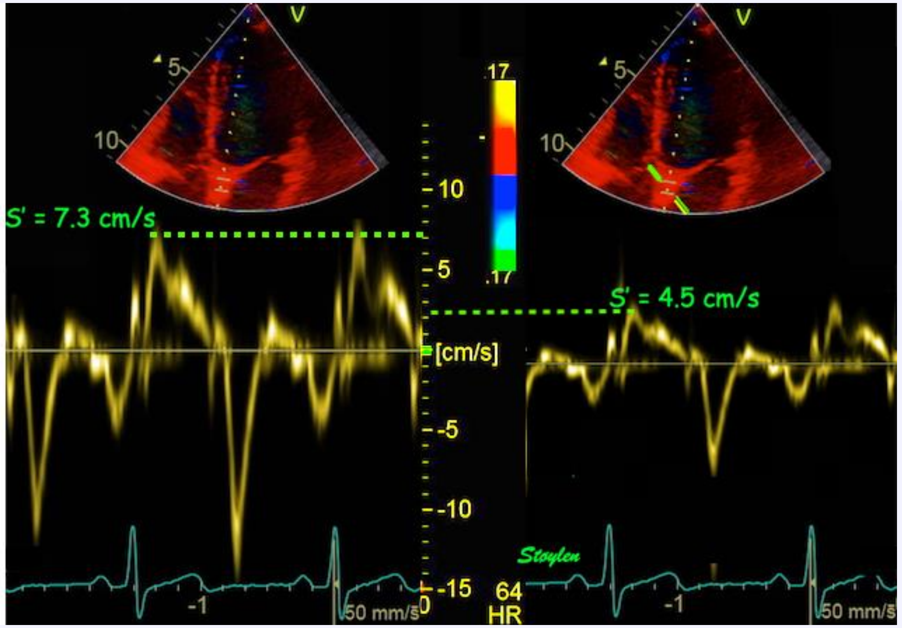


Colour Coded Doppler



Vascular colour ultrasound. Left : Near 90 degree insonation angle. Right: less angle of insonation, higher colour Doppler velocity

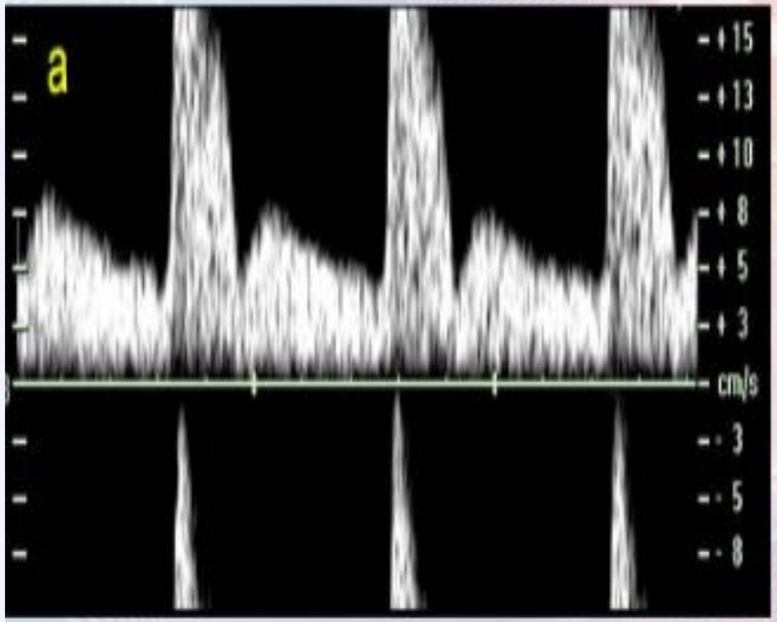




Measured velocities decrease by the cosine function, being 0 at the 90 degree insonation angle and 1 at 0 degree insonation

Angle distortion in Doppler. The image on the left has applied angle correction, and then adjusted to the scale

Aliasing



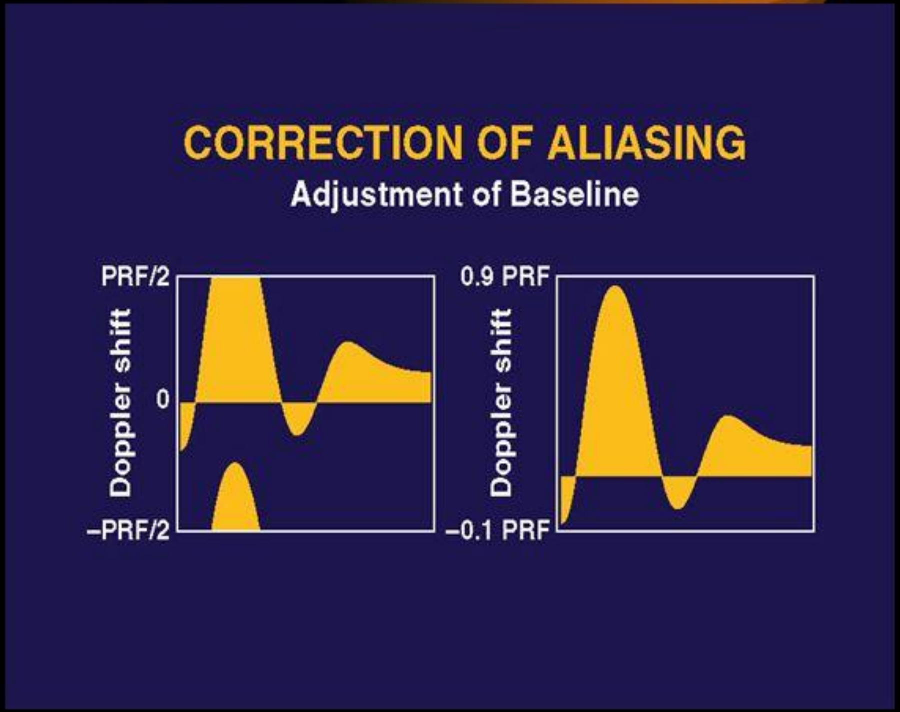
Aliasing occurs when Doppler shift > Nyquist frequency

Nyquist freq - $\frac{\text{Pulse Repetition Frequency}}{2}$

- Aliasing is production of artificial low frequency signals when the sampling rate is less than twice the doppler signal frequency. When the Doppler shifts exceed a value Nyquist frequency, velocities are perceived as going in opposite direction.

To get rid of aliasing:

- Change the velocity scale
- Change the baseline
- Use a <u>lower</u> ultrasound frequency
- Get closer!



Suggested reading materials

1. Basic perioperative TEE examination: ASE/ SCA Consensus statement. JASE May 2013.
2. Guidelines for performing a comprehensive TEE examination: ASE/SCA . JASE September 2013.
3. Guidelines for performing a comprehensive TEE examination in children and all patients with congenital heart disease. JASE February 2019

website Piemed
https://pie.med.utoronto.ca/TEE/TEE_content/TEE_standardViews.html

Simulator on Azad's APIL
http://apil.ca/projects/echocardiography-simulator/

Questions

Question 1

In which of the following TEE views, left atrial appendage can be seen?

A. ME 2-chamber view
B. ME mitral commissural view
C. ME long axis view
D. TG basal SAX view

Question 2

All of the following statements are correct EXCEPT

A. Non-coronary cusp of aortic valve is located adjacent to the interatrial septum
B. RVOT can be visualized in RV TG Basal View
C. Pulmonic valve can be seen in UE Aortic Arch Long Axis View
D. Short axis of mitral valve can be seen in TG Basal SAX View

Question 3

Which of the following statement IS CORRECT?

A. Hemiazygos vein can be visualized in UE Aortic Arch SAX View
B. Right pulmonary artery can be seen in ME Left Pulmonary Veins View
C. Left pulmonary artery can be seen in ME Ascending Aorta SAX view
D. Left atrial appendage can be seen in TG 2-Chamber View

Question 4

In which of the following TEE view coronary sinus can be visualized?

A. ME two-chamber view
B. ME Bicaval View
C. ME RV Inflow-Outflow View
D. TG RV Basal View

Question 5

All of the following statements about Doppler are correct EXCEPT

A. Nyquist limits in Colour Bar during colour Doppler echocardiography are showing the peak velocity of the blood
B. Aliasing can happen during PW and colour Doppler
C. In colour Doppler echo, sound waves going towards the transducer are coded in Blue
D. In colour Doppler echo, high velocity signals going away from transducer are coded as Dark Blue

Correct Answers

1- A
2- C
3- D
4- A
5- B


Toronto
Thank you.