BASIC TRANSESOPHAGEAL ECHOCARDIOGRAPHY WORKSHOP

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CURRENT INDICATIONS AND APPLICATIONS IN CONGENITAL HEART DISEASE

In 2005, the Pediatric Council of the American Society of Echocardiography published updated guidelines on the use of transesophageal echocardiography (TEE) in pediatric patients with congenital or acquired cardiovascular disease (group collectively referred to as "the patient with congenital heart disease"). {Ayres et al., 2005, #16660} Indications for TEE were subdivided into the following primary categories:

- *Diagnostic assessment*
- *Perioperative evaluation*
- *Related to interventions*

Diagnostic Assessment

In infants and young children, high-resolution transthoracic imaging allows for excellent definition of cardiovascular anatomy, assessment of hemodynamics, and evaluation of ventricular function. When the transthoracic echocardiography (TTE) is unable to provide the necessary clinically relevant information, TEE allows for diagnostic information in most cases cases. By overcoming limitations related to poor windows, suboptimal image quality or lung interference, TEE facilitates morphologic, hemodynamic, and functional assessment of congenital and acquired cardiac abnormalities. This is of particular benefit in patients with limited acoustic windows, such as those who have undergone multiple cardiothoracic interventions, adult individuals, or patients with a significant amount of soft tissue/body fat.

Perioperative Evaluation

The intraoperative evaluation currently represents the most common indication for TEE in patients with congenital heart disease. Indications in general include settings where there is potential for significant residual pathology and/or myocardial dysfunction. All patients undergoing TEE should have a complete preoperative TTE as this is considered a complementary imaging modality, rather than a substitute for a comprehensive TTE. TEE demonstrates the cardiac abnormalities to the perioperative providers prior to the intervention, allows for refinements or modifications in the surgical plan and facilitates anesthetic care. The main goal of intraoperative TEE is the assessment of hemodynamically significant residual defects that may need reintervention prior to leaving the operating room in an effort to improve overall clinical outcomes.

Guidance During Interventions

Interventional procedures are increasingly employed in the non-surgical management of congenital heart disease. TEE allows for safer and more effective application of catheter-based approaches and may reduce radiation exposure, amount of contrast material administered and duration of the interventional procedure. Major contributions during catheter-based interventions include: (1) acquisition of detailed anatomic and hemodynamic data prior to and during the procedure, (2) real time evaluation of catheter placement across valves, vessels, and cardiac structure, (3) immediate assessment of the results, and (4) monitoring and detection of complications associated with the interventions.

TEE TECHNOLOGY

Several imaging probes are currently available for TEE applications interfacing with various echocardiographic platforms. Probes are not interchangeable among different platforms. Furthermore, not all commercially available imaging probes from a particular vendor can be used with all their respective machines.

The TEE technology has evolved over several years the from single plane devices (monoplane) able to scan only in a single plane (0^0; transverse or horizontal plane), to biplane probes which added a second orthogonal plane (90^0; longitudinal or vertical plane), to multiplane devices that allow for interrogation of cardiovascular structures in any plane within an arc of 0-180^0. {Muhiudeen Russell et al., 1998, #48869} Although multiplane TEE probes are favored and have become the standard in pediatric and adult imaging, biplane and even monoplane devices are still available and may be used particularly in small infants. Recent advanced in TEE technology include the availability of three-dimensional imaging and further miniaturization of devices.

Currently two probes with multiplane capabilities (micro and mini-multiplane) are available for pediatric imaging (weight < 15 kg). At present the smaller of the two devices (micro-TEE probe) is marketed by a single company (Philips). This probe has been shown to provide diagnostic images in tiny infants and now allows an option in those under 3 kg as this was considered the lower weight limit for the regular pediatric multiplane device (mini-TEE probe). In the older child (~ >15-20 kg), the "adult " multiplane TEE probe is preferred. Three-dimensional TEE imaging is currently only available in adult devices (recommended lower weight limit ~30 kg).

TEE MANIPULATION

The TEE probe can be manipulated as follows {Shanewise et al., 1999, #37950}:

- *Advancing*: pushing probe more inferiorly (towards the stomach); *withdrawing*: pulling more superiorly
- *Turning rightward or to the right*: rotating probe clockwise; *turning leftward or to the left*: rotating counterclockwise
- *Anteflexion:* flexing probe tip anteriorly; *retroflexion*: flexing tip posteriorly
- *Flexing to the right* (to the patient's right) and *flexing to the left* (to the patient's left) with lateral tip movement. This is not as useful in pediatric patients and not even included in many of the current pediatric TEE multiplane probes.
- *Rotating forward* or *backward* to *x degrees*: rotation of the multiplane angle (where *x* represents the multiplane angle).

APPROACH TO THE TEE EXAMINATION

There are several options for performing a comprehensive TEE examination. Each approach presents unique advantages and potentially some disadvantages in the assessment of congenital heart disease.

View-based examination

A 'view-based exam', consisting of obtaining 20 established views as proposed by the Society of Cardiovascular Anesthesiologists and the American Society Anesthesiology, is favored by many (Attachment 1). This approach is based on moving the imaging transducer to various locations within the esophagus/stomach to obtain specific pre-defined views. Once these views are displayed the anatomy can be examined and corresponding functional and hemodynamic information can be obtained. This approach allows for easy identification of major cardiac structures in a relatively normal heart. Most, if not all of these views are routinely obtained during any comprehensive TEE examination regardless of the particular sequence or approach. However there are some potential disadvantages as follows: (1) this approach is based on guidelines proposed primarily for the examination of the adult patient with an anatomically normal heart, thus in many cases this may not be suitable to those with structural abnormalities, as is the case of patients congenital heart disease, (2) additional or alternate views, are not included or described in this exam; in many cases these are required to adequately assess the abnormalities in question, and (3) this approach requires visualizing various structures in a particular view, some at various depths in reference to the imaging probe, requiring multiple/frequent adjustments in image settings. Despite these limitations, the 'view-based exam' facilitates learning basic principles of TEE and represents an excellent foundation on the subject. Thus the focus of the workshop and simulation session will be on a discussion of the most common TEE views, how are they obtained, and what they information they provide.

Structure-based examination

This approach focuses on cardiovascular structures of interest that may be examined by TEE and fully evaluates each one in a combination planes (Attachment 2). The systematic nature of this exam avoids missing/skipping any important component of the interrogation as complementary views allow for a comprehensive examination of each structure. A 'structure-based exam' utilizes full power of the echocardiographic system to optimize visualization of the region(s) of interest. One potential limitation of this approach is that the exam may only target specific cardiac structures/pathologies that the examiner is familiar with and may overlook other structures that in fact may represent anatomic variants or significant abnormalities.

Segmental-sequential examination

The segmental sequential analysis has been proposed as the foundation of complete anatomic assessment in congenital heart disease. This assumes a systematic analysis of the three major cardiac segments (atria, ventricles and great arteries) in order to characterize the abnormalities in a given patient. The guiding principle of this approach is that specific cardiac chambers and vascular structures have characteristic morphologic properties that determine their identities, rather than their positions within the body. In this approach, also applicable to TEE, an organized, systematic interrogation of all cardiac structures or segments and their relationships to each other (connections or alignments between the segments) is carried out to define a given patient's anatomy and any abnormalities. This exam mimics in many ways the transthoracic examination as one navigates the heart and vessels with this in mind while moving across all the windows. This approach overcomes some of the limitations of a purely structure-based examination as all structures that can be examined by TEE are interrogated, exploiting the full potential of the technology and allowing for a more comprehensive assessment of cardiovascular structures. Despite these advantages, this approach may be less intuitive to those not familiar with segmental anatomy and potentially more time consuming.

REFERENCES:

1. Ayres NA, Miller-Hance W, Fyfe DA et al (2005) Indications and guidelines for performance of transesophageal echocardiography in the patient with pediatric acquired or congenital heart disease: report from the task force of the Pediatric Council of the American Society of Echocardiography. J Am Soc Echocardiogr 18:91-98

2. Cahalan MK, Abel M, Goldman M et al (2002) American Society of Echocardiography and Society of Cardiovascular Anesthesiologists task force guidelines for training in perioperative echocardiography. Anesth Analg 94:1384-88

3. Kamra K, Russell I, Miller-Hance WC (2011) Role of transesophageal echocardiography in the management of pediatric patients with congenital heart disease. Paediatr Anaesth 21:479-93

4. Mathew JP, Glas K, Troianos CA et al (2006) ASE/SCA recommendations and guidelines for continuous quality improvement in perioperative echocardiography. Anesth Analg 103:1416-25

5. Practice guidelines for perioperative transesophageal echocardiography (2010) An updated report by the American Society of Anesthesiologists and the Society of Cardiovascular Anesthesiologists Task Force on Transesophageal Echocardiography. Anesthesiology 112:1084-96

6. Shanewise JS, Cheung AT, Aronson S et al (1999) 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 89:870-84

7. Sundar S, DiNardo JA (2008) Transesophageal echocardiography in pediatric surgery. Int Anesthesiol Clin 46:137-55

TEXTBOOKS/MANUALS:

1. Practical Perioperative Transesophageal Echocardiography: Text with DVD-ROM, Sidebotham D et al, second edition, 2011

2. A Practical Approach to Transesophageal Echocardiography, Perrino and Reeves (Editors), second edition, 2007

3. Clinical Manual and Review of Transesophageal Echocardiography, Mathew J et al, second edition, 2011

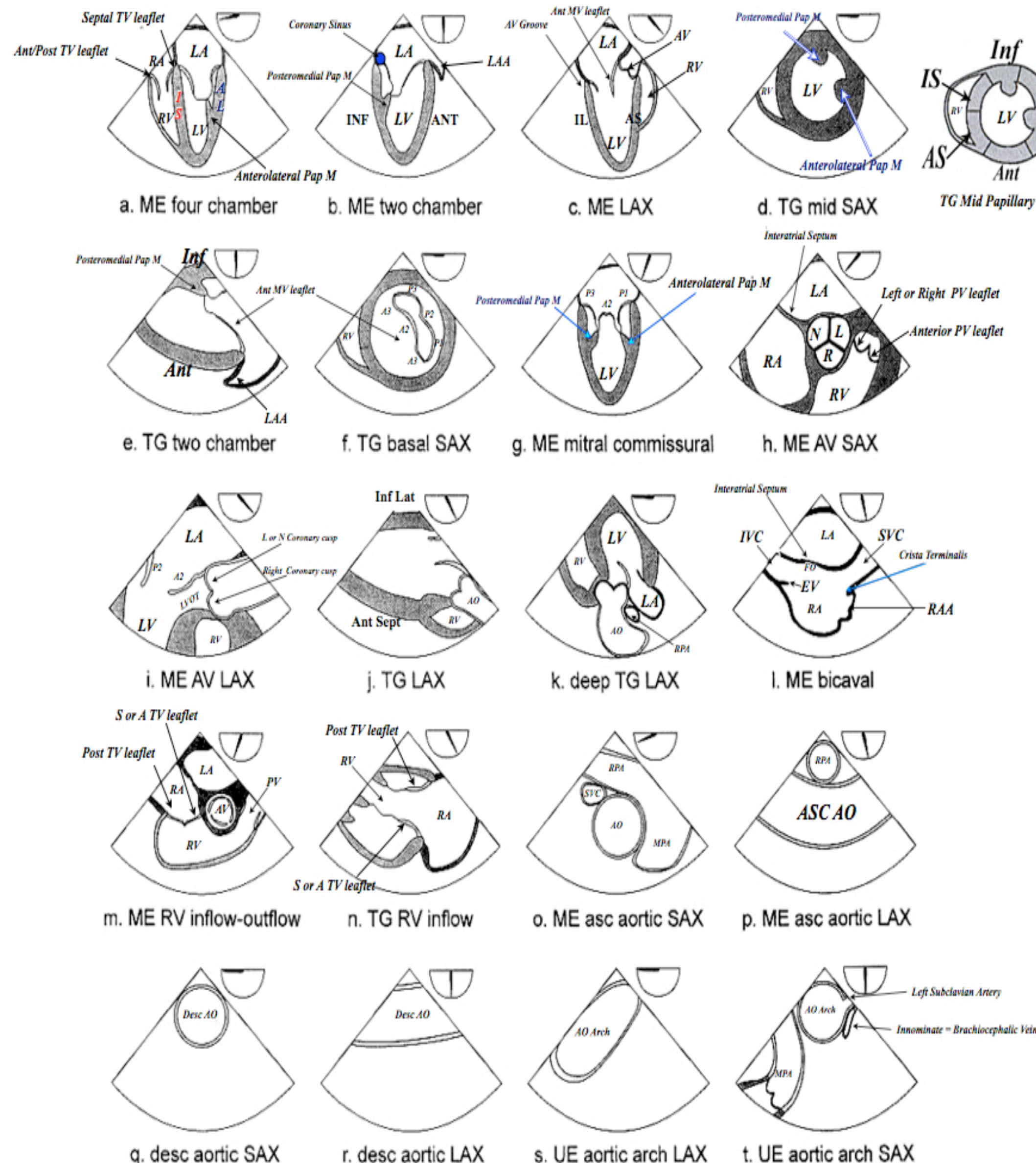
4. Comprehensive Textbook of Perioperative Transesophageal Echocardiography, Savage et al, second edition, 2010

ON LINE RESOURCES:

http://ptemasters.com/ (Thomas Burch, MD and Feroze Mahmood, MD)
http://pie.med.utoronto.ca/TEE/ (Annette Vegas, MD and Massimiliano Meineri, MD)

ATTACHMENT 1

VIEW-BASED TEE EXAMINATION



ATTACHMENT 2

STRUCTURE-BASED TEE EXAMINATION

Suggested intraoperative examination:

- Opening view-initial “overall big picture”- 4-5C view
- Valves: MV, AV, TV, PV
- Interatrial septum
- Coronary sinus
- Aorta
- Additional information (functional evaluation, hemodynamic calculations, etc.)

Opening view: initial “overall big picture”- Mid esophageal four-five chamber view:

The mid esophageal four-chamber (ME 4Ch) view is obtained as soon as the probe is placed in the mid esophagus at a multiplane angle of 0^0. With slight probe withdrawl a view that includes the left ventricular outflow/aortic valve (ME 5Ch view) may be evident. These views allow for an immediate global assessment of the patient’s status: systolic function, ventricular preload, gross valvular pathology, significant pericardial effusion, and overall size and condition of the cardiac chambers. This “overall big picture” takes approximately 15-20 seconds to obtain. From this view the probe can be turned to the left (to evaluate for a left sided pleural effusion or loculated pericardial effusion) and to the right (to assess for a right sided pleural effusion and qualitatively interrogate RV function). In the operating room, following the opening view described above, all portions of the examination that involve Doppler or gated 3D acquisition can be obtained prior to initiation of the case and electrocautery interference.

Valves:

<u>*Mitral Valve*</u>: The valve is interrogated with and without color in multiple planes. Interrogation from the ME 4 CH view by advancing the probe allows for evaluation of posterior aspects of the valve and withdrawing the probe displays more anterior aspects. Additional planes at the mid esophageal window allow for a more comprehensive assessment of the mitral valve. A short axis (en-face) view of the valve is obtained and interrogated from the transgastric basal short-axis (TG Basal) view, or from a 3D enface view (if these capabilities are available). In patients with mitral valve pathology additional anatomic and hemodynamic information should be obtained. A detailed discussion of applicable calculations is beyond

the scope of this syllabus, but is discussed in the narrated basic mitral valve lecture found at http://www.ptemasters.com/lectures/.

Aortic Valve: The aortic valve is interrogated with and without color in short and long axis views at the level of the mid esophagus (ME AV SAX and ME AV LAX). Anatomic evaluation is feasible in these views however assessment of disease severity (stenosis and regurgitation) may require additional views.

Tricuspid Valve: The tricuspid valve is interrogated with and without color from multiple views including: ME 4 Ch view and the mid esophageal right ventricular inflow-outflow (ME RV in-out) view at around 60-90 degrees.

Pulmonic Valve and Branches: The pulmonic valve is interrogated with and without color, usually from the ME-RV inflow-outflow view at around 60-90 degrees. The branch pulmonary arteries can be seen in the mid esophageal ascending aortic short axis (ME Asc Ao SAX) view as the probe is anteflexed and slightly withdrawn from the ME 4 Ch view. This allows for examination of the main pulmonary artery bifurcation and proximal aspects of the branches and is ideal to assess gradient across the pulmonary outflow tract.

Interatrial septum:

The interatrial septum is interrogated from multiple views to assess the presence of a communication (PFO or ASD). The Nyquist limit should be adjusted to enhance detection of low velocity flows.

Coronary sinus:

The size of the coronary sinus is evaluated. A large coronary sinus may indicate a persistent left superior vena cava (left SVC) which may complicate cannulation, cardioplegia administration or influence the surgical plan. If a persistent left SVC is suspected, contrast material can be injected into a left upper extremity intravenous line or left internal jugular catheter and if present. contrast will be seen entering the coronary sinus prior to draining into the right atrium.

Aorta:

Most frequently the aorta is evaluated by turning the probe to the left towards the spine and decreasing the image depth. The probe is then advanced into the stomach while visualizing the descending aorta until it can no longer be seen then the probe is withdrawn until the arch is seen and the structures are no longer visible. This is done at orthogonal planes (0 and 90^0). The probe is then turned back anteriorly and a ME AV LAX view is obtained and the angle is slightly decreased to around $90\text{-}110^0$. The probe is then withdrawn and the ascending aorta inspected. For a detailed discussion of the evaluation of the thoracic aorta see the thoracic aorta lecture at the following link: http://www.ptemasters.com/lectures/

Additional information:

1. Ventricular systolic function

2. Additional hemodynamic calculations may be relevant. These include but are not limited to the following:

- Quantitative assessment of systolic function
- Pressure gradients across valves
- Calculation of valve areas using calculations as well as planimetry and 3d tracing.
- Calculation/estimation o f intracardiac pressures
- Calculation of effective regurgitant orifice area, regurgitant volume, regurgitant fraction

A detailed discussion of these calculations is beyond the scope of this basic discussion but is provided during the hemodynamic calculations lecture at the following link: http://www.ptemasters.com/lectures/.

ATTACHMENT 3

SEGMENTAL-SEQUENTIAL TEE EXAMINATION

The TEE examination for CHD must be organized and systematic; each cardiac structure should be explored carefully, with judicious use all imaging modalities (2D/3D Doppler, M Mode) to perform as thorough an examination as possible. A methodical well-organized approach assumes greater relevance for TEE because of several inherent limitations with the technique.

The segmental approach facilitates a complete and organized approach to TEE evaluation, and encourages a thorough, step-by-step examination of all structures. It is particularly useful when dealing with complex CHD.

Details of the Examination

Segments Evaluated:

Veins

Atria

Ventricles

Great Arteries

Connections Examined:

Venoatrial

Atrioventricular

Ventriculoarterial

Additional Structures of Interest:

Interatrial septum

Coronary sinus

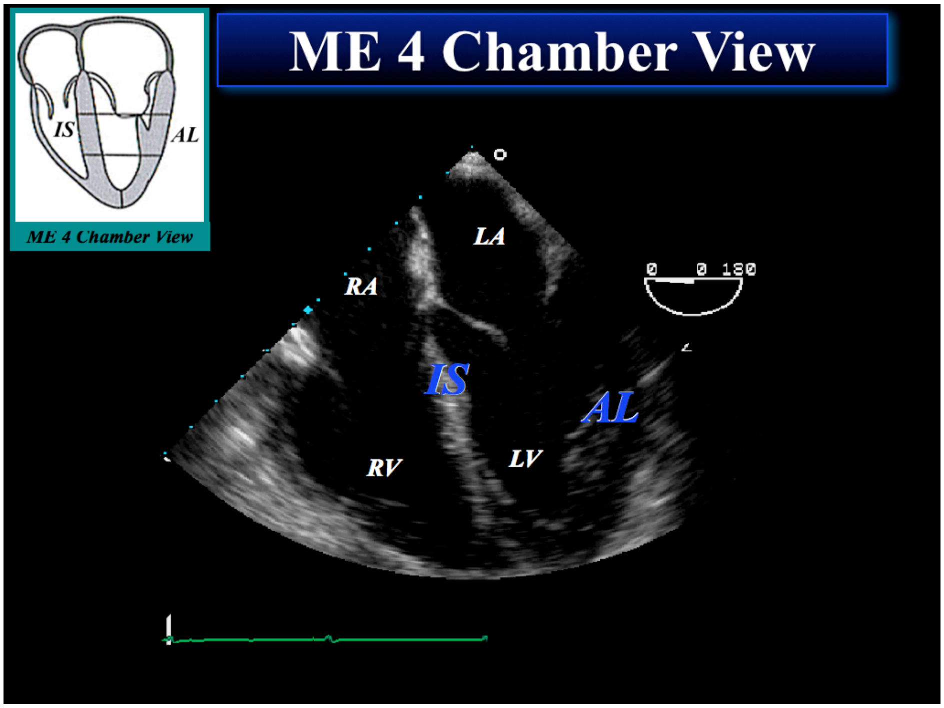
Interventricular septum

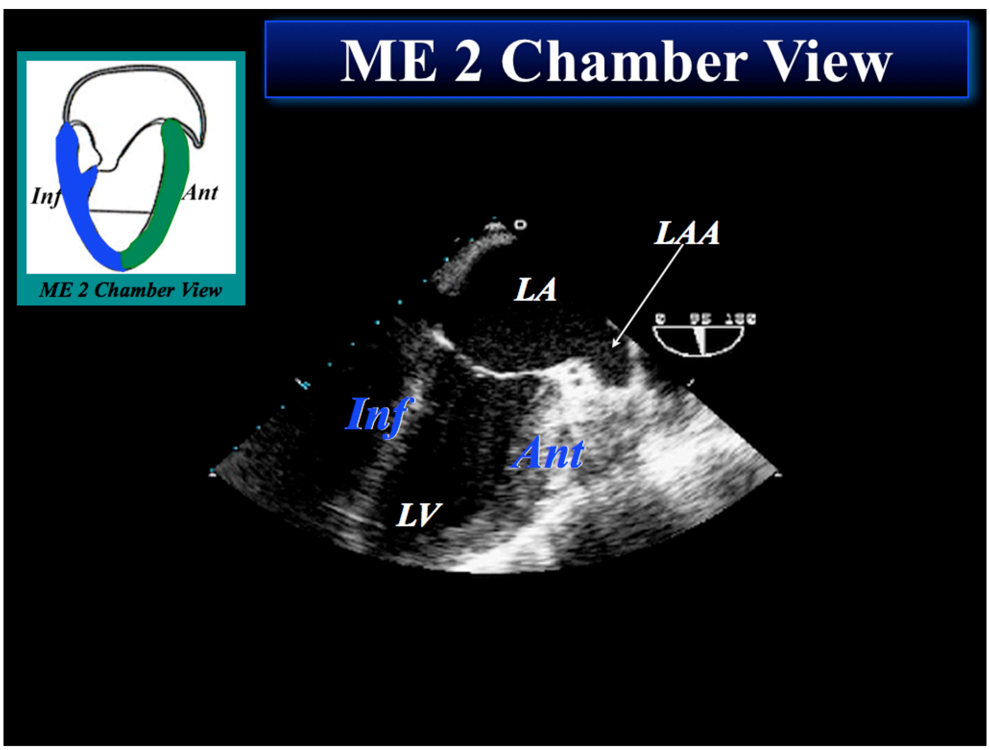
Branch pulmonary arteries

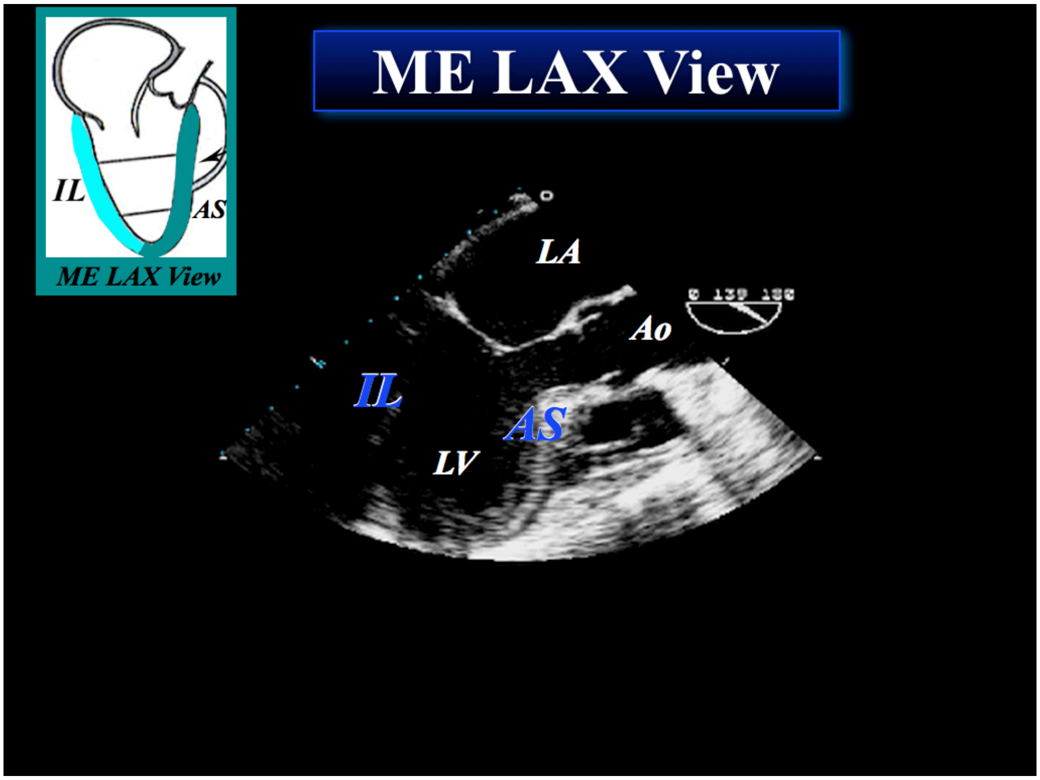
Aortic arch branches

Coronary arteries

Additional Figures of Views are included below:



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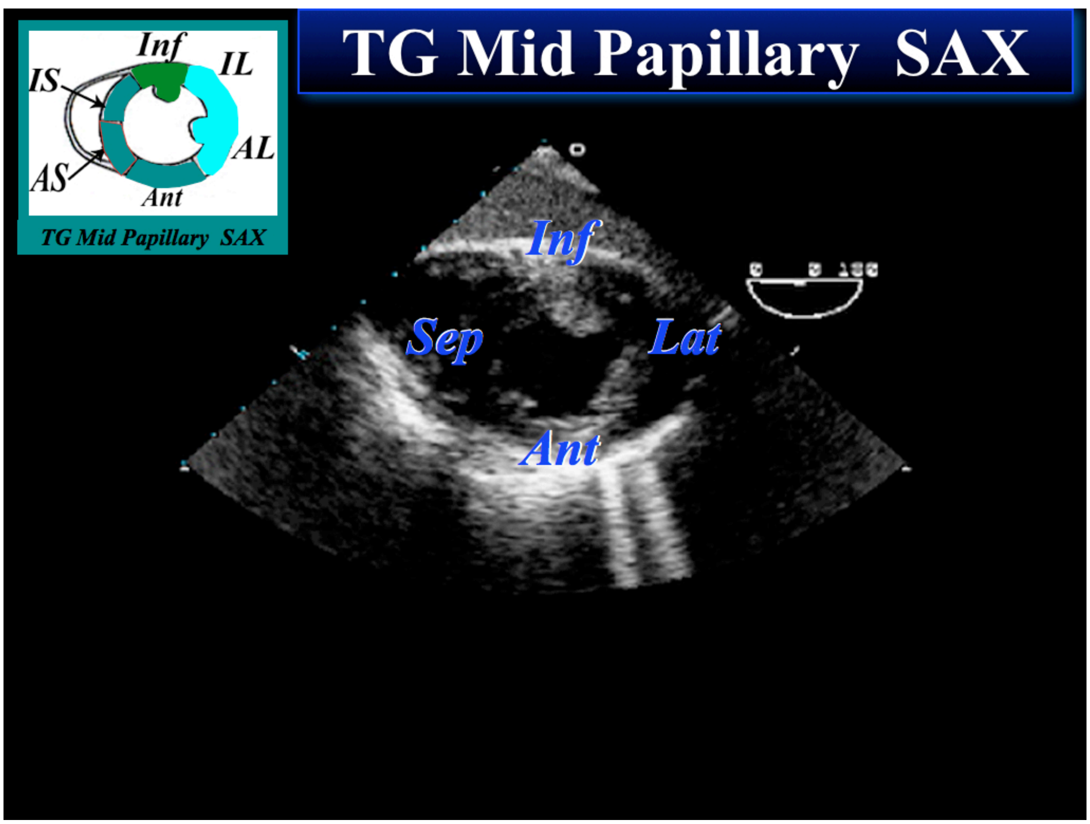
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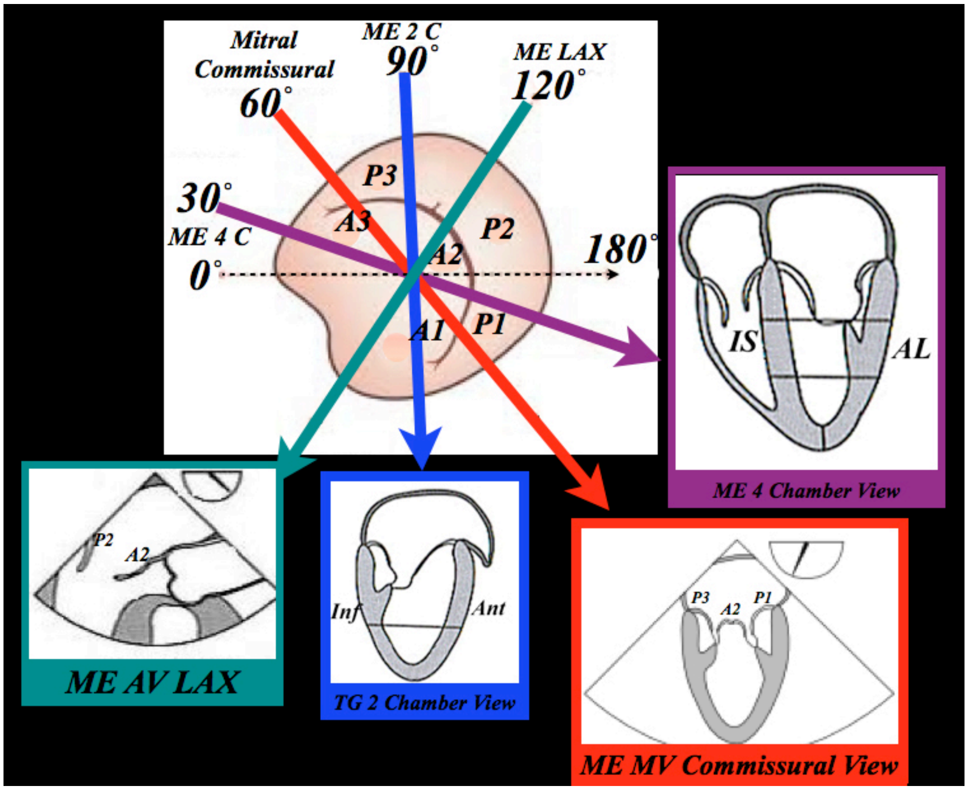
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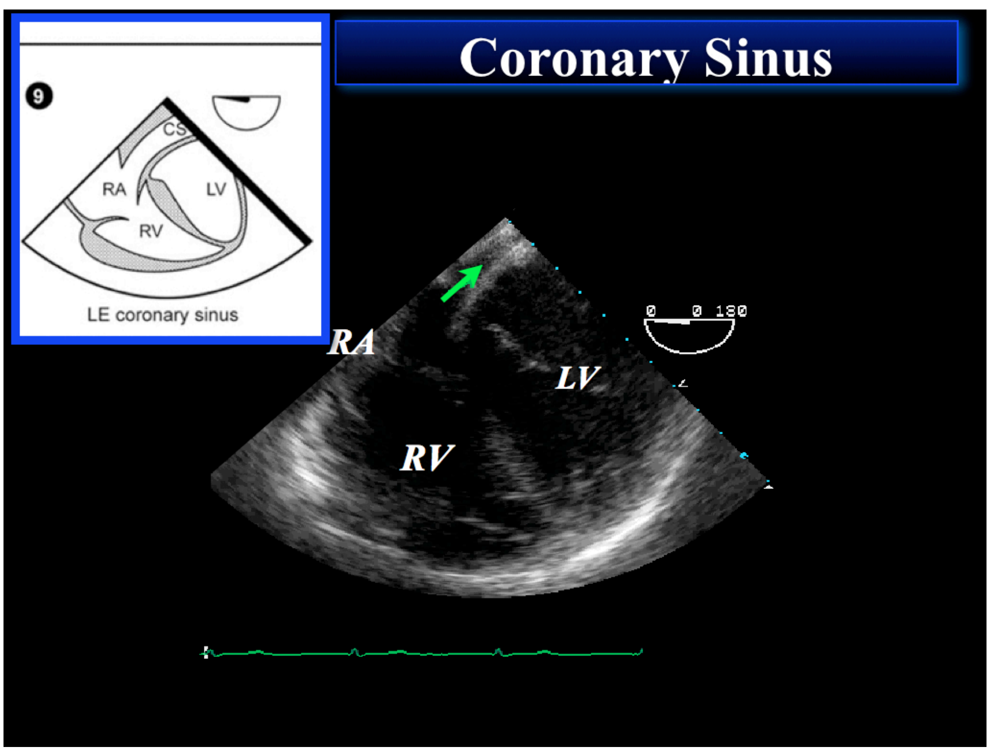
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