At the conclusion of this lecture, the participant should be able to:
1. Defend the use of TEE for a typical cardiac surgical case
2. State the importance of incidental findings with routine use
3. Verbalize the morbidity and potential mortality risks and benefits from routine TEE use
4. Describe how TEE can be used instead of a PA catheter

The utility of TEE during a cardiac case should be more than a comprehensive (or focused) examination before or after the surgical procedure. After all, the TEE probe is left in place throughout the procedure (the norm in the majority of the cases), the anesthesiologist has immediate access to it and there are many combinations of pressure, flow and rate/rhythm changes that beg for interpretation. For those of us using a non-invasive, dynamic index of circulatory status, the TEE can be better than a non-invasive “pulmonary artery catheter”. The potential applications of TEE will be described in chronological order (as the typical cardiac surgical case is evolving); feel free to comment at the end of the talk or by email to njs2002@med.cornell.edu, for more, innovative uses!

A. Pre-incision

This is the time that the patient is anesthetized, “lined-up” and prepped. For those lacking a portable ultrasound system for real-time ultrasound-guided central venous (and arterial) catheter insertion, the epiaortic probe of the TEE system can be used. It is important to position the screen of the ultrasound system in front of the operator. (Troianos CA, Hartman GS, Glas KE, Skubas NJ, Eberhardt RT, Walker JD, Reeves ST, and for the Councils on Intraoperative Echocardiography and Vascular Ultrasound of the American Society of Echocardiography. Special Article: Guidelines for Performing Ultrasound Guided Vascular Cannulation: Recommendations of the American Society of Echocardiography and the Society of Cardiovascular Anesthesiologists. Anesth Analg. January 2012;114:46-72)

A full comprehensive TEE exam (or at least, the focused part, as related to the surgical structure, i.e., myocardium/ventricles, valve(s), aorta) should be completed prior to skin incision, to avoid interference from the electrocautery, and to establish a baseline before the hemodynamic perturbations. The table below is one suggestion, and one should/will develop his/her own sequence.

<table>
<thead>
<tr>
<th>Evaluation of:</th>
<th>Measurement/view/mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left Ventricle</td>
<td></td>
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<tr>
<td>Preload</td>
<td>EDV (Simpson’s in ME4/2C)</td>
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<tr>
<td></td>
<td>EDA (TG mid SAX)</td>
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<td></td>
<td>EDD (TG 2C)</td>
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<tr>
<td>Stroke Volume (and Ejection</td>
<td>2D: Simpson’s in ME4/2C</td>
</tr>
<tr>
<td>Fraction)</td>
<td>3D</td>
</tr>
<tr>
<td></td>
<td>Doppler: PWD in LVOT (deep TG LAX)</td>
</tr>
<tr>
<td>Systolic Function</td>
<td>Mitral annulus descent (M-mode in ME 2C): normal &gt;1 cm</td>
</tr>
<tr>
<td></td>
<td>%Fractional Shortening (TG 2C)</td>
</tr>
<tr>
<td></td>
<td>%Fractional Area Change (TG mid SAX)</td>
</tr>
<tr>
<td></td>
<td>(+)ve dp/dt (MR jet)</td>
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</tbody>
</table>
### Myocardial Performance Index (ME 4C, deep TG LAX)
- DTI: average of S’ velocities from mitral annulus: EF >50% if S’ >8 cm/s
- Flow in the two main coronary arteries

### Regional function
- Wall motion abnormalities – wall motion score index

### Diastolic function
- TMF and PVF (ME 4C)
- Color propagation velocity (ME 4C)

### Filling pressures
- LV mean diastolic pressure: TMF-E/DTI-E’, or
- LV mean diastolic pressure = 1.9 + (1.24 × E/E’)
- LV end-diastolic pressure: PVF-rA – TMF-A durations

### Right Ventricle

#### Systolic function
- %FAC (ME 4C)
- TAPSE (M-mode in deep TG LAX)
- DTI: S’ velocities from inflow and outflow (deep RV TG LAX)
- RV stroke volume: PWD in main PA/RVOT (UE arch SAX, deep RV TG LAX)

### Valve
- Anatomy with 2D and 3D
- Function/Functional orifice area of stenosed valve or regurgitant orifice

### Aorta
- Size (diameter in SAX)
- Disease: Dissection
- Atheroma

### Cavae, etc
- Size, tumors
- Interatrial septum defects/PFO (especially if cardiotomy is planned)
- Coronary sinus

### Pericardium
- Pericardial effusion

### Pleura
- Pleural effusions

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**B. Incision to pre-cannulation**

1. Surveillance for CO₂ absorption during endoscopic vein harvesting (ME bicaval view, “bubbles”)

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2. Regional wall motion abnormalities during preparation for cannulation

3. Re-establish a baseline after autologous whole blood withdrawal, fluid infusion, etc.


C. Cannulation

1. Aortic cannula: rule out aortic dissection (ME ascending aorta and descending aorta); if femoral artery cannulation: visualize the guidewire; if IABP: ensure proper depth, inflation and deflation of the balloon and flow is not interrupted in the left subclavian artery (Klopman MA, Chen EP, and Sniecinski RM. Echo Didactics: Positioning an Intraaortic Balloon Pump Using Intraoperative Transesophageal Echocardiogram Guidance. Anesth Analg 2011;113:40-43)


4. Ensure LV vent is inside the left atrium and through the mitral valve

D. Cardiopulmonary Bypass

1. Left Ventricle: is it decompressed? This is important in cases with AR but, in any case, if one considers that the aortic root is exposed to continuous bypass flow and the AV can become incompetent at any time as the heart is manipulated. This should be repeated during cardioplegia administration. The suggested view is the ME AV LAX: any AR is readily seen and the LV size can be quickly appreciated. If the LV vent is under suction it can be visualized with color flow Doppler, and of course, the LV size should be minimal following aorta cross-clamping.

2. Right Ventricle: is it decompressed? If not, it may be the reason for any acute changes in venous drainage and the need to decreased arterial pump flow. The two-stage or the two single-stage cannulae should be imaged with color flow Doppler. (Iannoli ED. The use of transesophageal echocardiography for differential diagnosis of poor venous return during cardiopulmonary bypass. Anesth Analg 2007;105:43-4)

3. Coronary perfusion: as for the pre-CPB period, the coronaries can be seen in the ME AV SAX/LAX and the circumflex course can be followed parallel to the coronary sinus. This may be important not only to verify whether the coronary arteries are perfused, but for the circumflex in particular, if it gets traumatized during a mitral valve intervention. (Tanzola RC, Allard R. Transesophageal Echocardiography of an Anomalous Circumflex Coronary Artery: Anatomy and Implications. Anesth Analg 2009;109:1029-31, Pybus DA. Transesophageal Imaging of an Internal Mammary Artery Graft During Repeat Cardiac Surgery. Anesth Analg. 2010;111:1128-31, Ender J, Singh R, Nakahira J, Subramanian S, Thiele H, Mukherjee C. Visualization of the Circumflex Artery in the Perioperative Setting with Transesophageal Echocardiography. Anesth Analg July
4. The flow in the descending aorta should be easy to visualize with color flow and pulsed wave Doppler directing from the right of the sector to the left (in the descending aorta LAX view); this basically excludes aortic dissection from arterial cannula insertion. (Pybus DA. Aortic atheromatous plaque instability associated with rotational aortic flow during cardiopulmonary bypass. Anesth Analg 2006;103:303-4)

5. The flow in the carotid arteries is imaged with color flow Doppler in the upper esophageal views. This may be important to document if the arterial cannula is inserted too distal or a surgical intervention of the ascending aorta or arch is underway. (Jerath A, Roscoe A, Vegas A. Normal Upper Esophageal Transesophageal Echocardiography Views. Anesth Analg 2012; 115:507-510)

E. After aortic unclamping

1. De-airing. This is important when cardiotomy occurred. Air is imaged as “fire-flies” moving in the direction of the blood flow.

1. Check for valvular function following AVR/repair (ME AV LAX/SAX) and MVR/repair (ME views). Any para-AVR leaks should be easy to diagnose, even if the LV is not contracting. The examination of the MV intervention should be done with the heart contracting and ejecting blood.

2. What is the ventricular contractility? The TG mid SAX view can give a quick estimate in CABG cases, the LVED area can provide a quick approximation of end-diastolic volume, and the %FAC of vascular tone and global systolic function. Inspection for RWMA should be done after blood has filled the LV; compare evolution of (any) RWMA from the pre-CPB period. The effect of the RV epicardial pacing on the motion of the septal wall segments should be considered.

3. What is the rhythm? Examination of the LA appendage or transmitral flow with pulsed wave Doppler will help distinguish whether the LA is contracting and blood is filling the LV at end-diastole.

4. Examine the right upper pulmonary vein (in a modified ME bicaval view) after removal of the LV vent catheter for increased blood velocity with color flow and pulsed wave Doppler. Although the consequences of the finding are not well understood, some flow is better than no flow at all!

F. Off CPB

1. Left ventricular function. Calculate the LV stroke volume with pulsed wave Doppler in the deep TG LAX view (quick: compare the velocity with the one from pre-CPB; long: trace the spectral envelope, obtain the VT and calculate the actual SV). Combine that with a visual estimation of the LV preload (TG mid SAX), and an “eyeball” estimate of EF and regional wall motion abnormalities.

2. Focused examination of the valvular intervention. Look for paraprosthetic leaks/flow. Prior to protamine administration, the effective orifice areas of the AVR prosthesis or the repaired/replaced MV should be estimated (color flow Doppler: acceleration means increased blood flow or small orifice) or measured.

3. The repeated examination of the RV and LV function are important up until and after chest closure. More so, if the volume of the infused blood and blood products is large.

4. Examine for residual air after the chest is closed and prior to transfer to the bed.

5. Examine the pleural and pericardial space for any collections.