Advanced Transesophageal Echocardiography
Objectives

- Identify four major adverse cardiac events (MACE) associated with anesthesia
- List four risk factors associated with MACE
- Define “rescue echo” as it relates to MACE
- Compare risk/benefit of PTE to more invasive hemodynamic monitors such as CVP and pulmonary artery catheters
Cardiac Ablation for Typical Flutter

- 50 year-old UPS carrier with two month history of atrial flutter HR 130
- Mild SOB, 8 METS by history (still working)
- EF 55%, mild mitral regurgitation two months ago
- General anesthesia due to use of TEE to rule out LAA thrombus
The “Bend and Snap”

- 2 mg midazolam
- Lidocaine 100 mg
- Fentanyl 100 mcg
- 150 + 50 mg propofol
- 50 mg rocuronium
- Easy mask, grade 1 view
- Easy intubation
Aftermath of the Bend and Snap

- Resuscitated after:
  - CPR/DCCV
  - 2 mg epinephrine
  - 4 units vasopressin
  - 25 mg ephedrine
- Case cancelled, TEE at bedside
- Global LV dysfunction (EF 10%)
- 4+ mitral regurgitation
- 5.1 cm atrium
Major Adverse Cardiac Events (MACE)

- Used as an index of safety and effectiveness of various treatment approaches
  - Death (all-cause mortality)
  - Myocardial infarction
  - Stent thrombosis
  - Need for revascularization
  - Cardiac arrest
  - Stroke

- Helps associate predictive risk with need for additional therapies/evaluations

History/Risk Factors

- Reduced function status (< 4 METS)
- Ischemic heart disease
  - MI/angina
  - Stents/CAB
- Heart failure/class
- Cardiomyopathy
- Severe/symptomatic heart valve disease especially aortic stenosis
- Significant dysrhythmias
- Chronic renal failure
- CVA or TIA
- Insulin-dependent diabetic
- Chronic pulmonary disease
- Obesity
- Anemia
# Patient Predictors for Adverse Outcomes

<table>
<thead>
<tr>
<th>Major</th>
<th>Intermediate</th>
<th>Minor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unstable coronary syndromes</td>
<td>Mild angina pectoris</td>
<td>Advanced age</td>
</tr>
<tr>
<td>Decompensated CHF</td>
<td>Prior MI</td>
<td>Abnormal ECG</td>
</tr>
<tr>
<td>Significant arrhythmias</td>
<td>Compensated or prior CHF</td>
<td>Rhythm other than sinus</td>
</tr>
<tr>
<td>Severe valve disease</td>
<td>Diabetes mellitus (insulin dependent)</td>
<td>Low functional capacity</td>
</tr>
<tr>
<td></td>
<td>Renal insufficiency (Creatinine &gt; 1.5)</td>
<td>History of stroke with residual dysfunction</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uncontrolled hypertension</td>
</tr>
</tbody>
</table>

### Surgical Predictors for Adverse Outcomes

<table>
<thead>
<tr>
<th>High Risk (&gt;5%)</th>
<th>Intermediate Risk (1-5%)</th>
<th>Low Risk (&lt;1%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aorta and major vascular surgery</td>
<td>Abdominal surgery</td>
<td>Breast</td>
</tr>
<tr>
<td>Peripheral vascular surgery</td>
<td>Carotid surgery</td>
<td>Dental</td>
</tr>
<tr>
<td></td>
<td>Peripheral arterial angioplasty</td>
<td>Endocrine</td>
</tr>
<tr>
<td></td>
<td>Endovascular aneurysm repair</td>
<td>Eye</td>
</tr>
<tr>
<td></td>
<td>Head and neck surgery</td>
<td>Gynecology</td>
</tr>
<tr>
<td></td>
<td>Neurological/orthopedic (major)</td>
<td>Reconstructive</td>
</tr>
<tr>
<td></td>
<td>Pulmonary/renal/liver transplant</td>
<td>Orthopedic (minor)</td>
</tr>
<tr>
<td></td>
<td>Urologic (major)</td>
<td>Urologic (minor)</td>
</tr>
</tbody>
</table>

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Perioperative Events Associated with Hemodynamic Instability

- Myocardial ischemia
- Heart valve dysfunction
- Heart failure
- Dysrhythmias
- Congenital heart defects
- Pulmonary hypertension
- Hypo/hypervolemia
- Pericardial effusion
- Air/venous/thromboembolism
- Vascular dissection
Trends in MACE

Trends in MACE Based on Surgery Type

Limitations of CVP Monitoring

- **Indirect** measurement of left-sided filling volumes
- Unless very high or very low, **useful only as trend**
- Accuracy of filling volumes affected by
  - Decreased right ventricular function
  - Tricuspid valve disease
  - Positive pressure ventilation
  - Rapid volume infusion
Outcomes Using Pulmonary Artery Catheters

- Detect, treat and trend myocardial ischemia
- Measure and optimize ventricular preload and volume in surgery with large volume shifts and aortic cross-clamp
- Detect, treat and trend valvular dysfunction
- Limitations include no measurable effect on outcome and misinterpretation of data

<table>
<thead>
<tr>
<th>Outcome</th>
<th>PAC</th>
<th>No PAC</th>
<th>Statistical Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mortality (medical and surgical)</td>
<td></td>
<td></td>
<td>( p=0.68, \text{RR}=1.01 )</td>
</tr>
<tr>
<td>Mortality (surgical only)</td>
<td></td>
<td></td>
<td>( p=0.91, \text{RR}=0.98 )</td>
</tr>
<tr>
<td>ICU LOS</td>
<td></td>
<td></td>
<td>( p=0.74 )</td>
</tr>
<tr>
<td>Hospital LOS (general intensive care)</td>
<td>✔️</td>
<td></td>
<td>( p=0.41 )</td>
</tr>
<tr>
<td>Hospital LOS (high risk surgical)</td>
<td>✔️</td>
<td></td>
<td>( p=0.08 )</td>
</tr>
<tr>
<td>Cost of care</td>
<td></td>
<td></td>
<td>( p=0.62 ) (does not include physician fees)</td>
</tr>
</tbody>
</table>

Utility of Advanced Blood Pressure Monitoring

- Continuous real-time monitoring of BP
- Continuous cardiac output using pulse contour analysis
- Analysis of waveform
  - Upstroke or ejection velocity
  - Stroke volume from area under curve
  - Systole/Diastole
  - Pulse Pressure Variation

Flotrac Limitations—Tool or Toy?

- Dependent on arterial waveform quality
- Demographic/algorithim issues
- Affected by hemodynamic instability?
- Affected by arrhythmias (e.g., atrial fibrillation)
- Affected by altered SVR/vasopressors
- Strict tidal volume requirements (8-10 ml/kg)
- Affected by right heart failure and pulsus alternans
- Affected by IABP (new algorithm compensates?)
- Affected by ventricular assist devices
- Advanced blood pressure monitoring may be beneficial
  - Beat-to-beat BP/stroke volume/SVV
  - Easy to interpret, ability to monitor ABG
- Risk and benefit should guide use of more advanced cardiovascular monitors
  - Pulmonary artery catheter
  - Transesophageal Echo

<table>
<thead>
<tr>
<th>Parameter</th>
<th>TEE</th>
<th>PAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV, RV, global and regional function</td>
<td>+++</td>
<td>Indirect</td>
</tr>
<tr>
<td>Left and right heart preload</td>
<td>Direct</td>
<td>Indirect</td>
</tr>
<tr>
<td>CO and stroke volume</td>
<td>+</td>
<td>+++</td>
</tr>
<tr>
<td>Pulmonary artery pressure</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Anatomy</td>
<td>+++</td>
<td>-</td>
</tr>
<tr>
<td>Shunts</td>
<td>+++</td>
<td>+</td>
</tr>
<tr>
<td>Tamponade</td>
<td>+++</td>
<td>Indirect</td>
</tr>
<tr>
<td>Valve dysfunction</td>
<td>+++</td>
<td>Indirect</td>
</tr>
<tr>
<td>Observer dependent</td>
<td>Significant</td>
<td>Moderate</td>
</tr>
<tr>
<td>Complications</td>
<td>&lt;1%</td>
<td>1-5%</td>
</tr>
</tbody>
</table>

Lobo, de Oliveira-Clinical review: What are the best hemodynamic targets for noncardiac surgical patients? Critical Care, 2014, 17:210-217
Recommended Uses of TEE

- Cardiac Surgery
  - All open heart procedures (e.g., heart valves) and aorta procedures
  - CABG for new or unsuspected pathology or to assess results of surgical intervention
  - Transcatheter intracardiac procedures (e.g., TAVR)

- Noncardiac Surgery
  - Surgery or known CV pathology might result in severe hemodynamic compromise
  - Unexplained life-threatening circulatory instability persists despite corrective therapy

- Critical Care
  - Diagnostic information expected to alter management cannot be obtained by TTE or other modalities

Hemodynamic Assessments using TEE

- LV/RV ejection fraction
- LV contractility
- LV filling status
- Wall motion and ischemia
- Heart valve function
- Stroke volume
- Cardiac index
- Pulmonary artery pressures
- Heart valve function
Rescue Transesophageal Echocardiography

- Urgent and emergent use of transesophageal echocardiography (TEE)
- Allows effective diagnosis of the causes of hemodynamic instability during cardiac and noncardiac surgical procedures
- Intraoperative causes can be categorized as types of
  - Hypovolemic shock
  - Cardiogenic shock
  - Distributive shock
  - Obstructive shock

Key Rescue TEE Windows

Transgastric Midpapillary

Midesophageal Four Chamber

Midesophageal Long Axis

Images showing different views of the heart:
- Transgastric Midpapillary view highlighting the inferior, anterior, and lateral views.
- Midesophageal Four Chamber view showing the left atrium (LA), right atrium (RA), right ventricle (RV), and left ventricle (LV).
- Midesophageal Long Axis view with the left atrium (LA) and aortic valve (Ao) highlighted.
Midesophagaeal Four Chamber and Apical Four Chamber
Midesophageal Long Axis and Parasternal Long Axis
Transgastric Midpapillary Short Axis and Parasternal Short Axis
Myocardial ischemia was present in up to 27 percent of patients undergoing rescue TEE.

Normal ventricular systolic function includes both endocardial excursion toward the center of the LV cavity and systolic thickening of the LV wall.

Myocardial ischemia is qualitatively assessed by detecting RWMAs on the TEE short and long-axis views of the LV.
Myocardial Ischemia/
Anterior Wall Motion Abnormality
Left Ventricular Dysfunction
Hypovolemia
Hypovolemia
Hypovolemia
Aortic Stenosis

- Severe AS is suggested by heavily calcified or poorly mobile aortic valve leaflets
- Continuous-wave Doppler is used to confirm diagnosis
  - Transvalvular gradient using velocity
  - Aortic valve area using VTI
- LVH is often present and hemodynamic management dictated by this finding
Aortic Stenosis with 117 mmHg Gradient
Aortic Stenosis
Aortic Insufficiency

- Color flow Doppler is used to measure the largest jet width in the LVOT.
- Jet width is expressed as a percentage of the width of the LVOT.
- Mild regurgitation is a jet width <25 percent of the LVOT (severe ≥65 percent of the LVOT).
- Causes of acute aortic regurgitation include acute aortic dissection involving the aortic root or endocarditis.
Aortic Insufficiency
Aortic Insufficiency
Mitral Regurgitation

- Causes of severe MR:
  - Chordal/papillary rupture
  - Myocardial ischemia
  - Decompensated heart failure
  - Septal Anterior Motion (SAM)

- MR is qualitatively estimated in the ME 4C or ME LAX
  - Color-flow Doppler
  - Vena contracta

- Ongoing assessment may provide an index of the success of interventions
Mitral Regurgitation
Severe mitral stenosis (MS) is best identified using the ME 4C view

- Mitral valve thickening is observed with reduced leaflet opening
- High-velocity LV inflow on color-flow Doppler imaging

Severe MS is often accompanied by severe RV dysfunction and pulmonary hypertension
Mitral Stenosis
Hypertrophic Cardiomyopathy

- Dynamic LVOT obstruction and/or mitral valve SAM have been noted in approximately 4 percent of patients undergoing intraoperative rescue TEE.
- LVOT obstruction and the severity of MR are influenced by cardiac loading conditions and inotropic state.
- Tachycardia and low SVR worsen the SAM and decrease forward flow.
HOCM with SAM
Aortic Dissection

- Rescue TEE findings consistent with aortic injury may be found
- Aortic dissection or other injury is most commonly diagnosed by TEE in certain patients presenting to the ER
- Only limited visualization of the distal ascending aorta and proximal aortic arch is possible with TEE examination (TTE suprasternal view better)
Aortic Dissection
Aortic Dissection
Atrial Septal Defect
Ventricular Septal Defect

- Rescue TEE used for any cardiopulmonary instability, including hypoxemia
- While uncommon, ASD/VSD may be found in the setting of hypoxemia especially with recent MI
- Color flow mapping demonstrates blood flow direction and velocity
Pulmonary Embolism
General Indications for Rescue TEE

- Refractory hypotension
- Hypoxia
  - Patent foramen ovale
  - Atrial septal defect
- ECG changes/arrhythmias
- Shock/cardiac arrest
- Myocardial ischemia
- Tamponade
- Dissection
- Rescue TEE can provide a working diagnosis that led to additional therapies in >80 percent of patients

Instability due to Hypovolemia

- Hypotension and low cardiac output is due to reduced intravascular volume
- Up to 42% of all patients requiring rescue TEE had findings consistent with hypovolemia
- Hypovolemia manifests as a small LV cavity size associated with normal or hyperdynamic global LV systolic function
Instability due to Vasodilation

- Hemodynamic instability due to severe peripheral vasodilation with reduced systemic vascular resistance.
- Findings consistent with low SVR states were present in 4-10% of rescue echo patients.
- Low SVR manifests as a very small left ventricular (LV) cavity at end-systole, but with normal end-diastolic values.
Hemodynamic instability with inflow/outflow obstruction is due to reduced cardiac output caused by an extracardiac cause of cardiac pump failure.

Usually associated with physical obstruction of the great vessels or heart.

Pulmonary embolism and tamponade are the most common forms (nail in the heart least common).
Cardiac Tamponade

- Hemodynamic instability due to cardiac tamponade is present in 7 to 9 percent of patients.
- The incidence is highest in trauma patients, CPR and in pacemaker or defibrillator lead extraction.
- Findings in cardiac tamponade typically include collapse of the right atrium (RA), right ventricle (RV) and possibly left ventricle (LV).
Pulmonary Embolism

- Rescue echo diagnoses thromboembolic PE in up to 16 percent of noncardiac surgical patients (usually orthopedic surgery)
- Overall sensitivity of TEE for PE detection is typically 50-80%
- Rescue TEE or transthoracic echocardiography (TTE) has also been used to diagnose air, fat, cement, tumor, or amniotic fluid embolic phenomena
Cardiogenic Shock-LV Failure

- Hemodynamic instability with cardiogenic shock is due to reduced cardiac output (CO)
- Findings consistent with LV failure were present in up to 50 percent of patients during rescue TEE
- Using transgastric LV midpapillary short-axis (TG LV SAX) view, qualitative estimates of LV systolic function and LV ejection fraction (LVEF) can be rapidly obtained
Cardiogenic Shock - RV Failure

- Hemodynamic instability due to moderate or severe RV failure were present in up to 29 percent of patients.

- Causes of RV dysfunction include PE, myocardial ischemia or infarction, pulmonary arterial hypertension, or primary respiratory failure.

- Global RV failure is qualitatively assessed on the ME 4C view, with TR or reduced tricuspid valve annular plane systolic excursion towards the RV apex.
Most Common Findings in Rescue TEE (Jasdavius)

- Systematic review of echo use in high risk (n=568) or hemodynamically unstable (n=400) patients
- The most frequent diagnoses were valvulopathy, low LVEF, hypovolemia, PE, wall motion abnormalities, and RV failure
- Studies included employed comprehensive echo exams performed by those with advanced training

<table>
<thead>
<tr>
<th>Finding</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low EF</td>
<td>20.5%</td>
</tr>
<tr>
<td>RV Dysfunction</td>
<td>13.1%</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>32.2%</td>
</tr>
<tr>
<td>New Wall Motion Abnormality</td>
<td>10.2%</td>
</tr>
<tr>
<td>Pulmonary Embolism</td>
<td>5.8%</td>
</tr>
<tr>
<td>All other diagnoses</td>
<td>17.7%</td>
</tr>
</tbody>
</table>

Most Common Findings in Rescue TEE (Shilcutt)

- TEE exam (8 of 11 PTE views)
- TTE exam (4 FATE and 3 other views)
- Impact was significant
  - Drug treatment change in 21 patients
  - Fluid or ventilator change in 10 patients

<table>
<thead>
<tr>
<th>Finding</th>
<th>n/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV Dysfunction-Systolic</td>
<td>14 (45%)</td>
</tr>
<tr>
<td>LV Dysfunction-Diastolic</td>
<td>10 (32%)</td>
</tr>
<tr>
<td>RV Dysfunction</td>
<td>9 (29%)</td>
</tr>
<tr>
<td>Hypovolemia</td>
<td>5 (16%)</td>
</tr>
<tr>
<td>New Wall Motion Abnormality</td>
<td>4 (13%)</td>
</tr>
<tr>
<td>Cardiac Tamponade</td>
<td>1 (3%)</td>
</tr>
<tr>
<td>Pulmonary Embolism</td>
<td>5 (16%)</td>
</tr>
</tbody>
</table>

Interventions Based on Findings (Markin)

- Review of 364 rescue echo studies at Utah
- Rescue TEE consult obtained, exam by established perioperative TEE team
- Emphasis was on diagnoses and management impact
- 62% of TEE exams resulted in management changes
- 41% resulted in volume administration, 17% in inotropes, 12% in vasopressors

### Management Impact of Interventions

#### Management Changes as a Result of Rescue Echocardiography Findings

<table>
<thead>
<tr>
<th>Management Changes N = 364</th>
<th>Number of Rescue Echocardiograms Showing Management Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total (%)</td>
</tr>
<tr>
<td>All management changes</td>
<td>214 (58.8%)</td>
</tr>
</tbody>
</table>

**Types of management changes:**

<table>
<thead>
<tr>
<th>Type</th>
<th>Management Changes</th>
<th>Number of Rescue Echocardiograms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid administration</td>
<td>113 (31.0%)</td>
<td>83 (41.1%)</td>
</tr>
<tr>
<td>Inotropes</td>
<td>64 (17.6%)</td>
<td>34 (16.8%)</td>
</tr>
<tr>
<td>Vasopressors</td>
<td>40 (11.0%)</td>
<td>25 (12.4%)</td>
</tr>
<tr>
<td>Inhaled vasodilators</td>
<td>8 (2.2%)</td>
<td>3 (1.5%)</td>
</tr>
<tr>
<td>Diuretics</td>
<td>5 (1.4%)</td>
<td>1 (0.5%)</td>
</tr>
<tr>
<td>Surgical changes</td>
<td>27 (7.4%)</td>
<td>9 (4.5%)</td>
</tr>
<tr>
<td>Other medical changes</td>
<td>18 (4.9%)</td>
<td>11 (5.4%)</td>
</tr>
</tbody>
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## Rescue TEE-Diagnostic Targets

<table>
<thead>
<tr>
<th>Clinical Interest</th>
<th>Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV systolic <strong>function</strong> and dimensions</td>
<td>LV dysfunction, dilation (Eyeball EF)</td>
</tr>
<tr>
<td>RV systolic <strong>function</strong></td>
<td>RV dysfunction (TAPSE, free wall motion)</td>
</tr>
<tr>
<td><strong>Volume</strong> status</td>
<td>Chamber size (Kissing paps, systolic size)</td>
</tr>
<tr>
<td>Pericardial <strong>effusion</strong></td>
<td>Presence of pericardial effusion, chamber compression</td>
</tr>
<tr>
<td>Gross signs of chronic heart disease</td>
<td>Atrial/ventricular hypertrophy, LV to RV size ratio</td>
</tr>
<tr>
<td>Gross <strong>valvular abnormalities</strong></td>
<td>Orifice, leaflet coaptation, Color Flow Mapping/Doppler</td>
</tr>
<tr>
<td>Intracardiac <strong>Masses</strong></td>
<td>Vegetations, intracardiac masses or thrombi</td>
</tr>
<tr>
<td><strong>Wall motion</strong> abnormality</td>
<td>Thickening, hypokinesis/akinesis</td>
</tr>
</tbody>
</table>
Relative and Absolute Contraindications for Transesophageal Echocardiography

- Esophageal disease
  - Stricture/Varices
  - Tumor
- Prior esophageal or stomach surgery
  - Esophagectomy
  - Gastric bypass
- Difficulty passing the TEE probe
- Anticoagulation
  - INR
  - Thrombocytopenia
- Facial or airway trauma
Summary

- MACE occurs up to 7% of noncardiac cases and risk factors have been delineated.
- TTE/TEE is useful before, during and after anesthesia in a wide range of patients and clinical settings.
- Transesophageal echo is easily placed and may change intraoperative management.
  - Monitoring
  - Diagnostics
- Rescue Echo has broad utility in the care of perioperative patients undergoing anesthesia.
  - Differential diagnosis of clinical findings
  - Rescue from cardiopulmonary instability
  - Rapid diagnosis, immediate assessment including response to treatment