Advanced Transesophageal Echocardiography

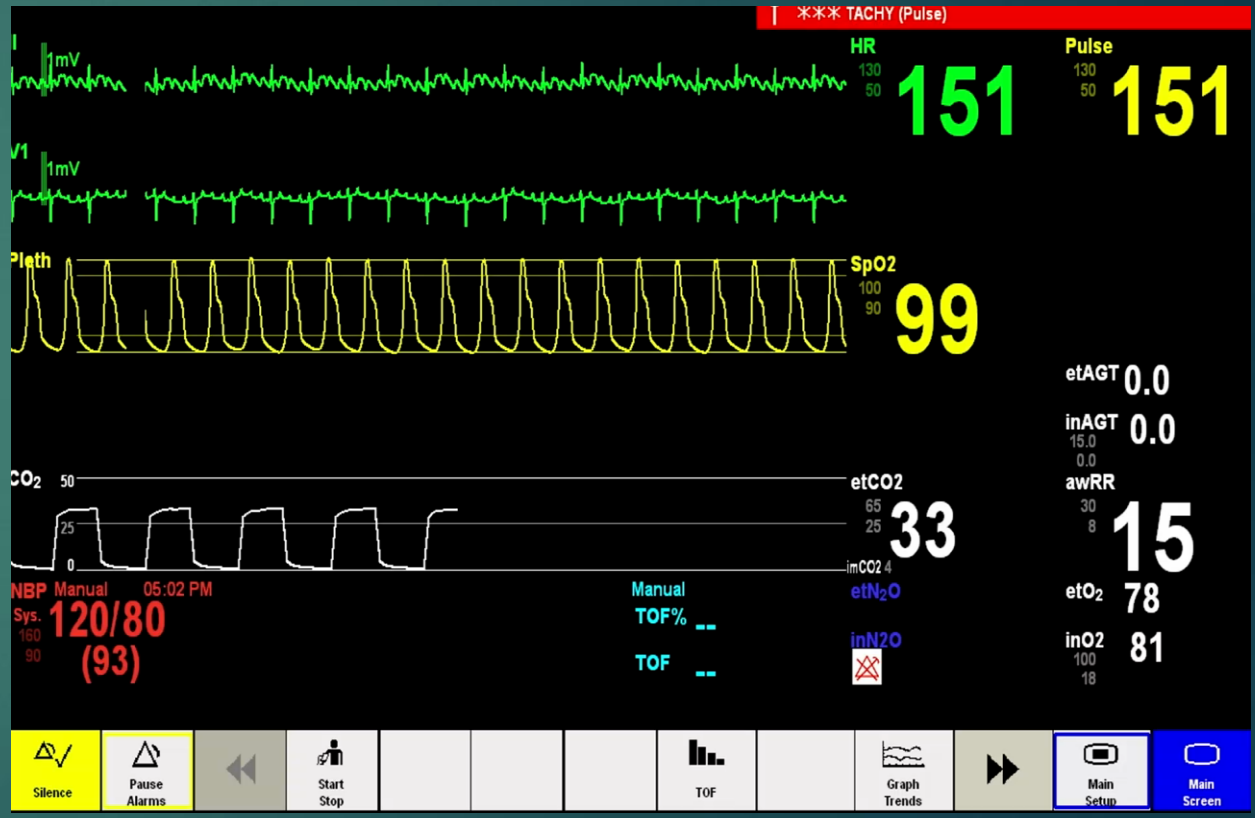
RESCUE ECHOCARDIOGRAPHY

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

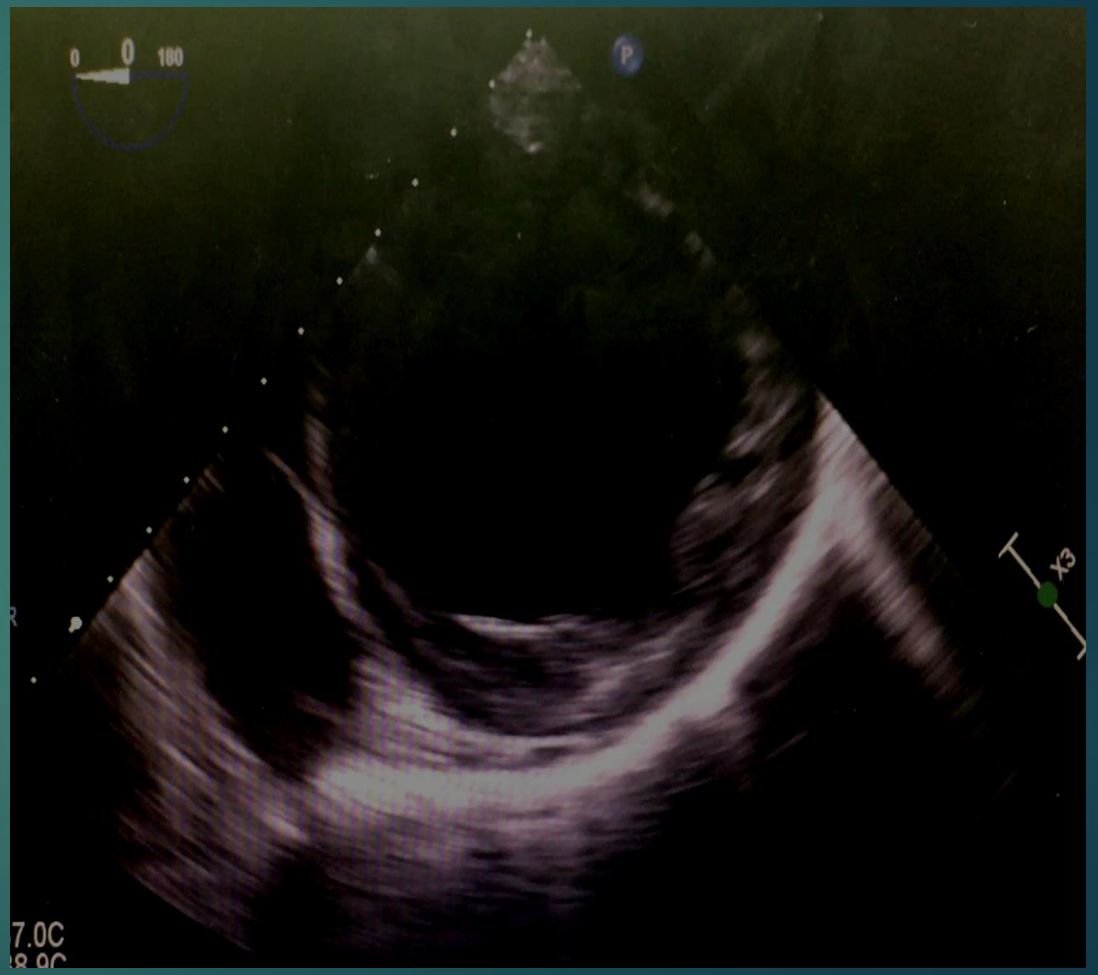


The “Bend and Snap”

- 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

Tashira et al. Perioperative risk of major non-cardiac surgery in patients with severe aortic stenosis: a reappraisal in contemporary practice. Eur Heart Journal, 2014

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

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

Eagle et al: ACC/AHA guideline update for perioperative cardiovascular evaluation for noncardiac surgery: executive summary: a report of the American College of Cardiology/ American Heart Association Task Force on Practice Guidelines JACC Vol. 39, No. 3, 2002:542–53

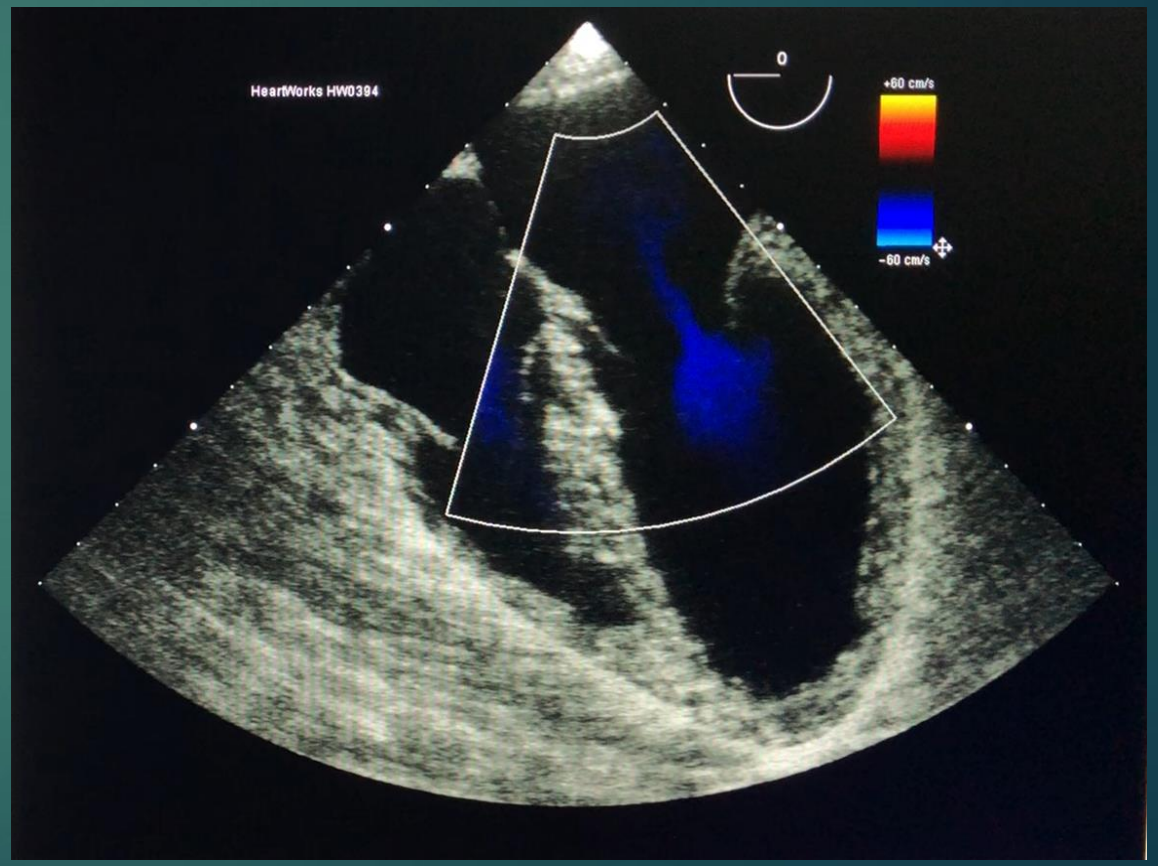
Surgical Predictors for Adverse Outcomes

High Risk (>5%)	Intermediate Risk (1-5%)	Low Risk (<1%)
Aorta and major vascular surgery	**Abdominal surgery**	Breast
Peripheral vascular surgery	**Carotid surgery**	Dental
	Peripheral arterial angioplasty	Endocrine
	Endovascular aneurysm repair	Eye
	Head and neck surgery	Gynecology
	Neurological/orthopedic (major)	Reconstructive
	Pulmonary/renal/liver transplant	Orthopedic (minor)
	Urologic (major)	Urologic (minor)

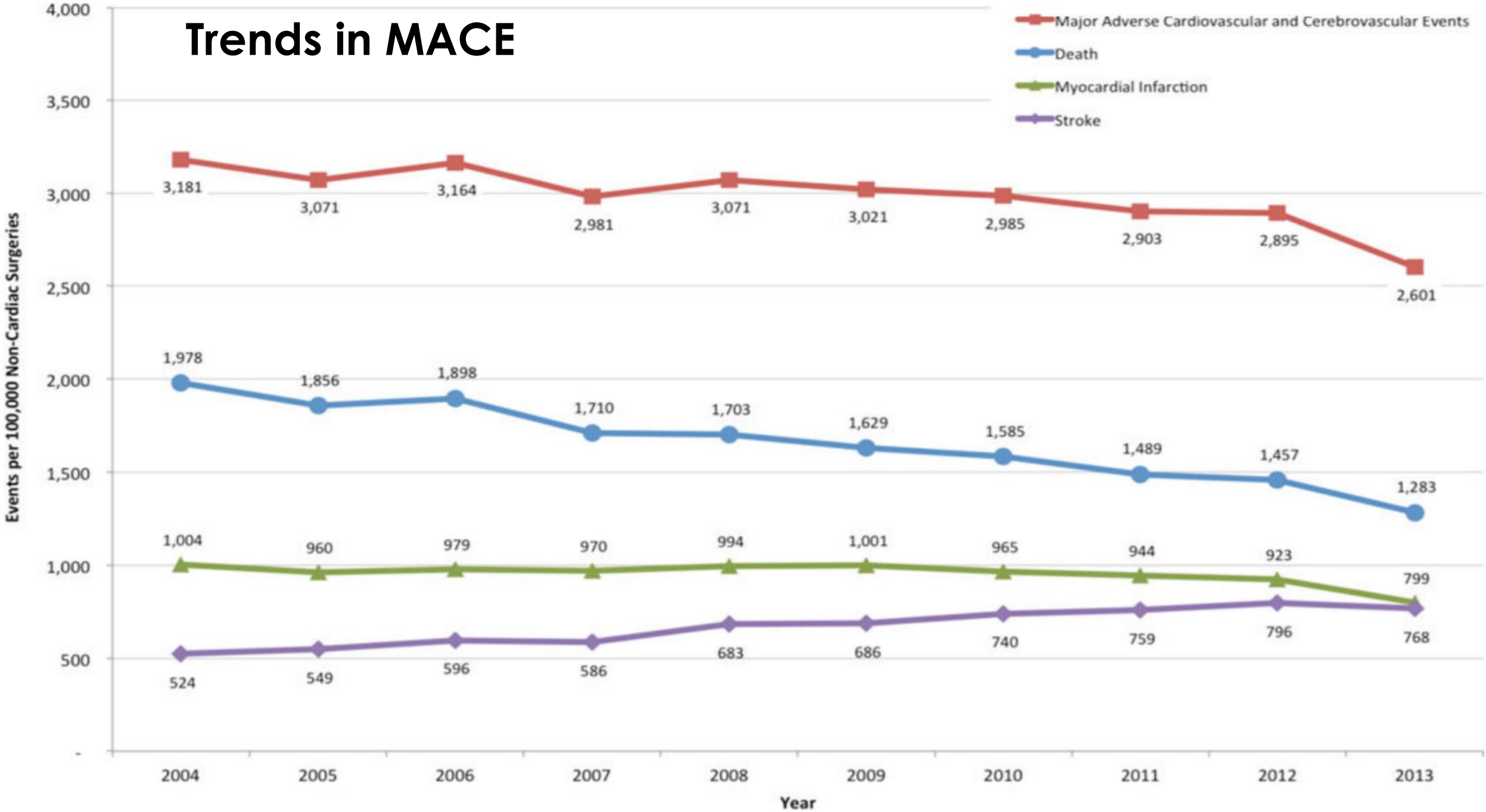
Task Force for Preoperative Cardiac Risk Assessment and Periop Cardiac Management. Guidelines for pre-operative cardiac risk assessment and perioperative management in non-cardiac surgery. 2009, Eur Heart J , 2769-2812

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

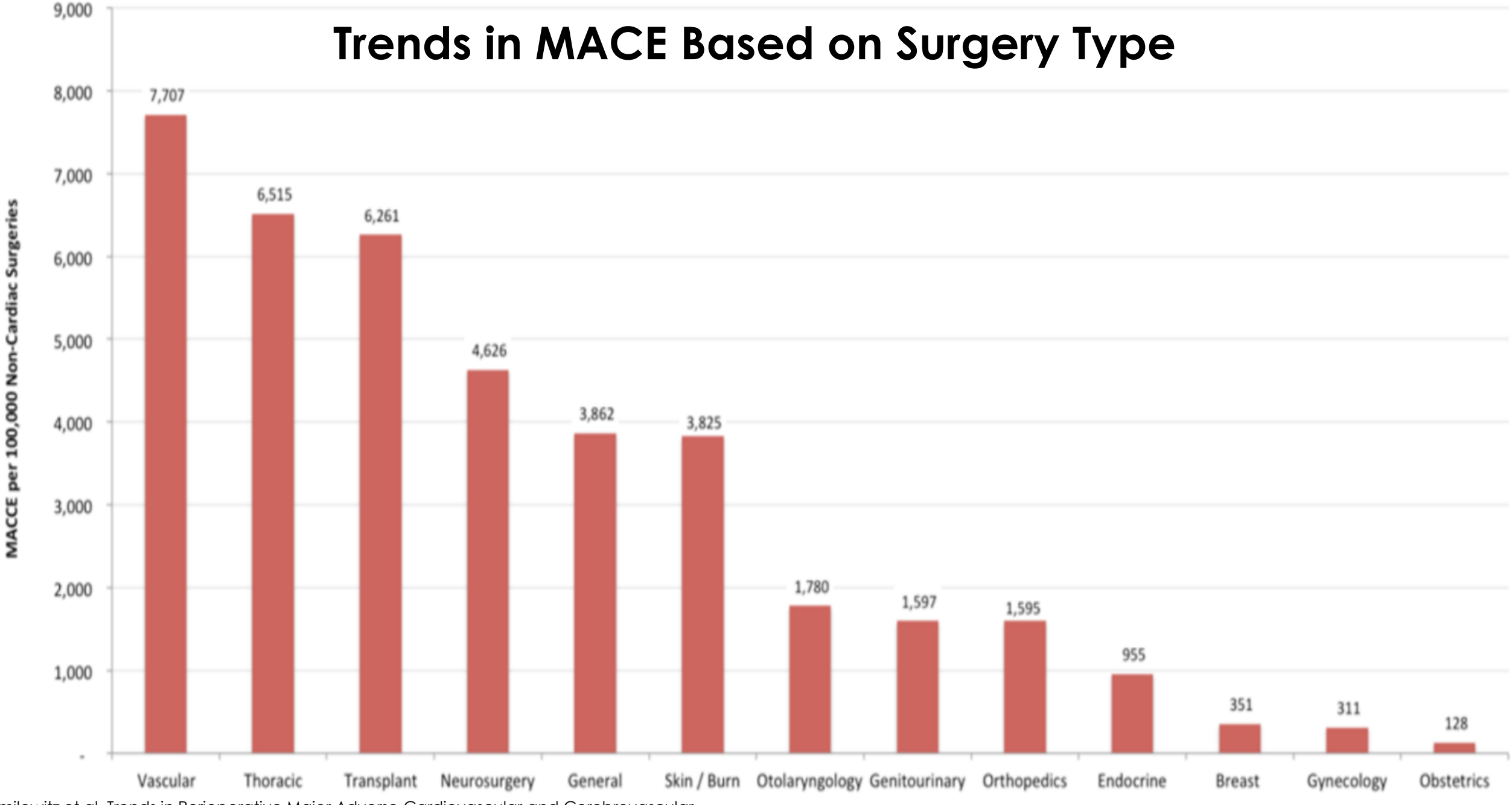


Trends in MACE



Smilowitz et al. Trends in Perioperative Major Adverse Cardiovascular and Cerebrovascular Events associated with Non-Cardiac Surgery. JAMA Cardiol. 2017; 2:181-187

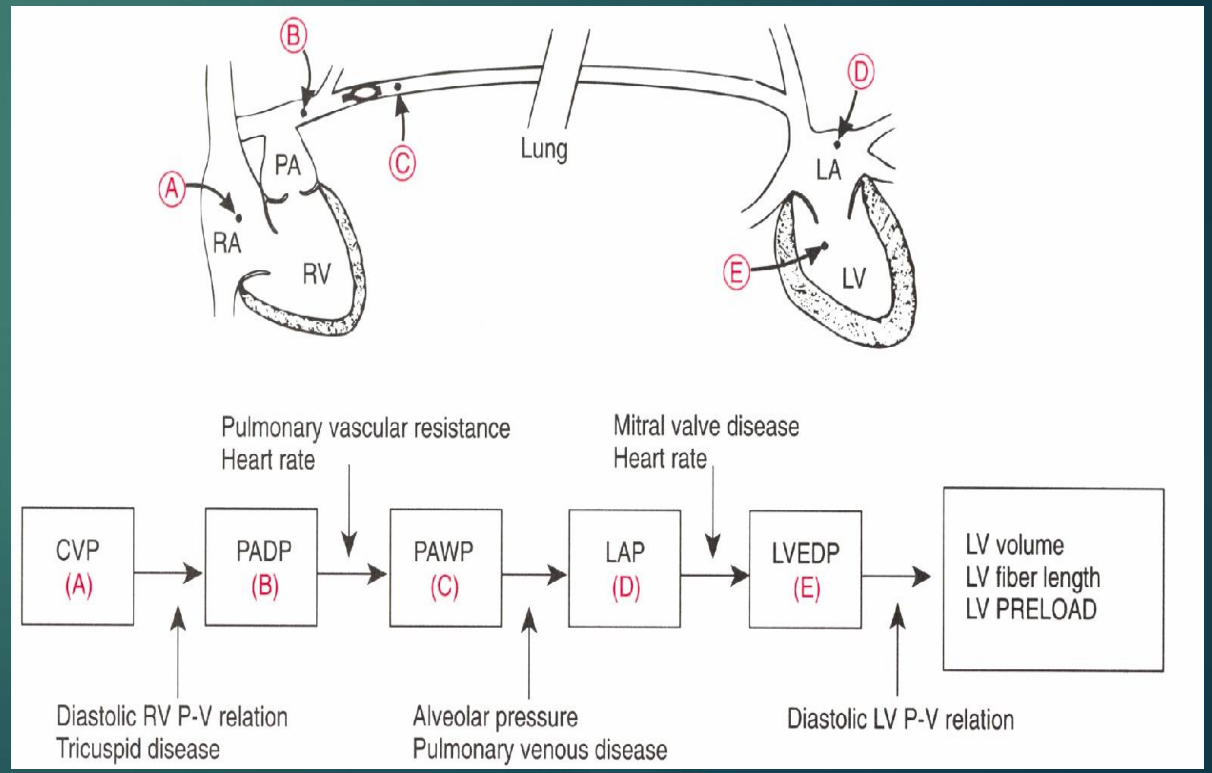
Trends in MACE Based on Surgery Type



Smilowitz et al. Trends in Perioperative Major Adverse Cardiovascular and Cerebrovascular Events associated with Non-Cardiac Surgery. JAMA Cardiol, 2017; 2:181-187

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

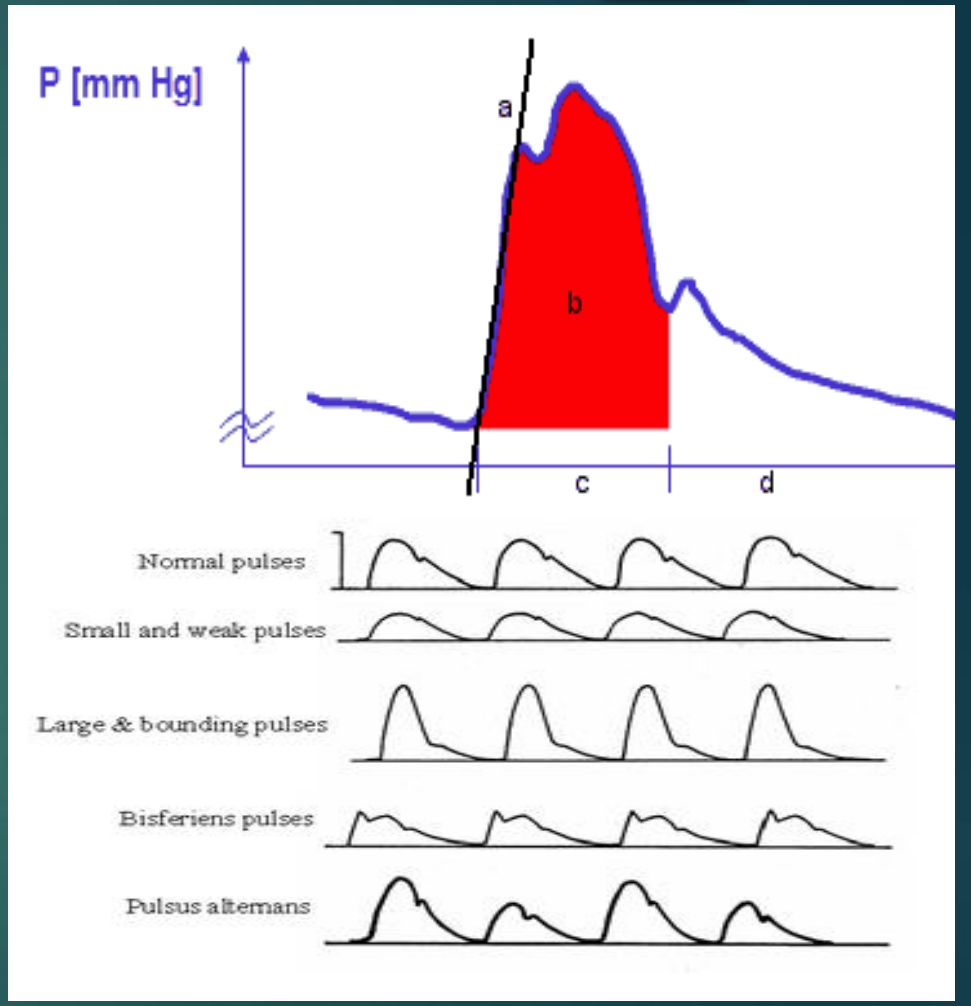
- Detect, treat and trend myocardial ischemia
- Measure and optimize ventricular preload and volume in surgery with large volume shifts and aortic cross-clamp
- Detect, treat and trend valvular dysfunction
- Limitations include **no measurable effect on outcome and misinterpretation of data**

Outcome	PAC	No PAC	Statistical Comparison
Mortality (medical and surgical)			*p*=0.68, RR=1.01
Mortality (surgical only)			*p*=0.91, RR=0.98
ICU LOS			*p*=0.74
Hospital LOS (general intensive care)			*p*=0.41
Hospital LOS (high risk surgical)			*p*=0.08
Cost of care			*p*=0.62 (does not include physician fees)

Rajaram et al-Pulmonary artery catheters for adult patients in intensive care. The Cochrane Collaboration, 2013

Utility of Advanced Blood Pressure Monitoring

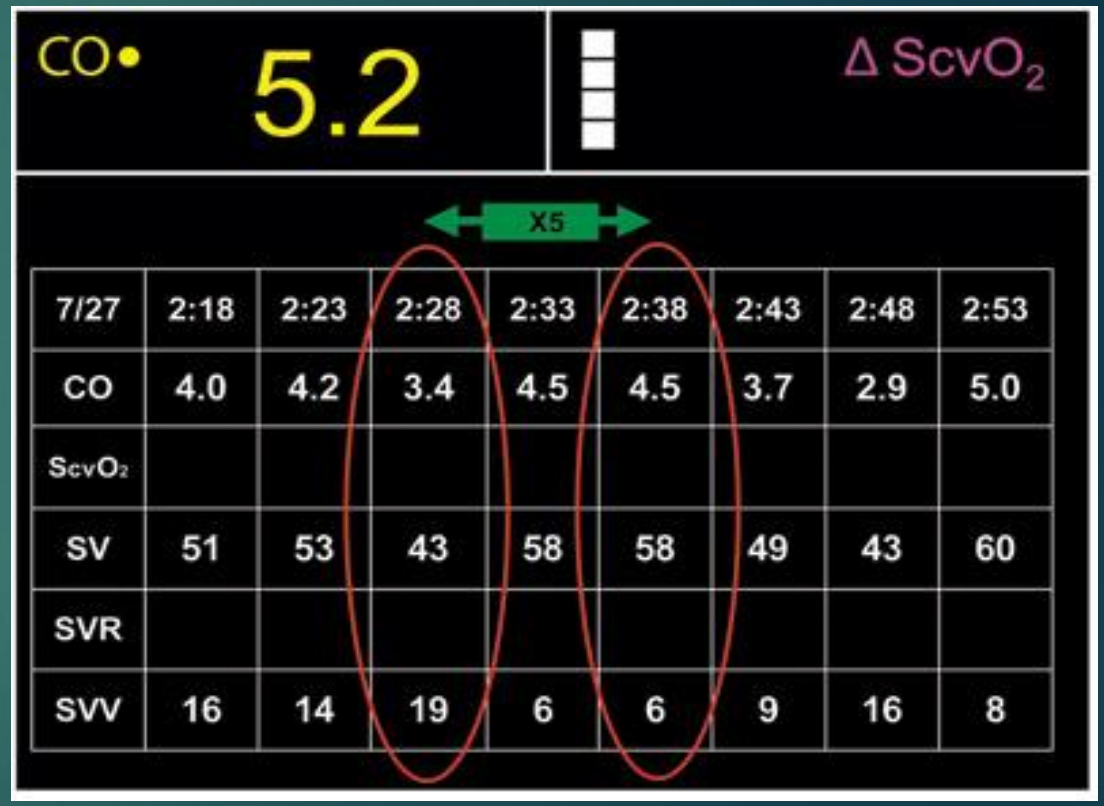
- Continuous real-time monitoring of BP
- Continuous cardiac output using pulse contour analysis
- Analysis of waveform
  - Upstroke or ejection velocity
  - Stroke volume from area under curve
  - Systole/Diastole
  - Pulse Pressure Variation



Michard et al-Relation between Respiratory Changes in Arterial Pulse Pressure and Fluid Responsiveness in Septic Patients with Acute Circulatory Failure. Am J Resp Crit Crare Med, 2000, 162:134-138

Flotrac Limitations-Tool or Toy?

- Dependent on arterial waveform quality
- Demographic/algorithm 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



7/27	2:18	2:23	2:28	2:33	2:38	2:43	2:48	2:53
CO	4.0	4.2	3.4	4.5	4.5	3.7	2.9	5.0
ScvO2								
SV	51	53	43	58	58	49	43	60
SVR								
SVV	16	14	19	6	6	9	16	8

Monnet-Third-generation FloTrac/Vigileo does not reliably track changes in cardiac output induced by norepinephrine in critically ill patients. BJA, 2012, 108:615-622

TEE: Advanced Hemodynamic Monitor?

- 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

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

Parameter	TEE	PAC
LV, RV, global and regional function	+++	Indirect
Left and right heart preload	Direct	Indirect
CO and stroke volume	+	+++
Pulmonary artery pressure	++	+++
Anatomy	+++	-
Shunts	+++	+
Tamponade	+++	Indirect
Valve dysfunction	+++	Indirect
Observer dependent	Significant	Moderate
Complications	<1%	1-5%

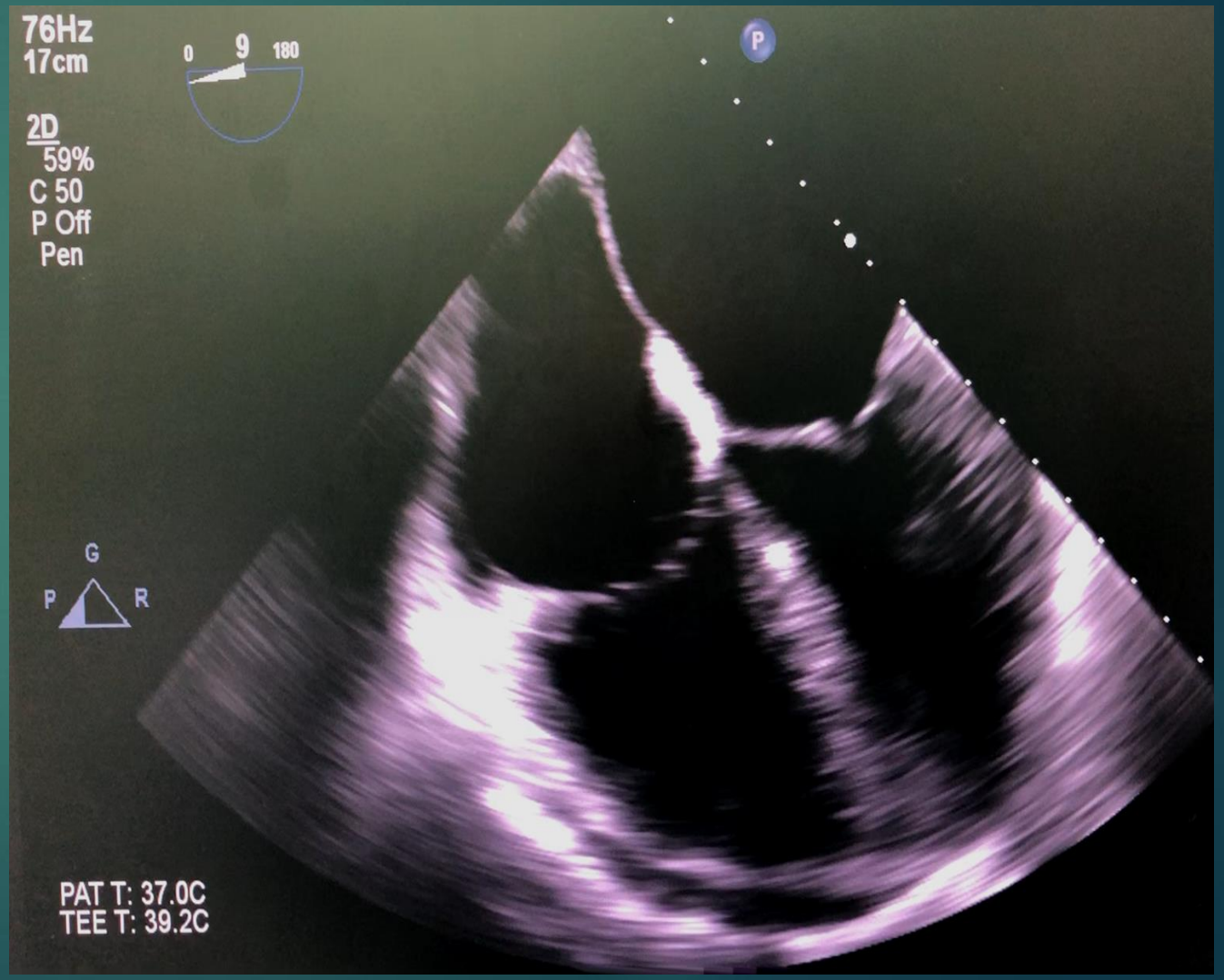
Recommended Uses of TEE

- 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

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

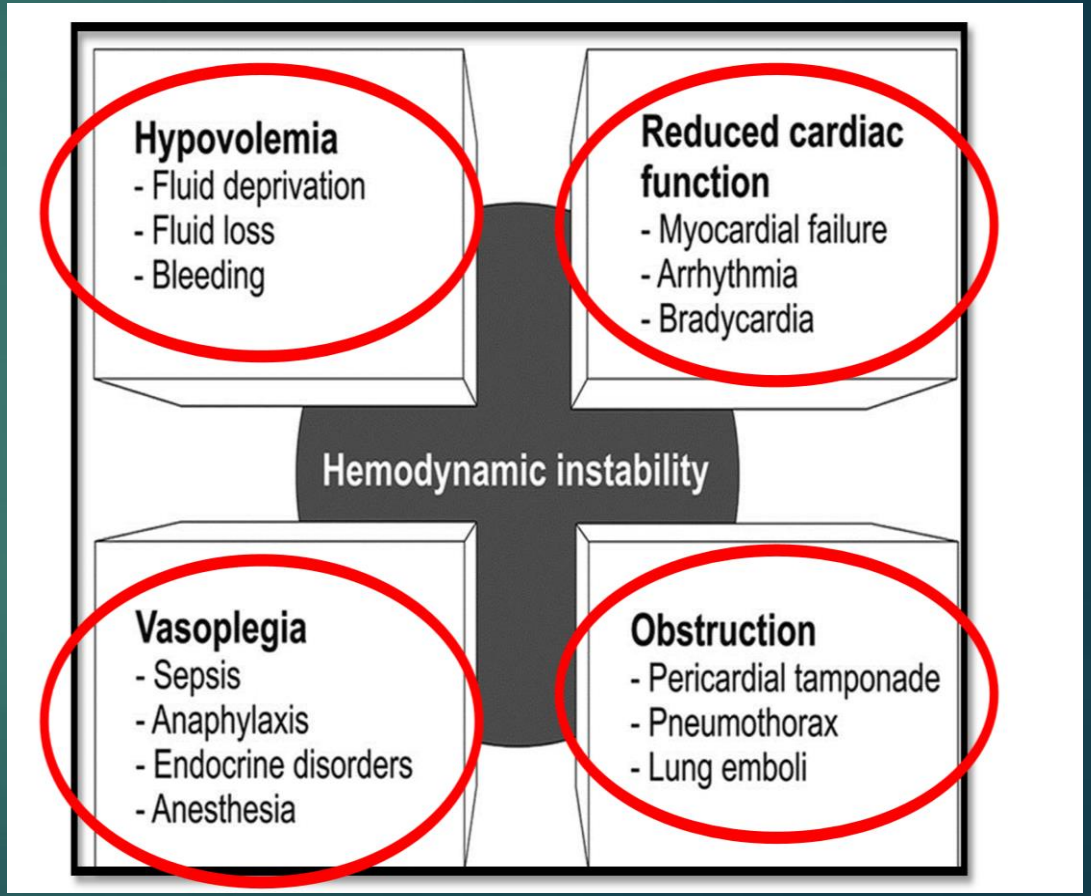
Hemodynamic Assessments using TEE

- 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

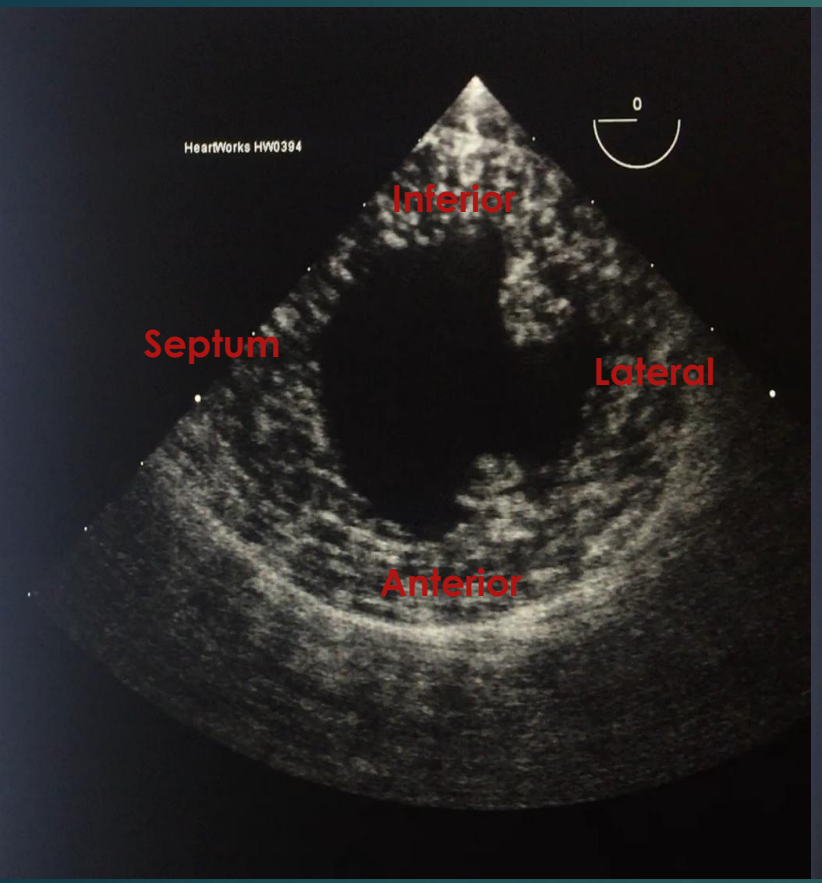
- Urgent and emergent use of transesophageal echocardiography (TEE)
- Allows effective diagnosis of the causes of hemodynamic instability during cardiac and noncardiac surgical procedures
- Intraoperative causes can be categorized as types of
  - Hypovolemic shock
  - Cardiogenic shock
  - Distributive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



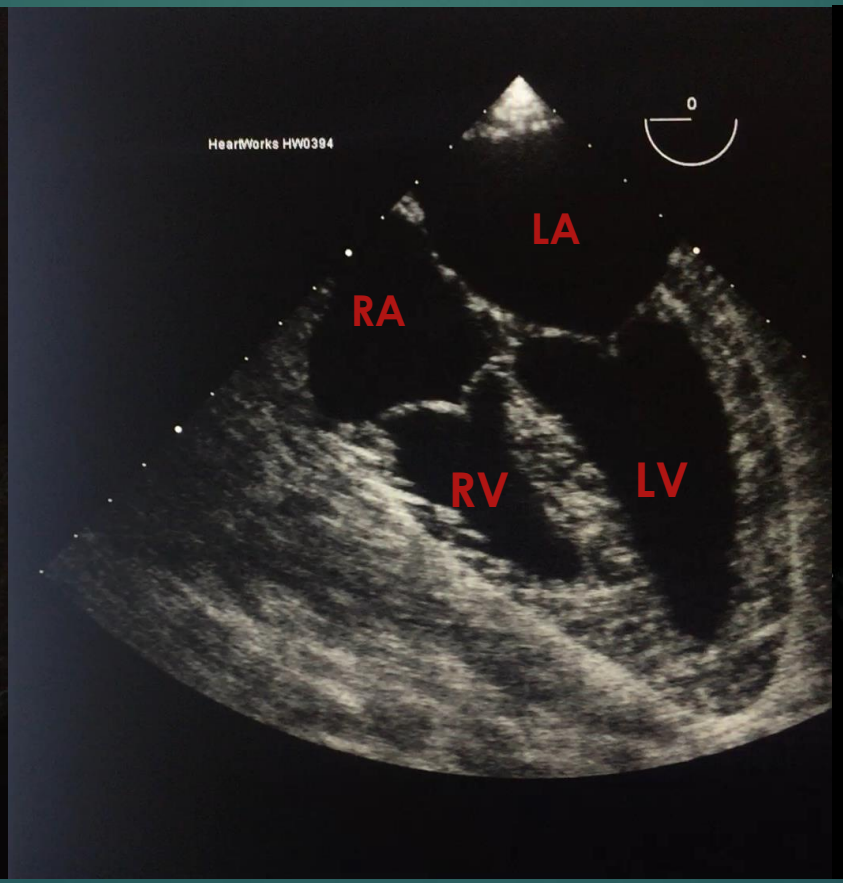
Hofer CK, Mizuguchi AK, Popescu WM. Monitoring the patient at risk of hemodynamic instability at remote locations. *Int Anesthesiol Clin*, 2012, 50:141-172.

Key Rescue TEE Windows

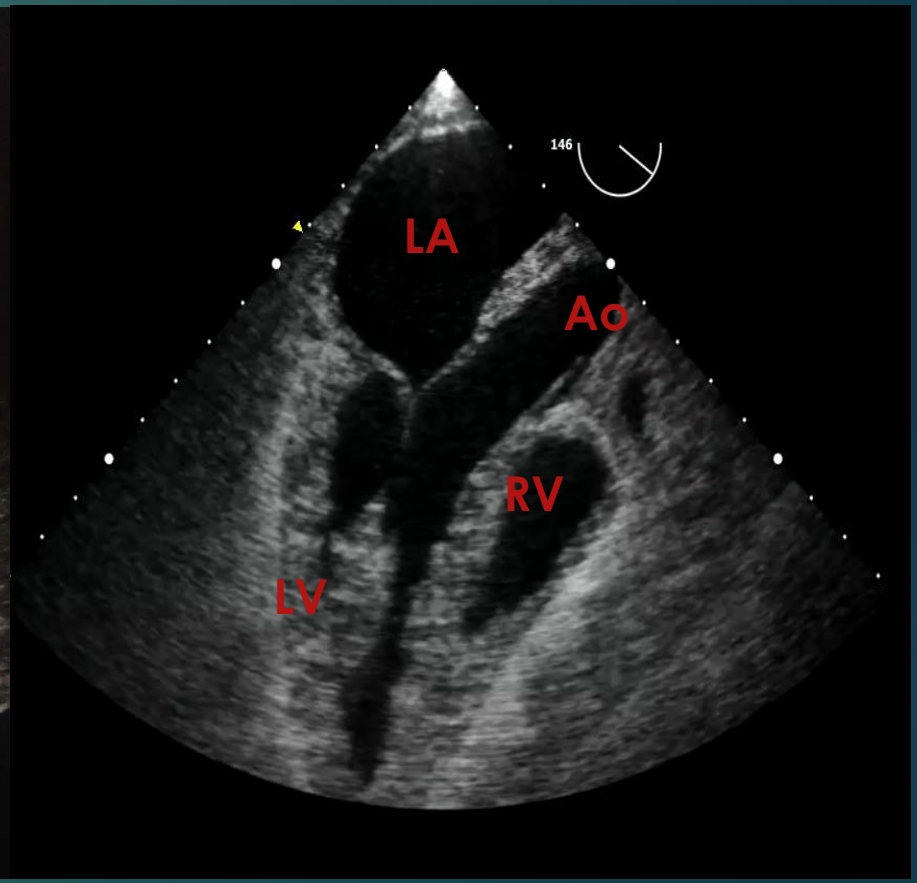
Transgastric
Midpapillary



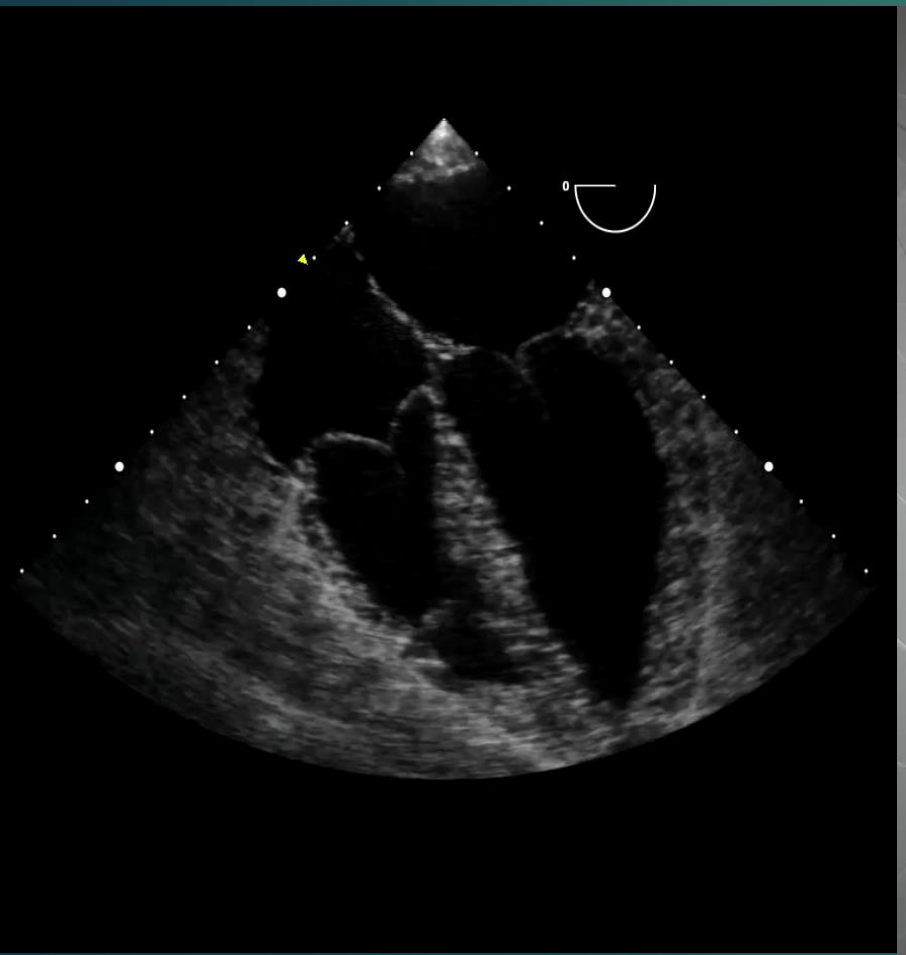
Midesophageal
Four Chamber

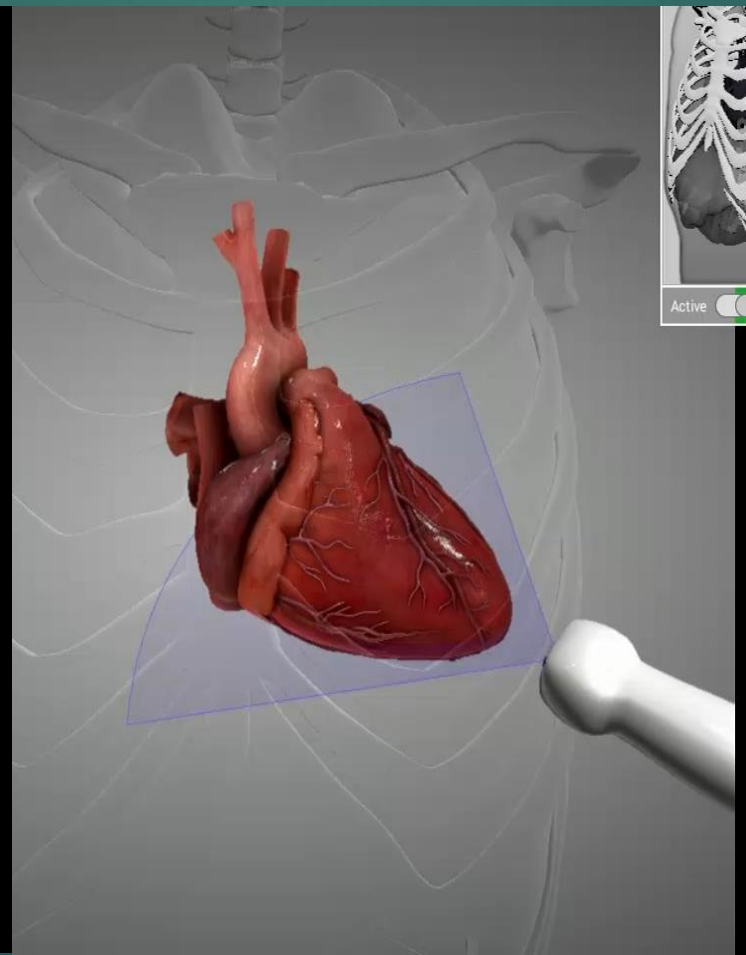


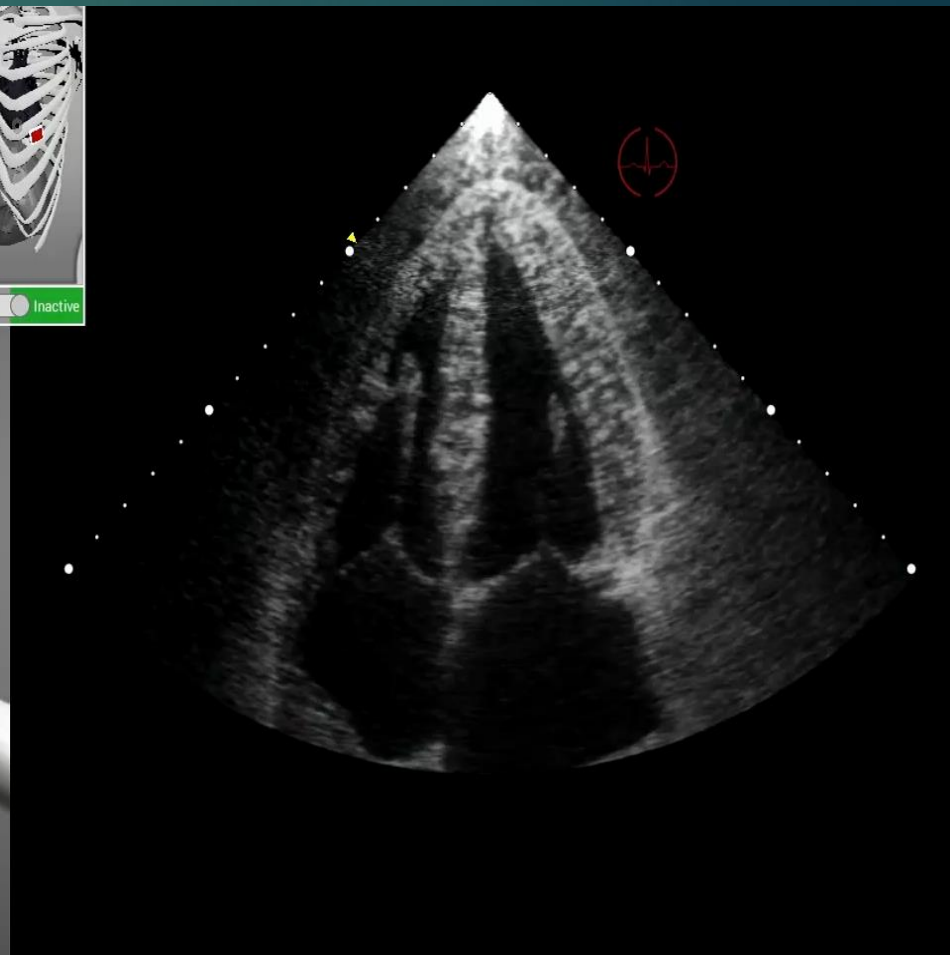
Midesophageal
Long Axis



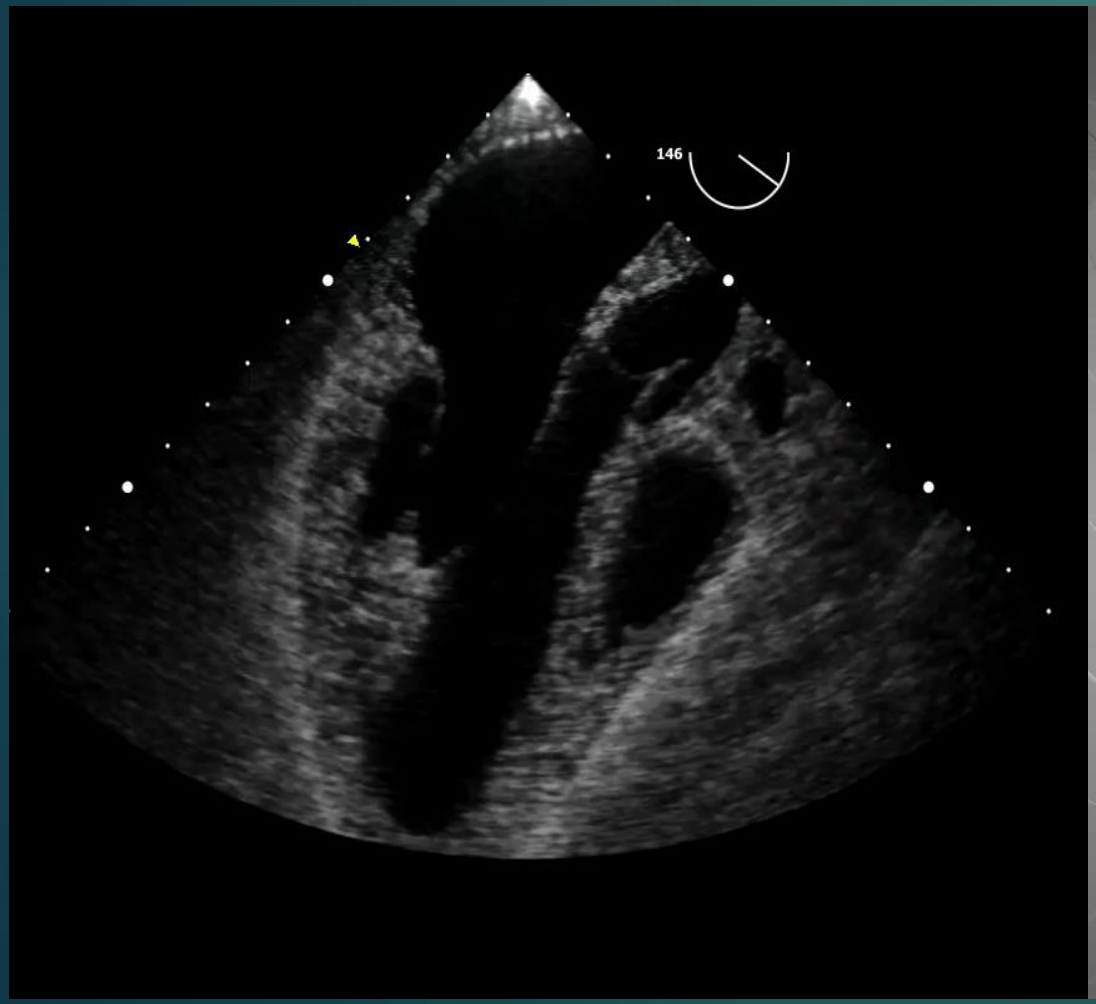
Midesophageal Four Chamber and Apical Four Chamber

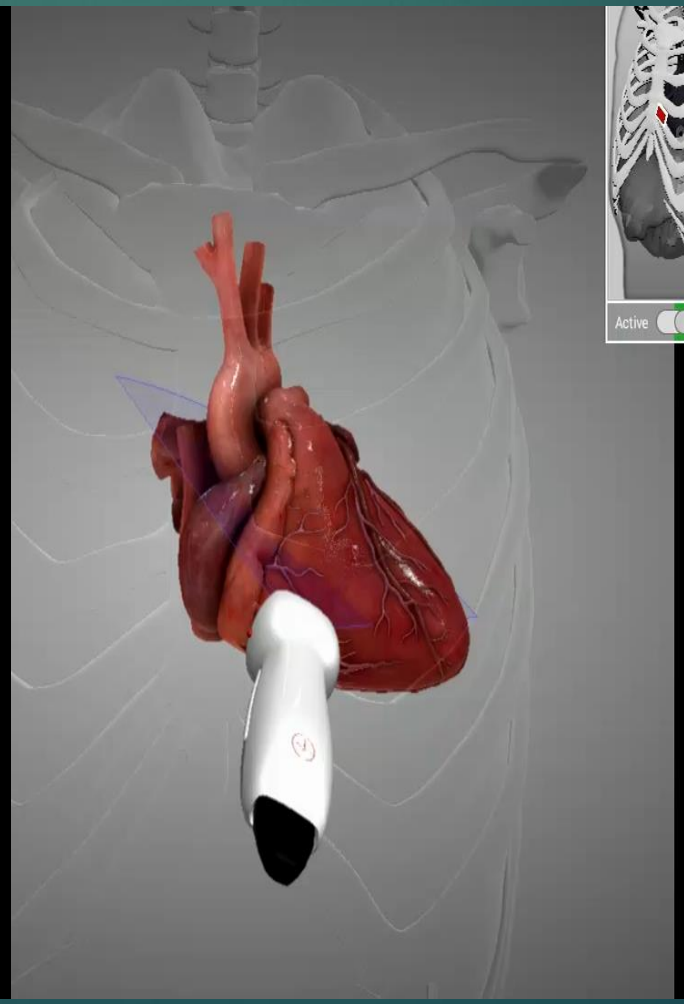


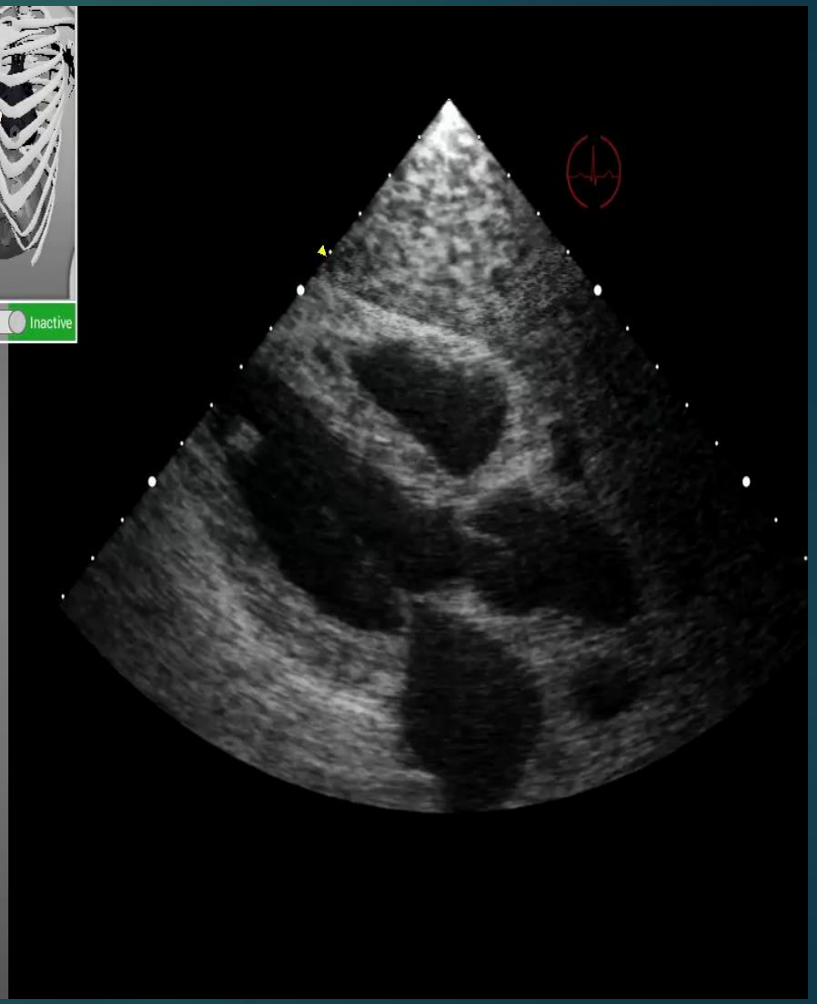




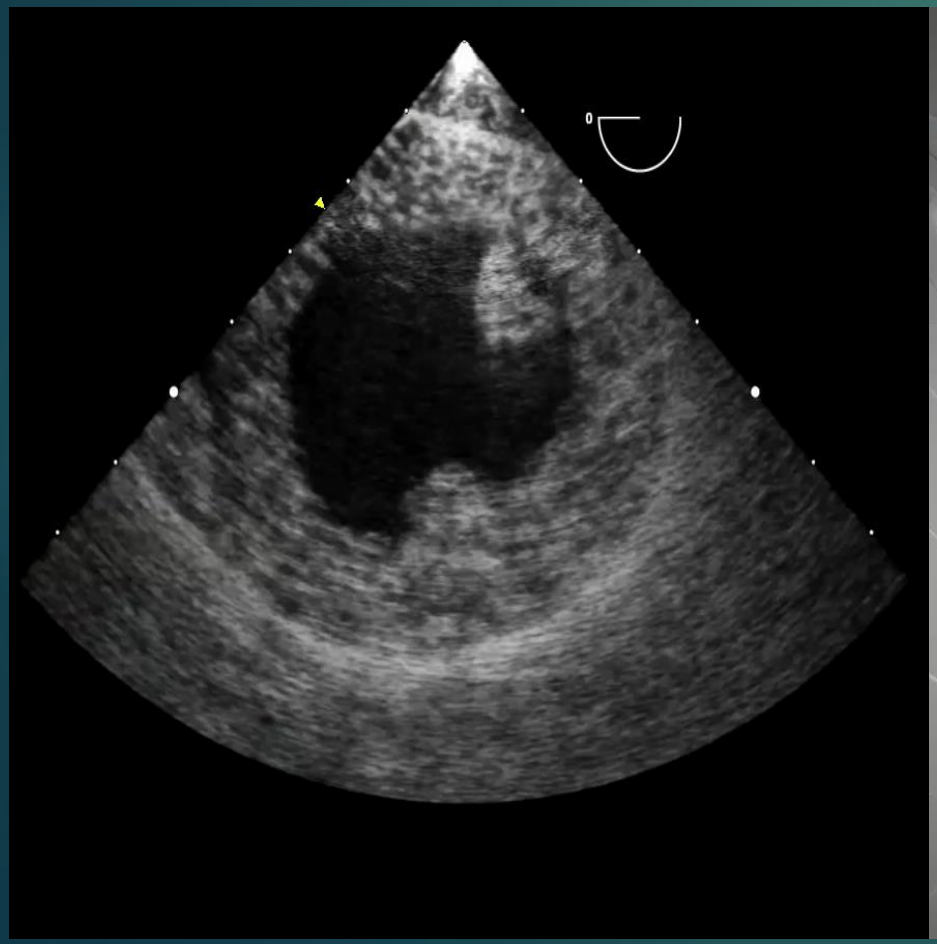
Midesophageal Long Axis and Parasternal Long Axis

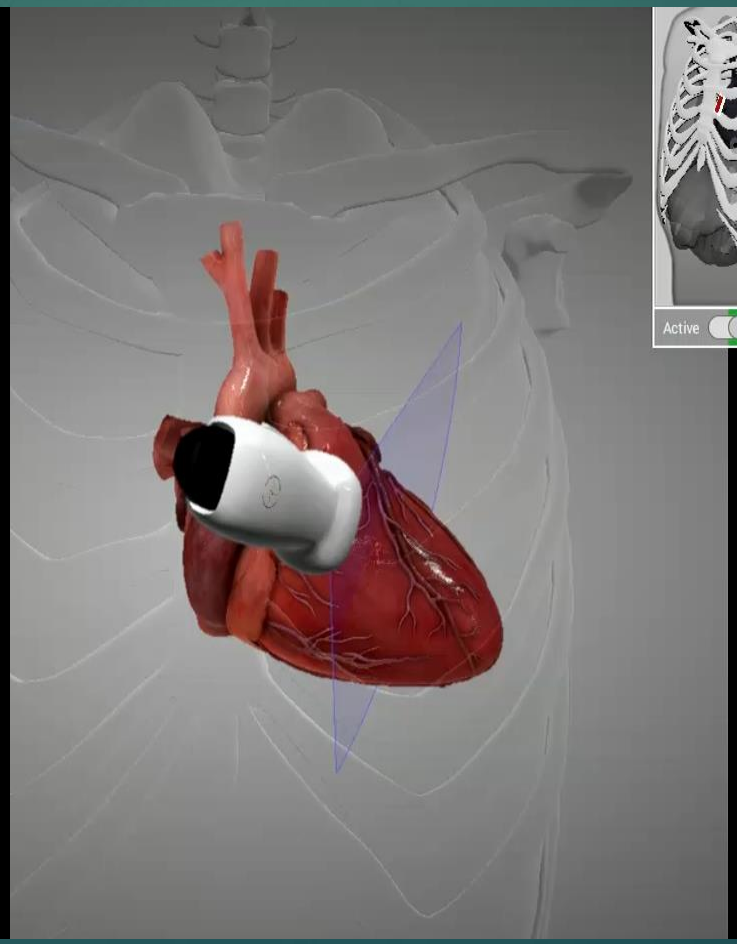


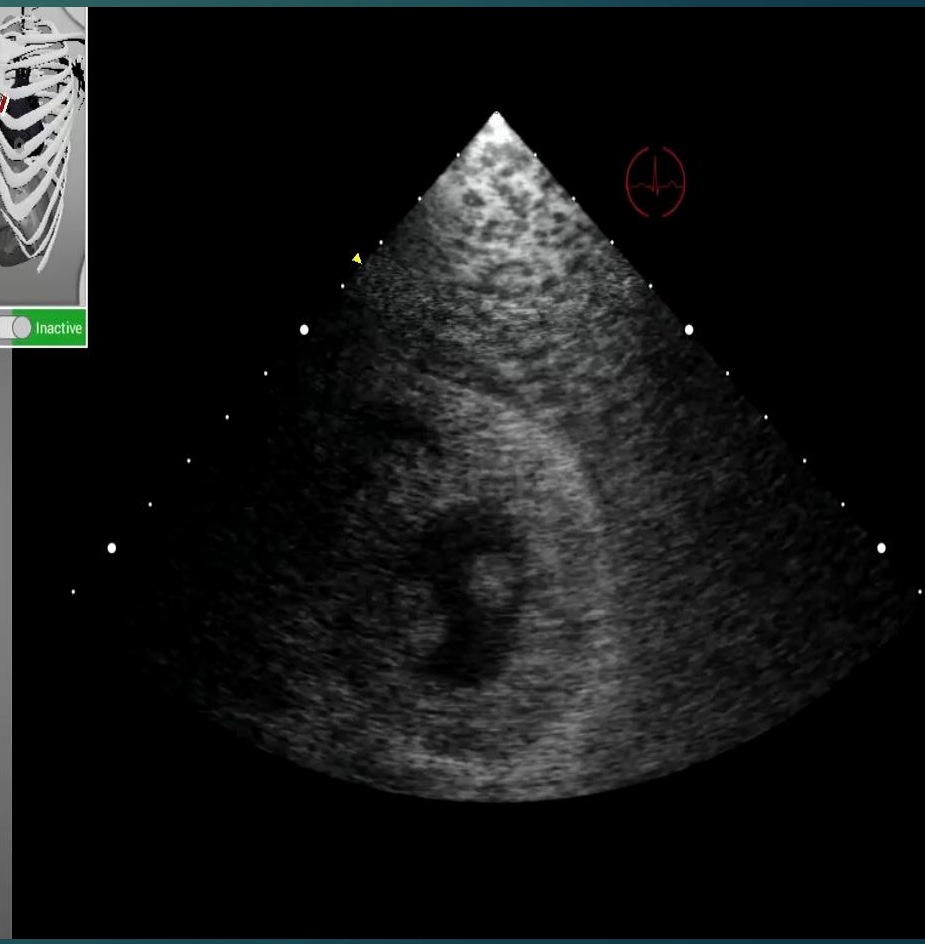




Transgastric Midpapillary Short Axis and Parasternal Short Axis

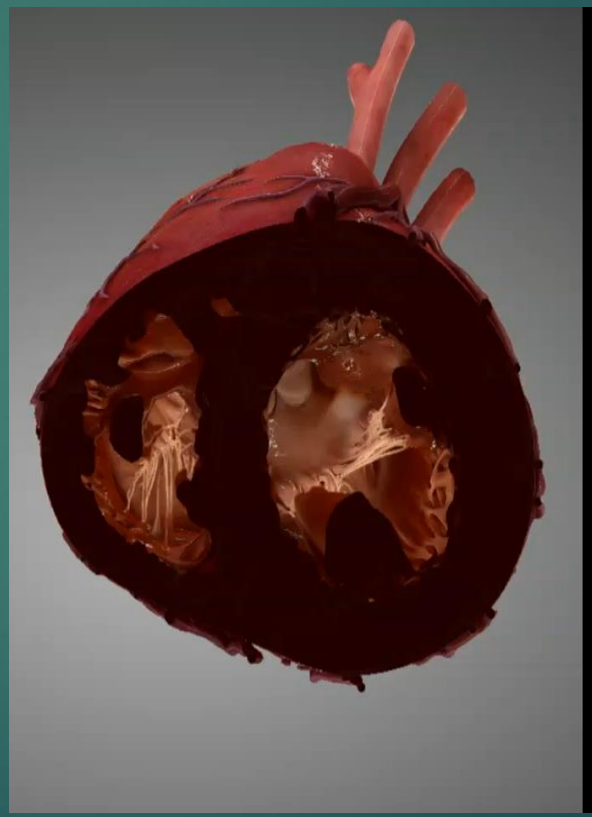


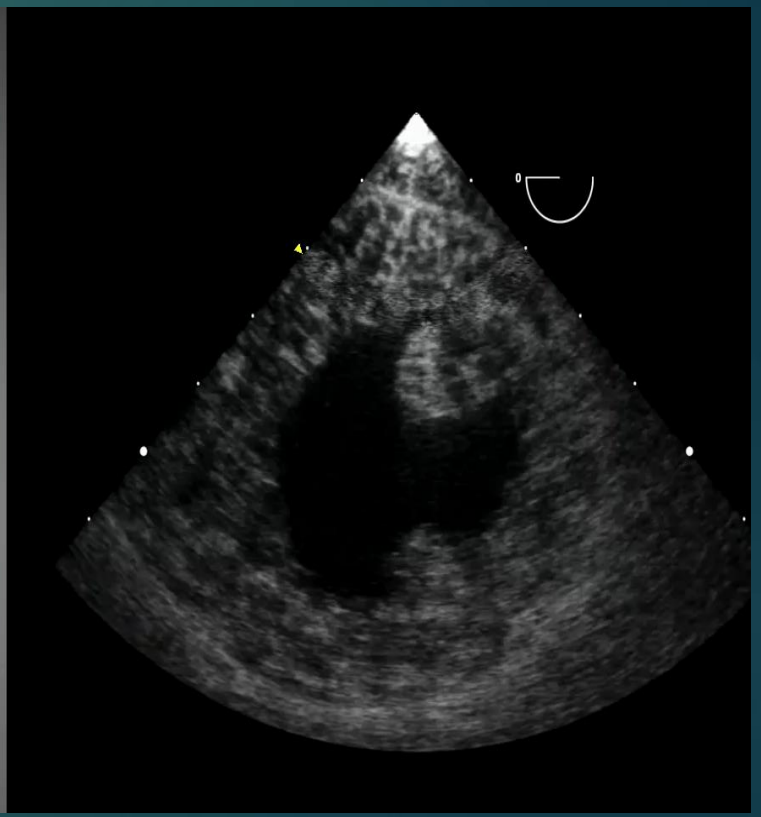




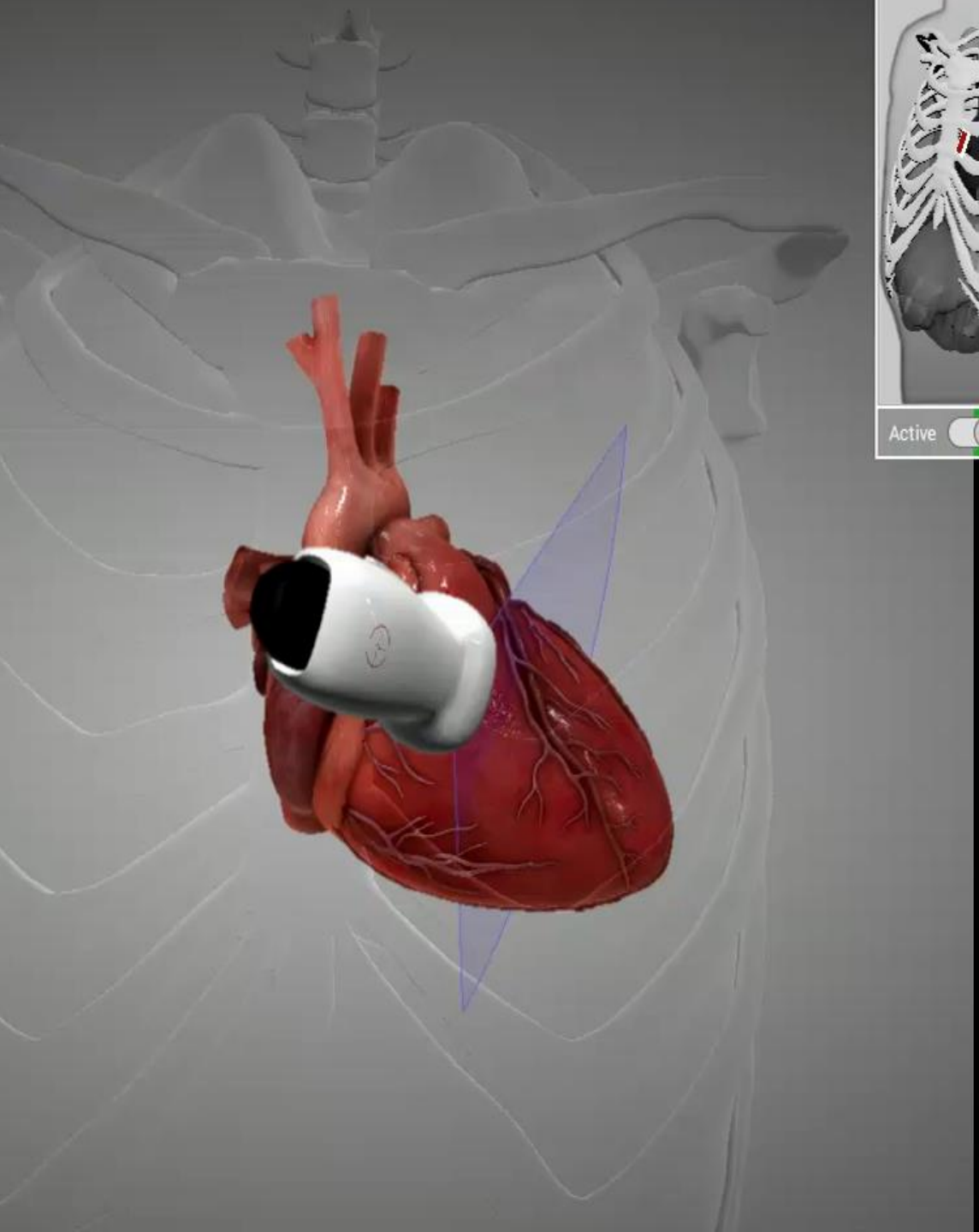
Myocardial Ischemia/Infarction

- 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

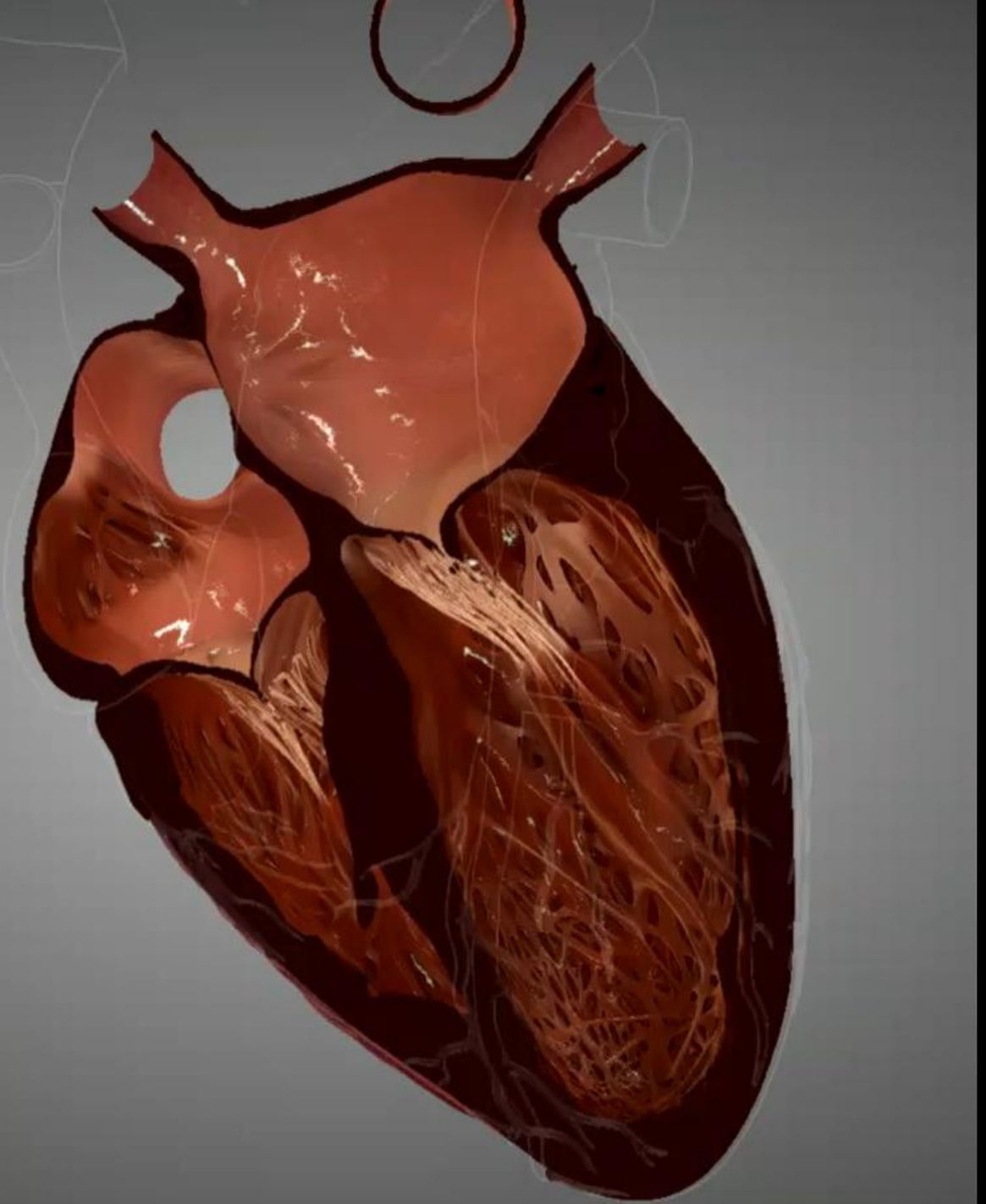


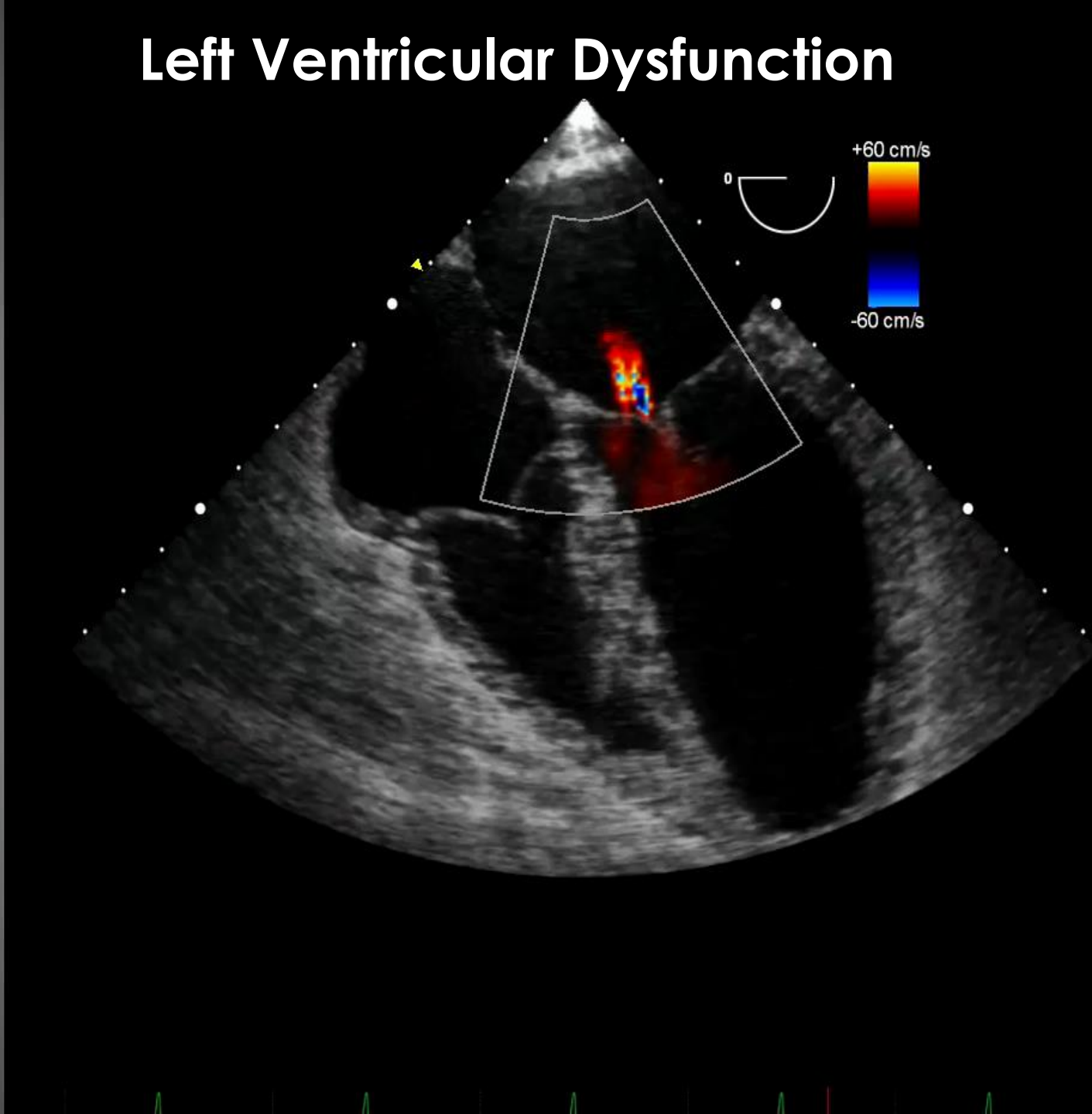


Myocardial Ischemia/ Anterior Wall Motion Abnormality



Left Ventricular Dysfunction





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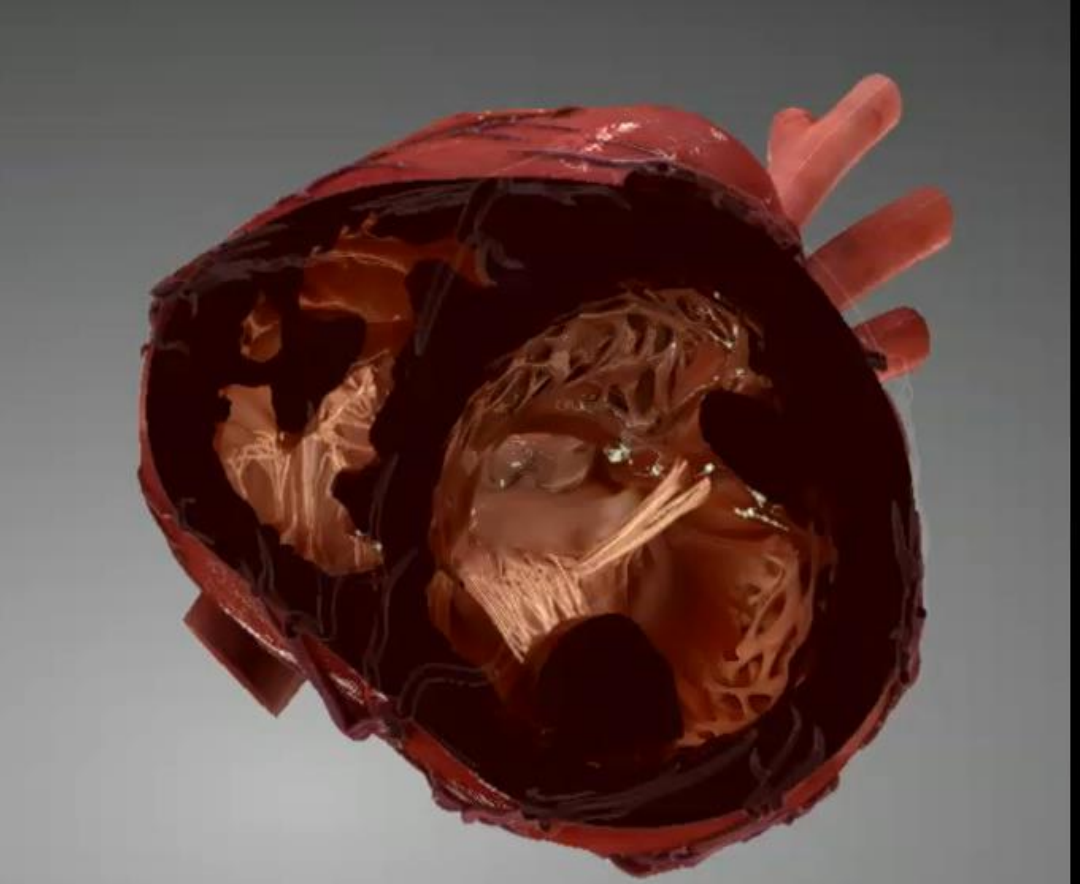
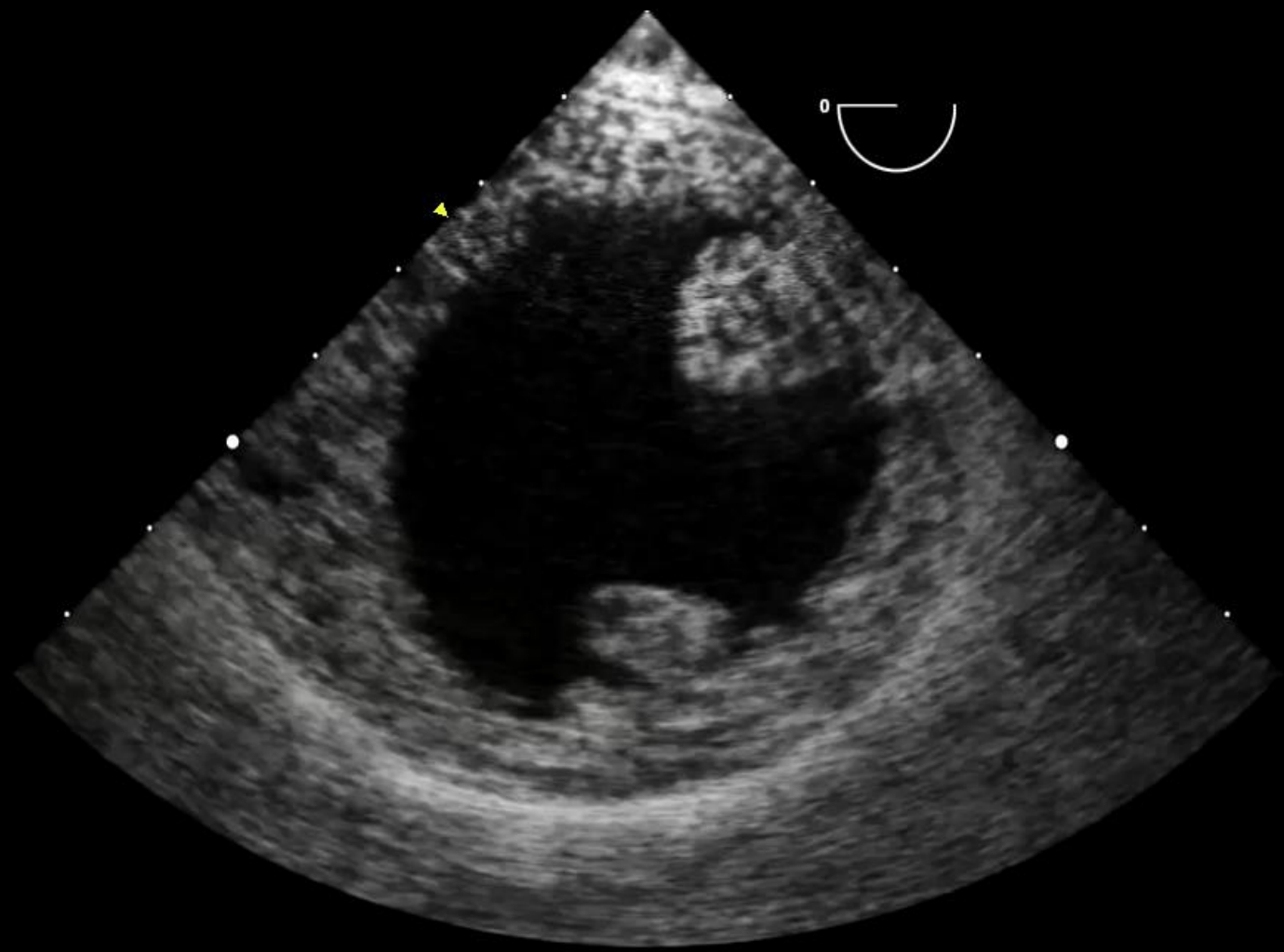
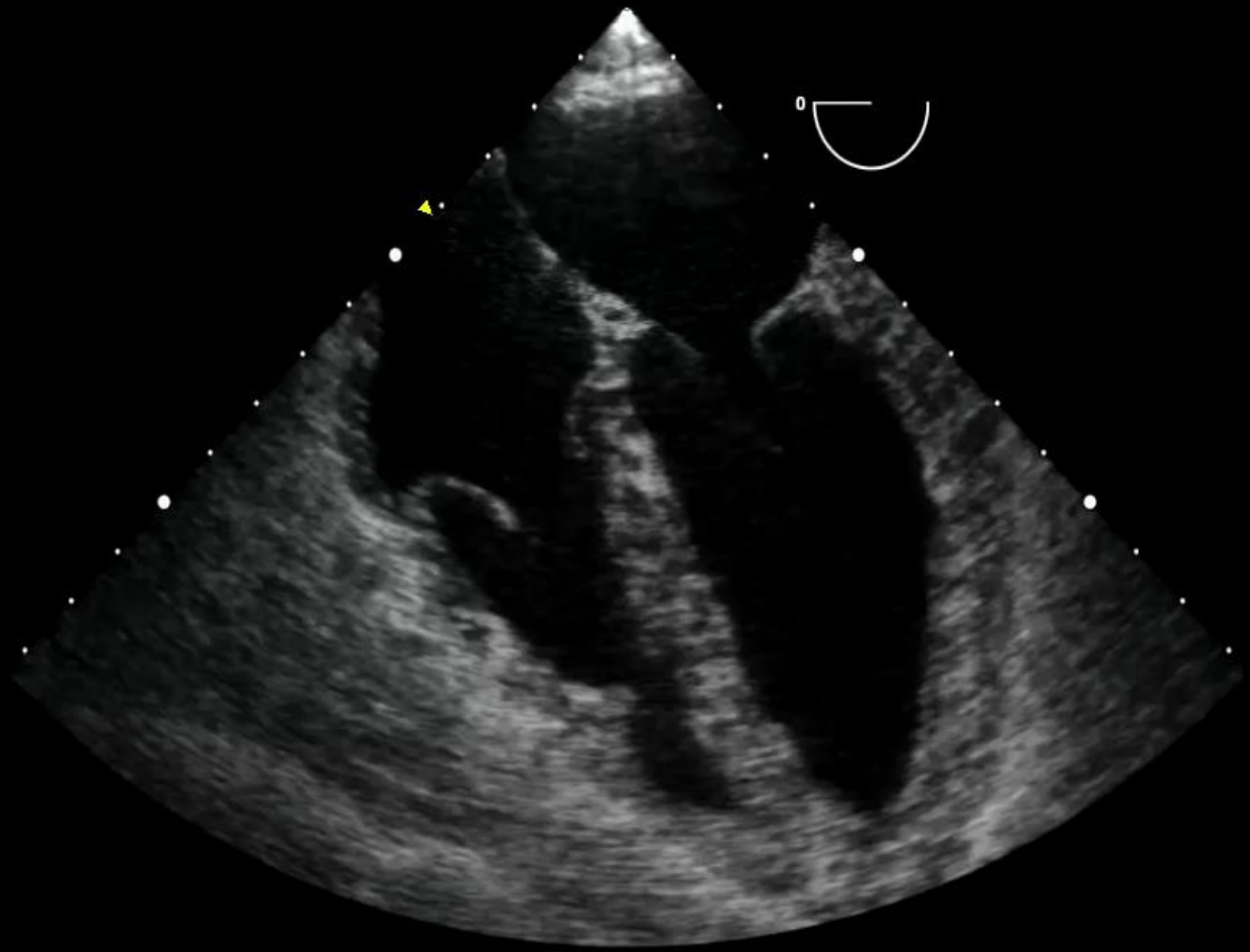
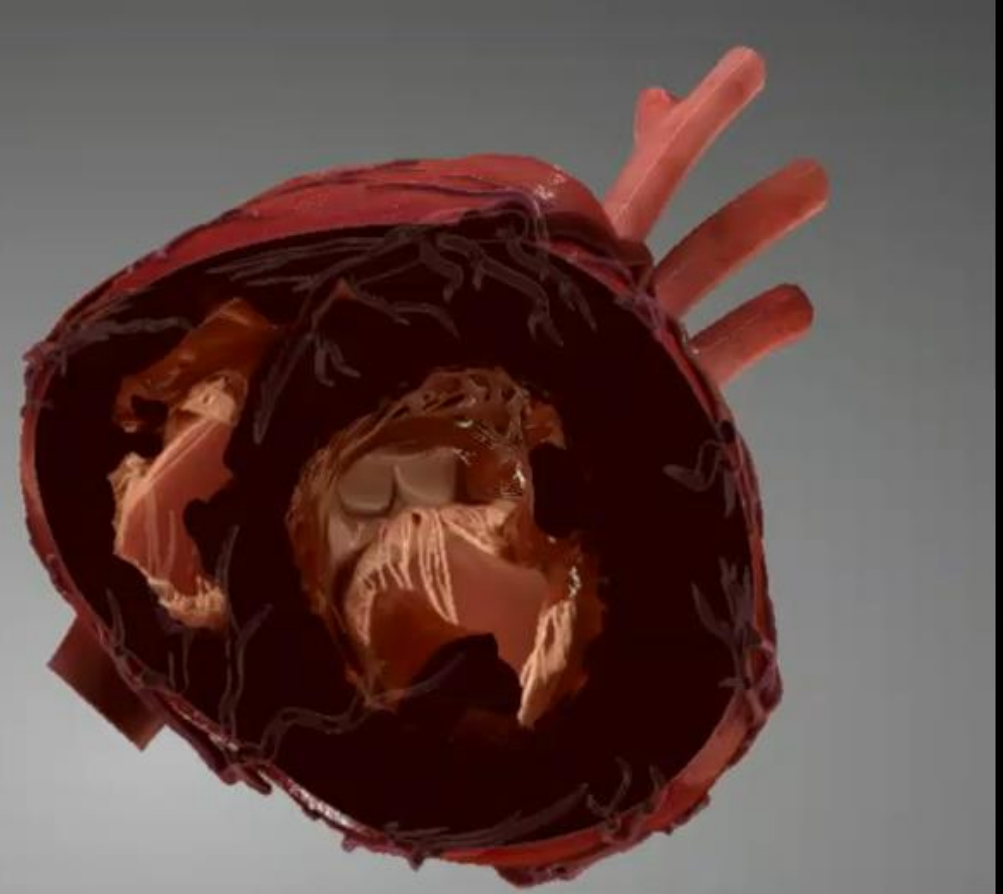


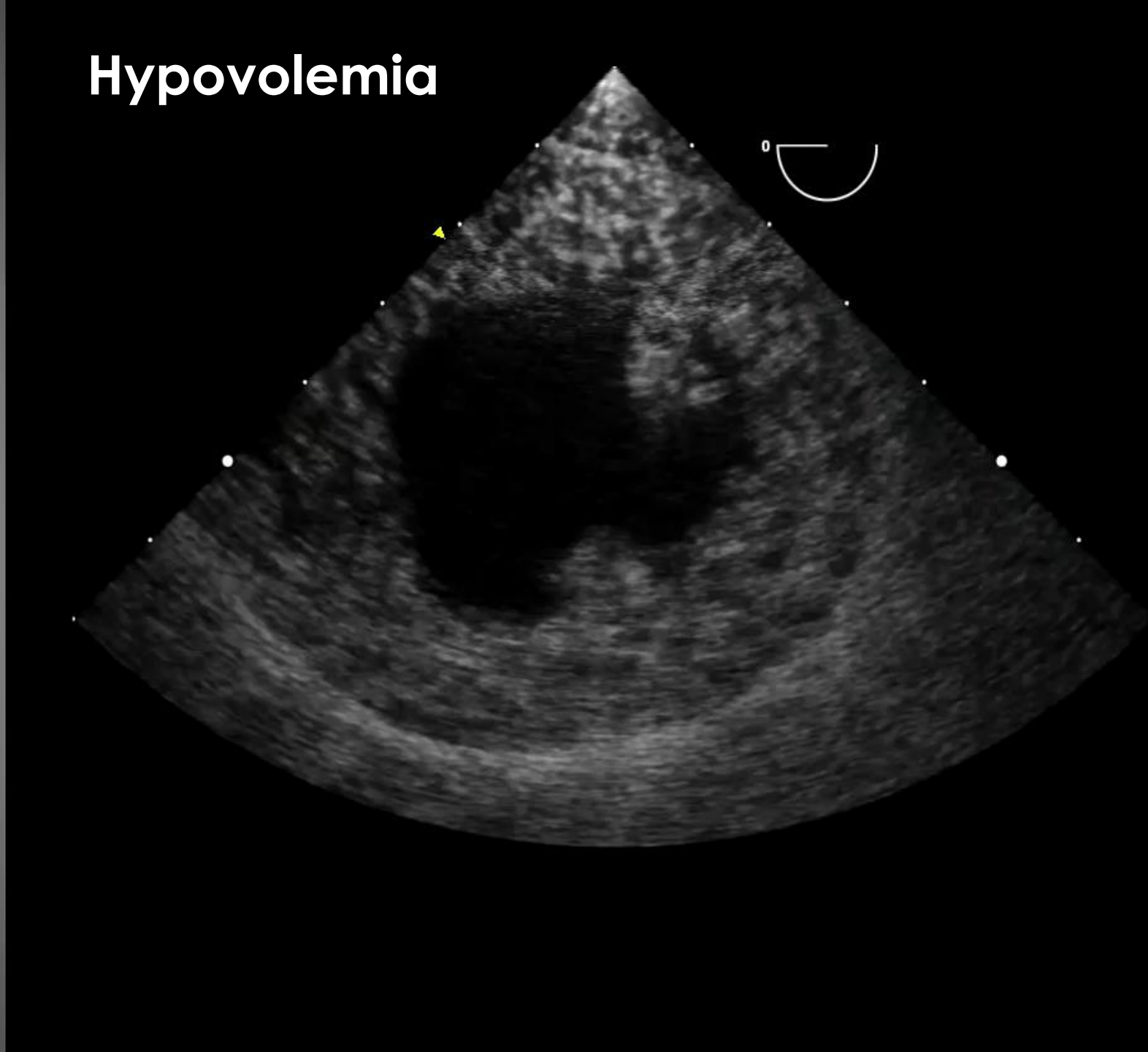


Hypovolemia

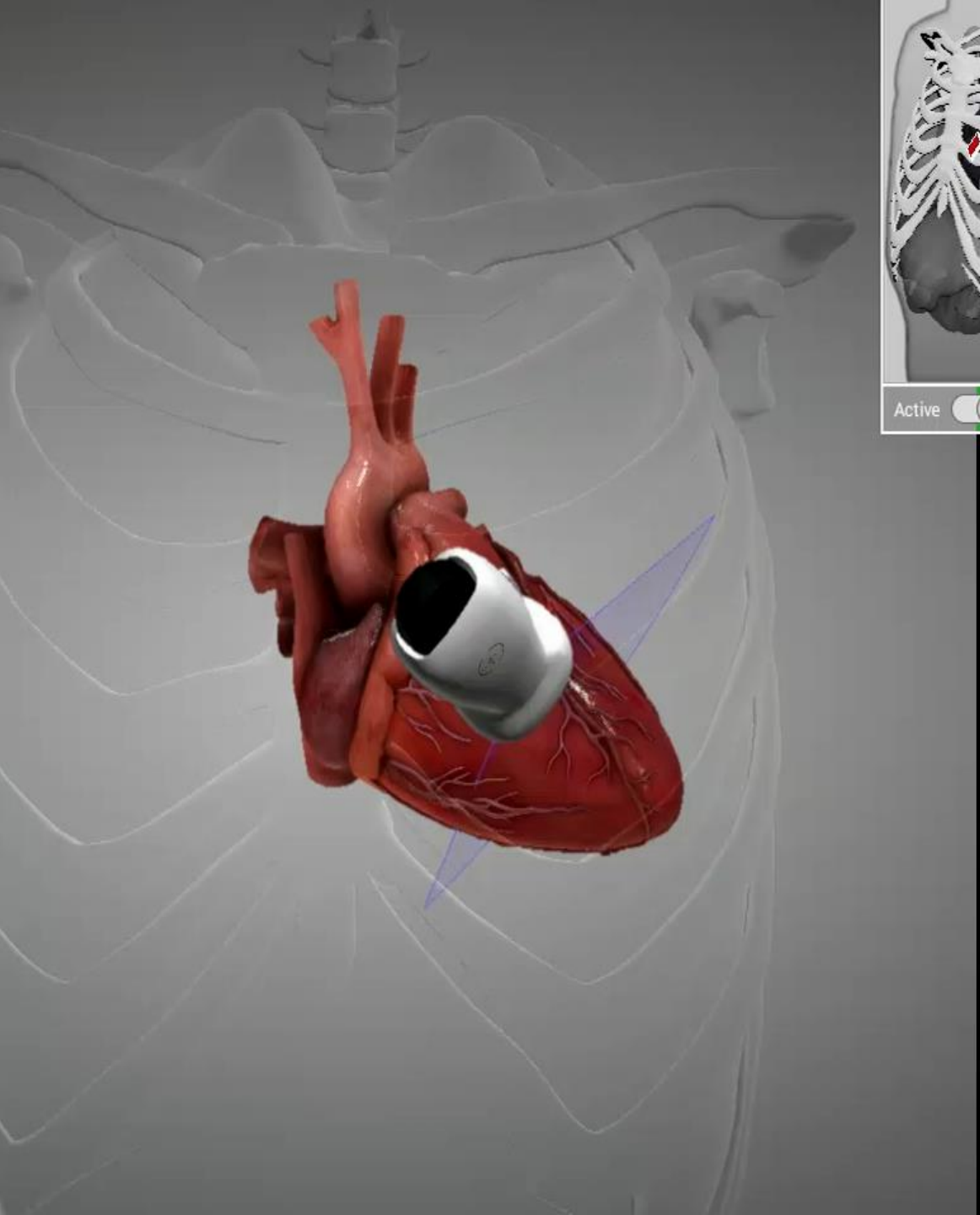


Hypovolemia



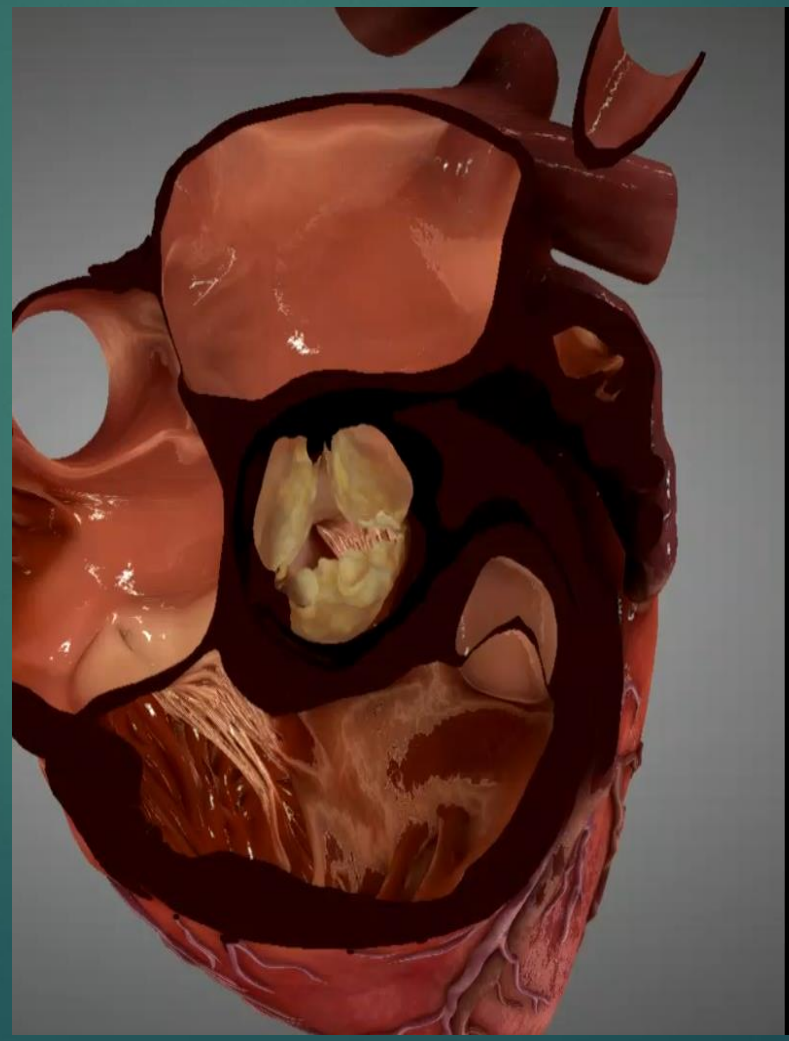


Hypovolemia

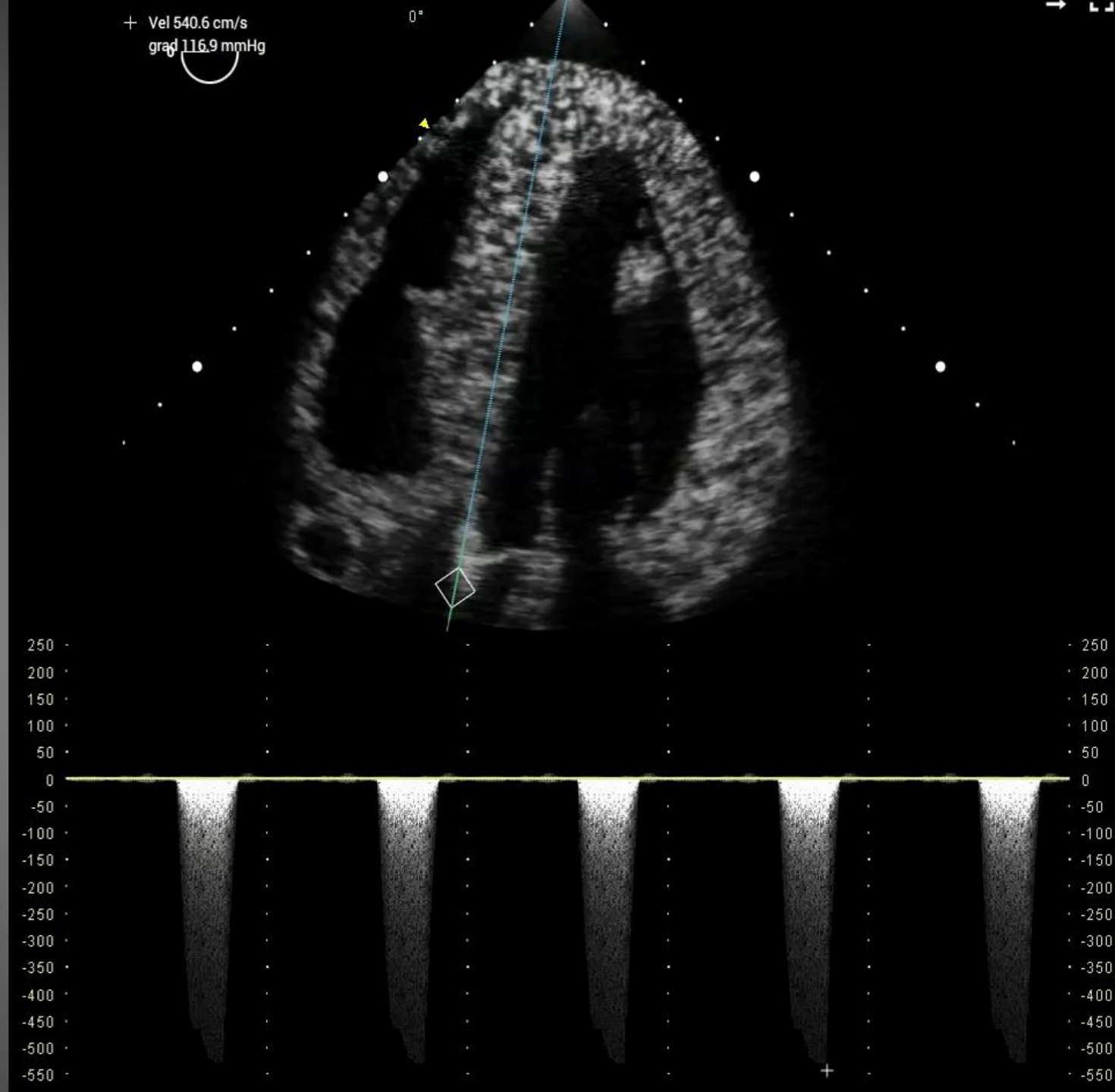


Aortic Stenosis

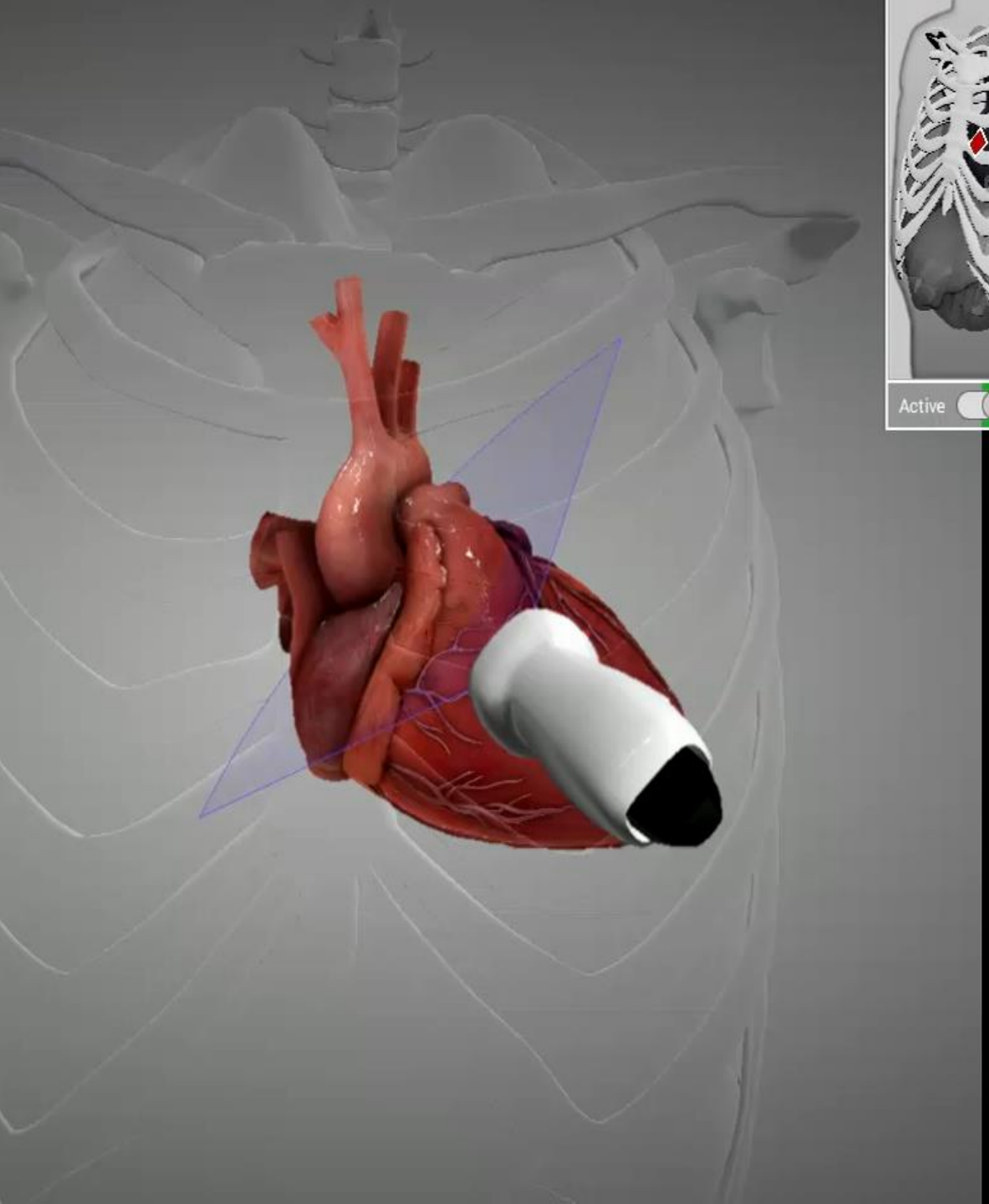
- Severe AS is suggested by heavily calcified or poorly mobile aortic valve leaflets
- Continuous-wave Doppler is used to confirm diagnosis
  - Transvalvular gradient using velocity
  - Aortic valve area using VTI
- LVH is often present and hemodynamic management dictated by this finding



Aortic Stenosis with 117 mmHg Gradient

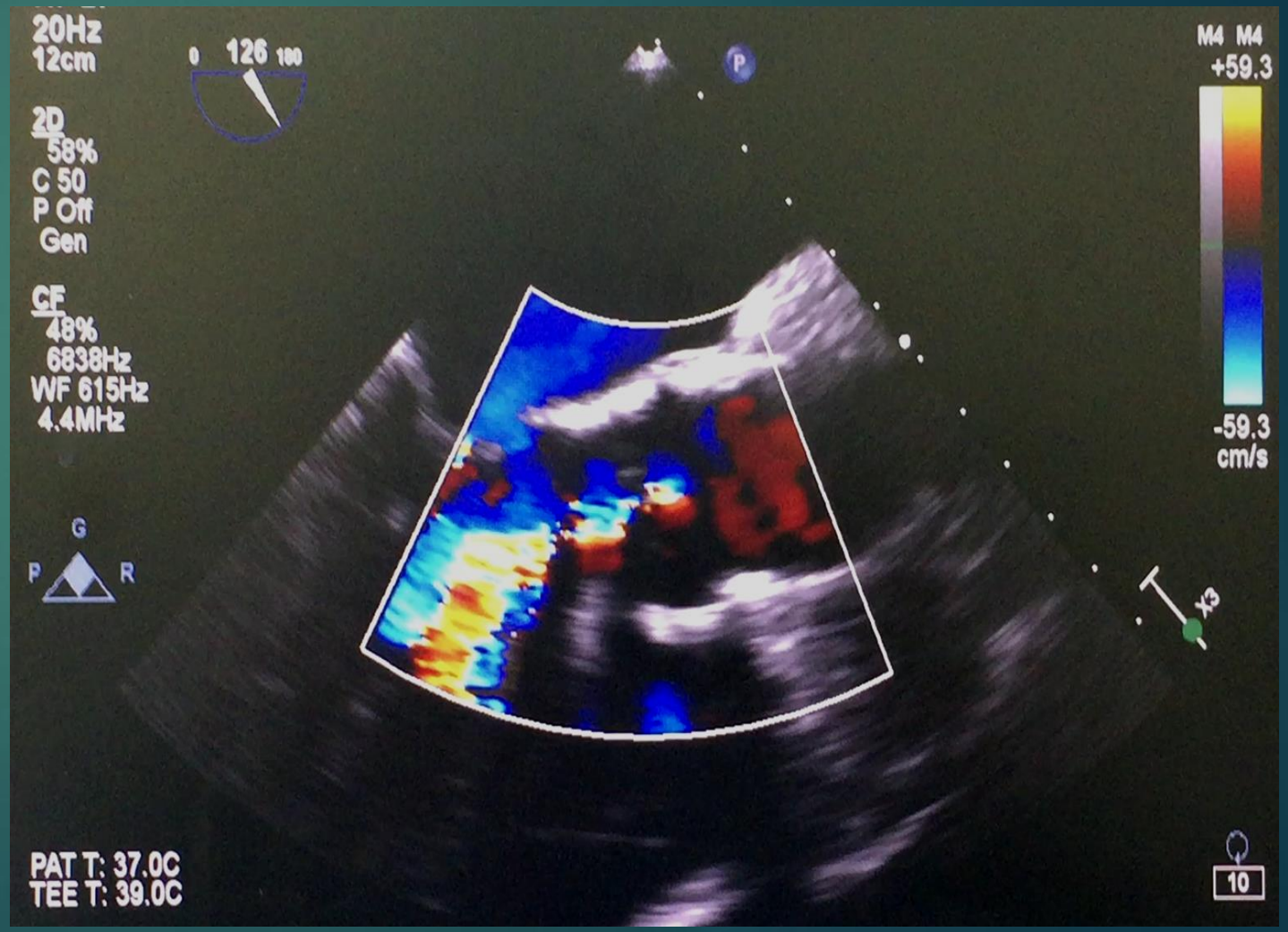


Aortic Stenosis

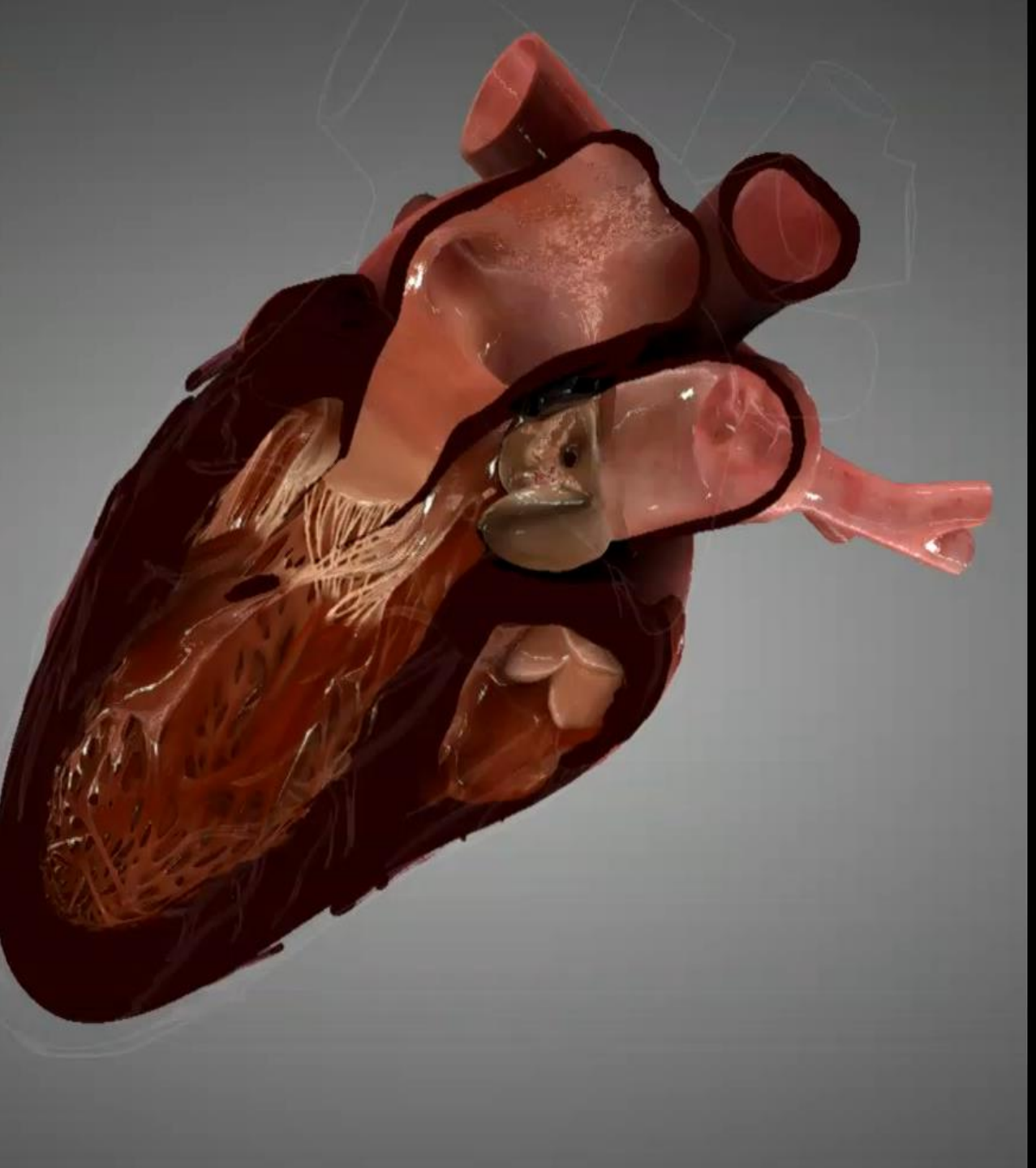


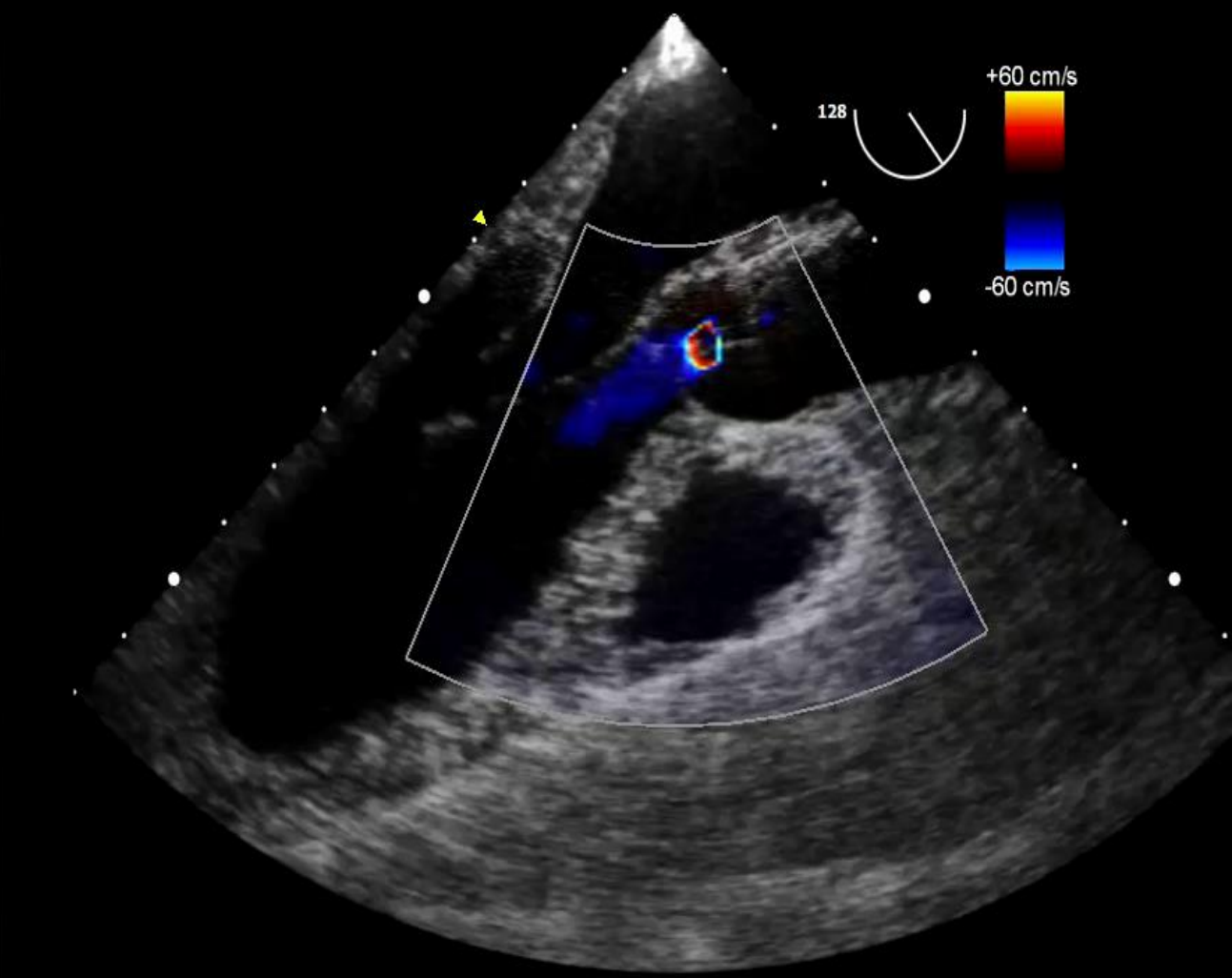
Aortic Insufficiency

- 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

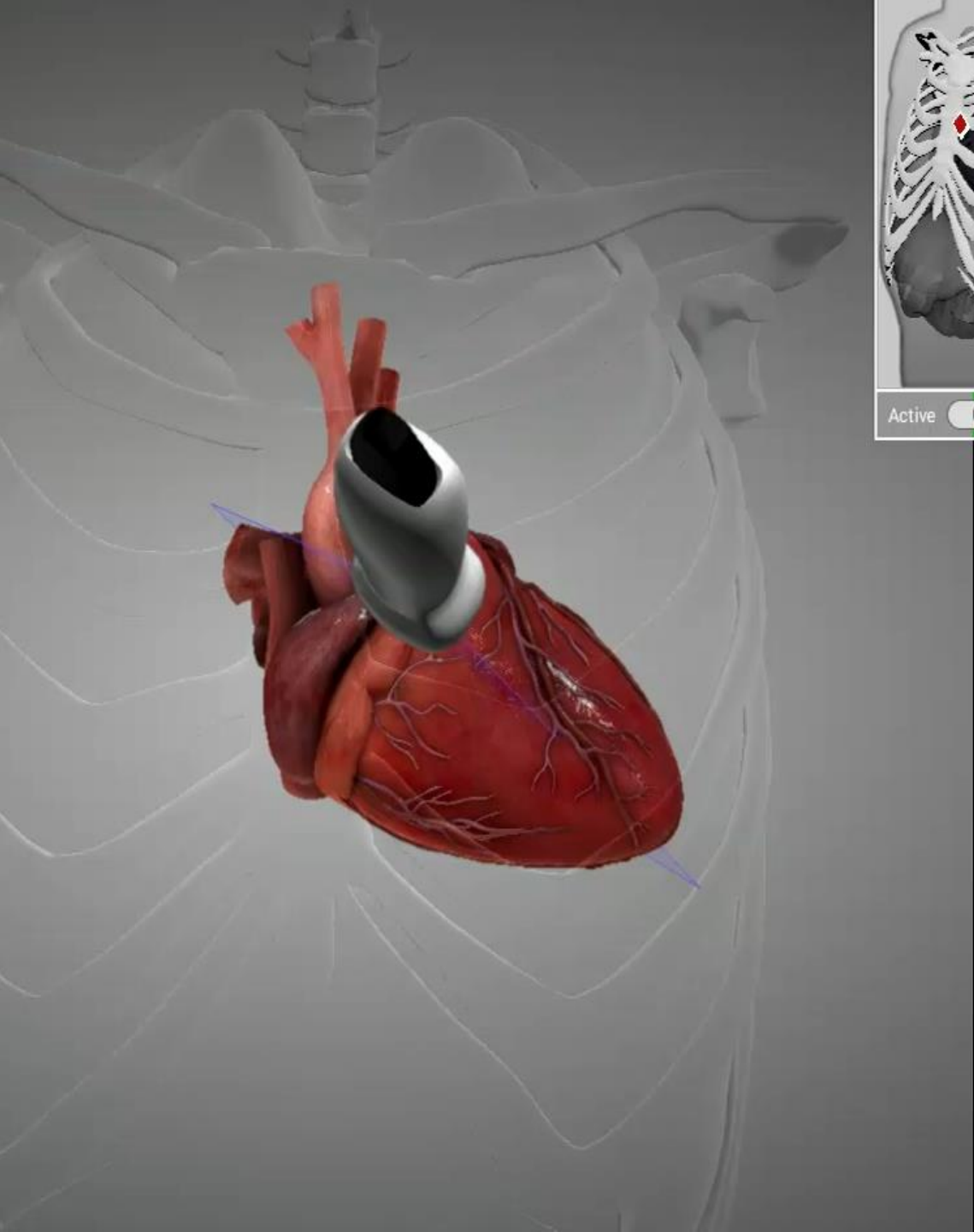


Aortic Insufficiency



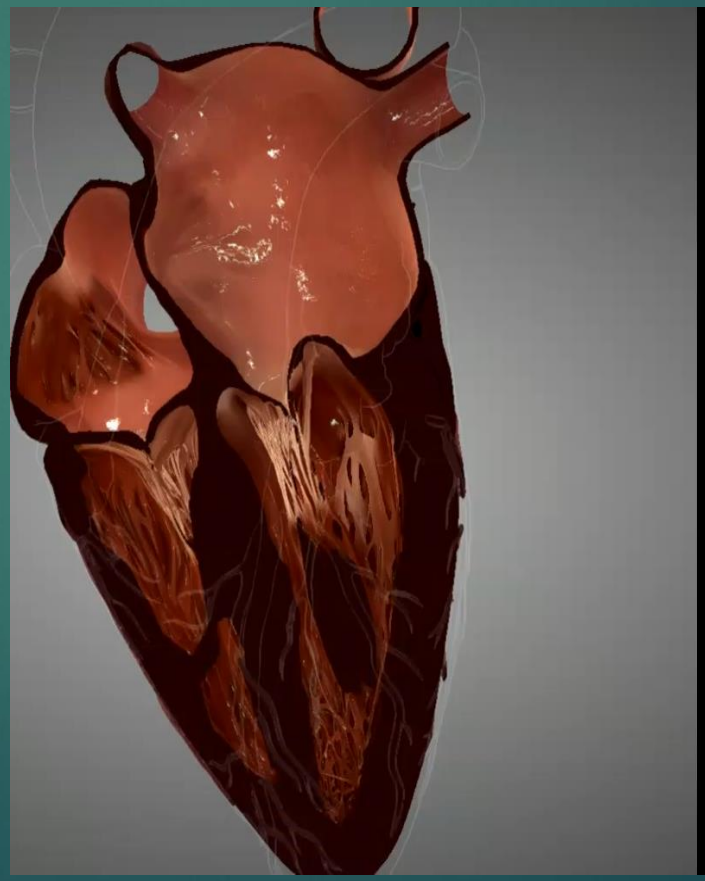


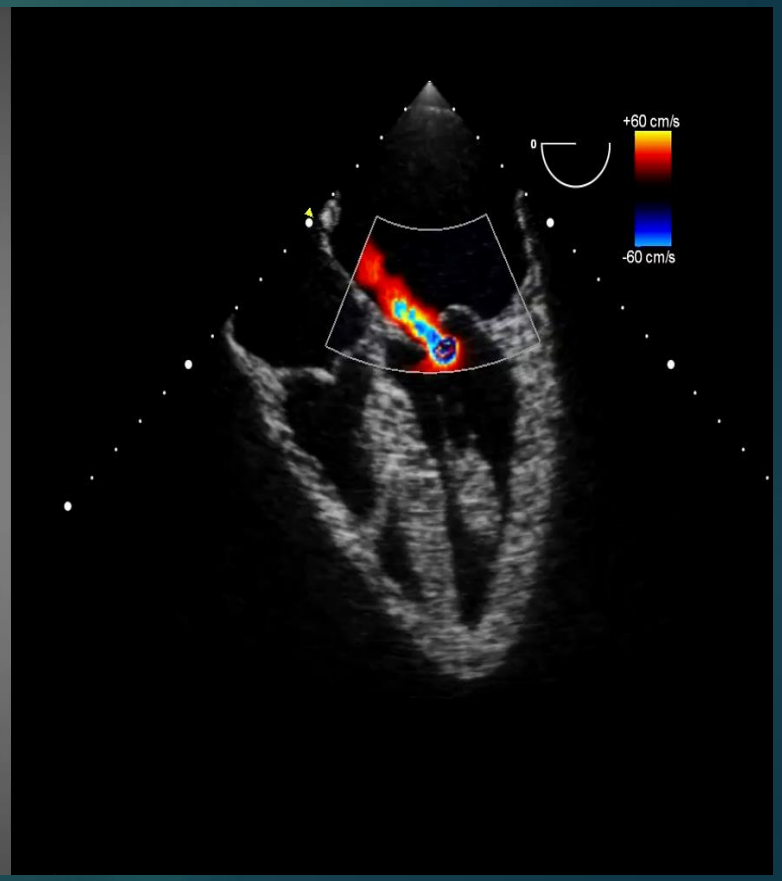
Aortic Insufficiency



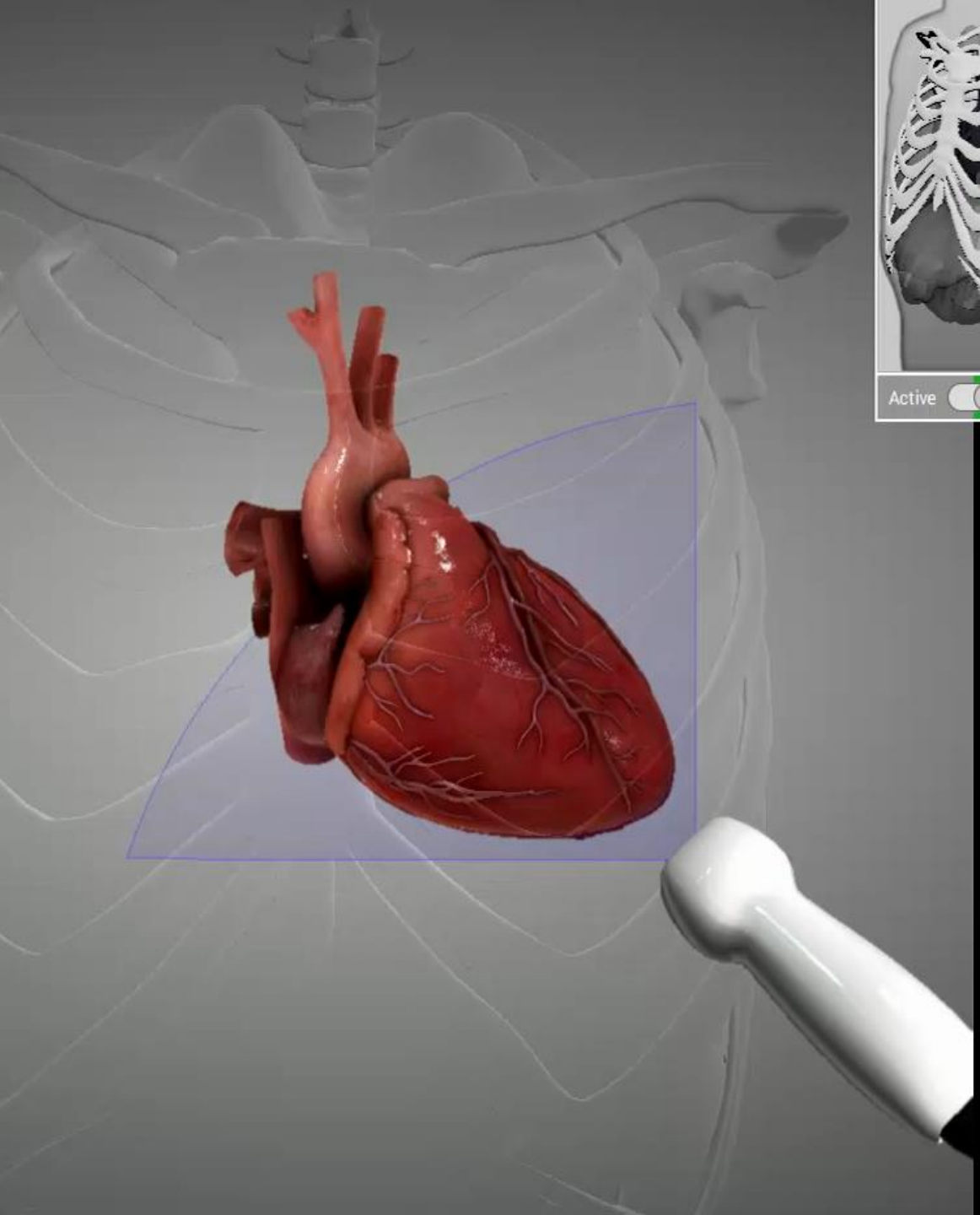
Mitral Regurgitation

- 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



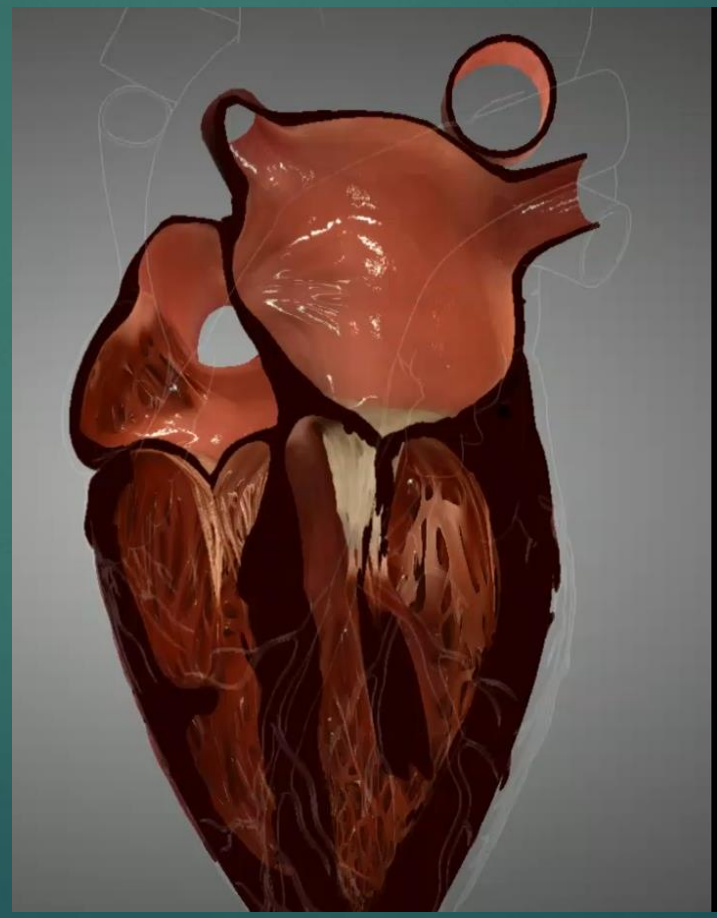


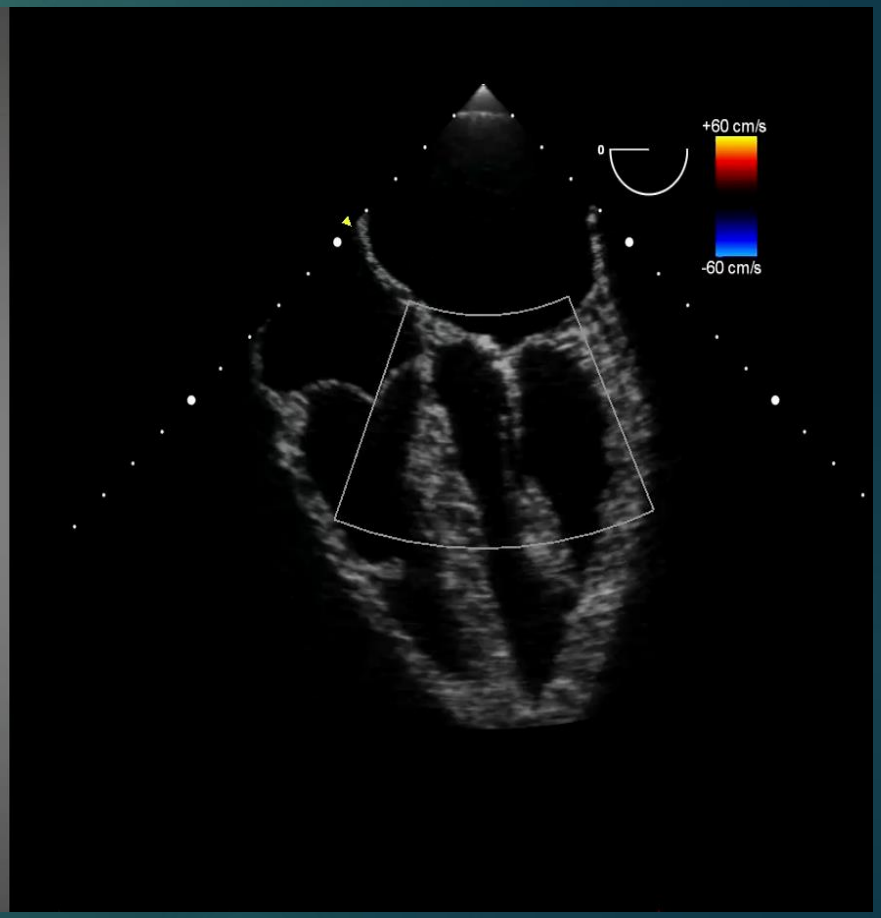
Mitral Regurgitation



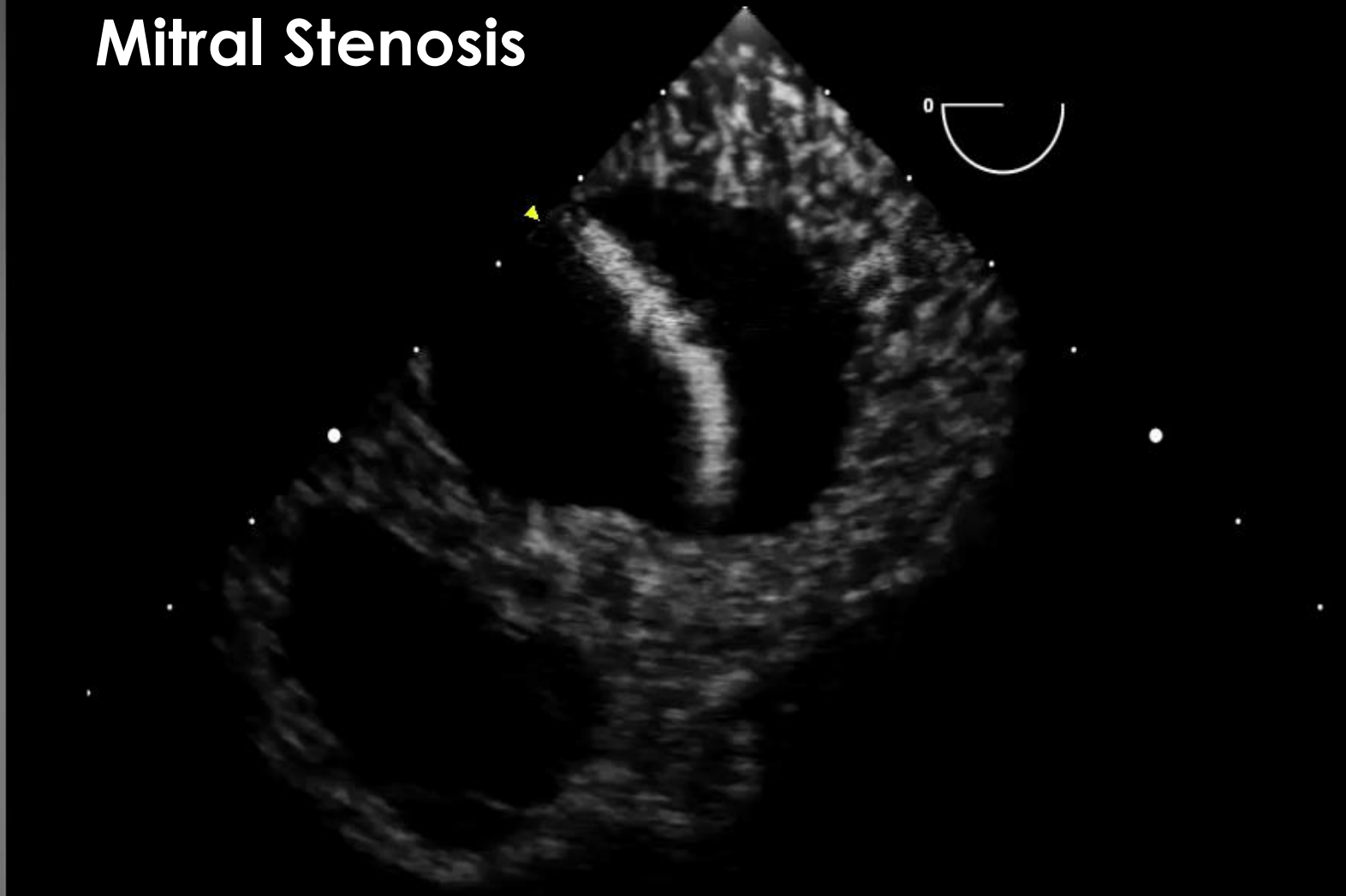
Mitral Stenosis

- 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

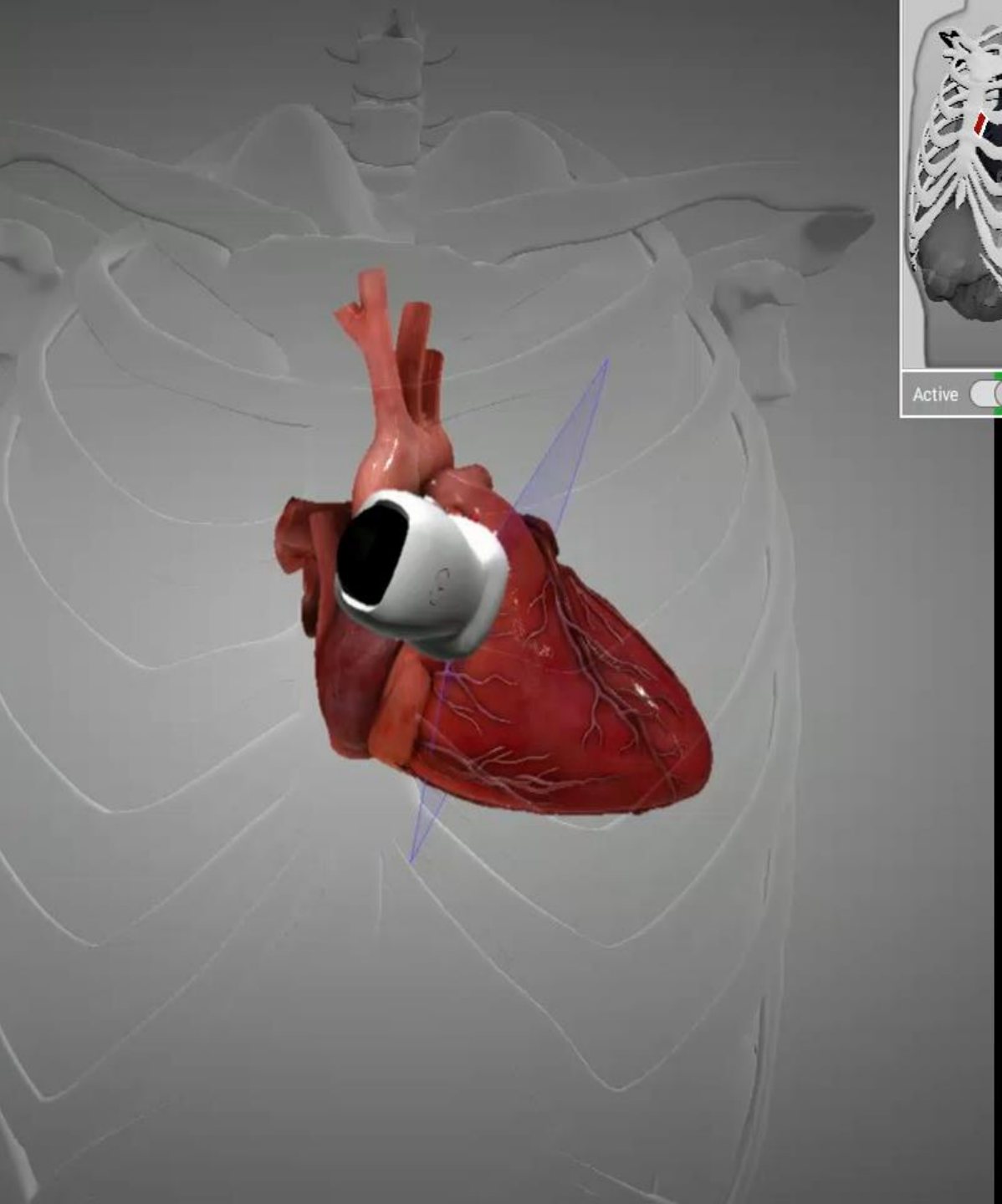




Mitral Stenosis

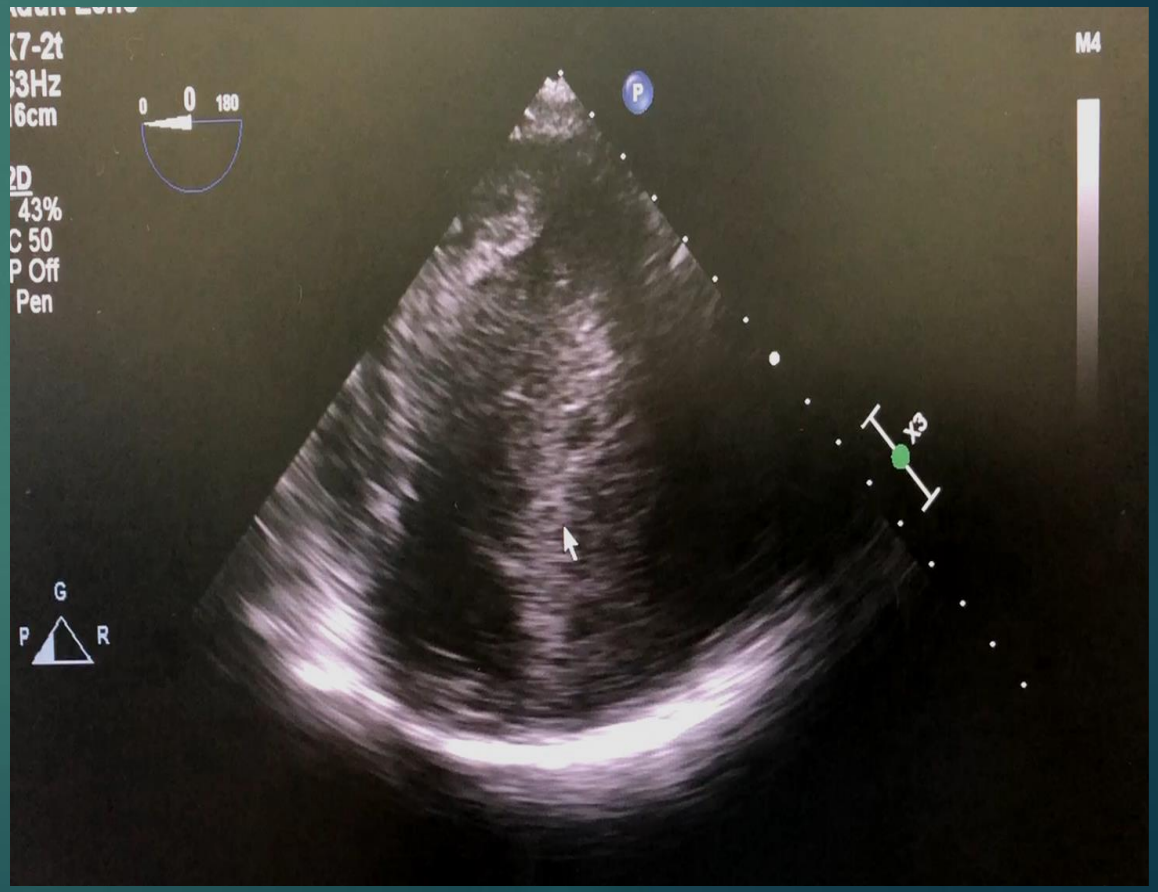


Mitral Stenosis

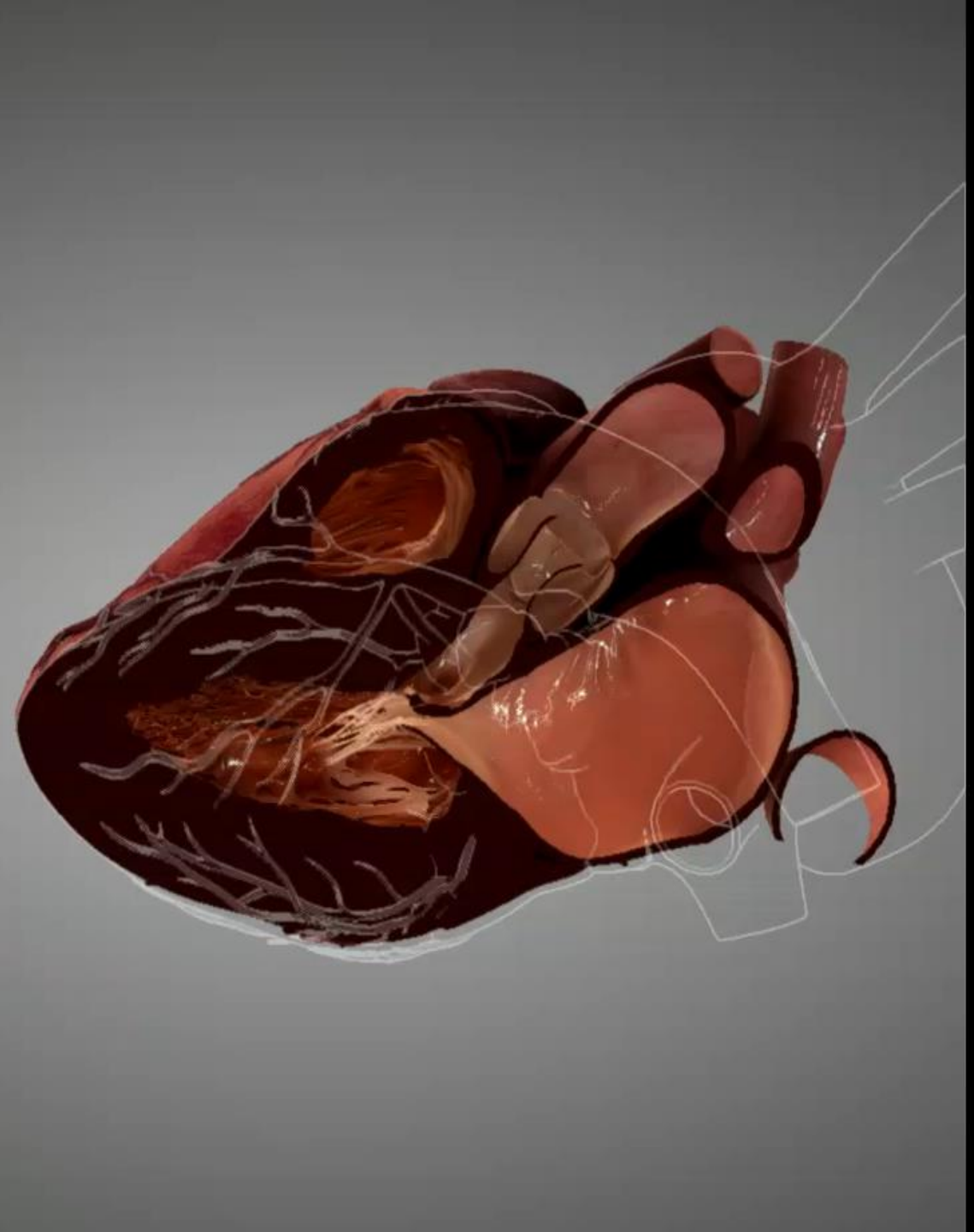


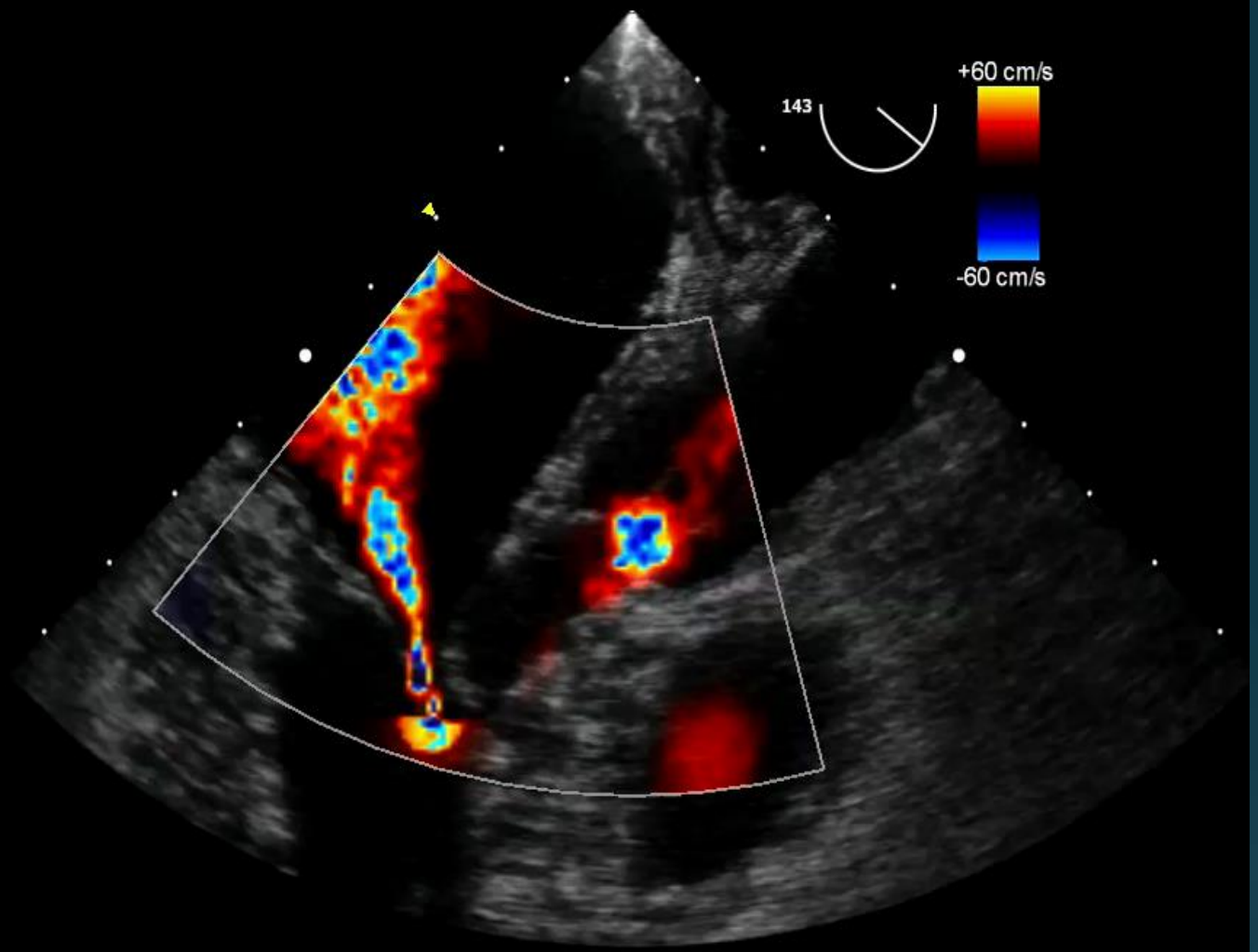
Hypertrophic Cardiomyopathy

- 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

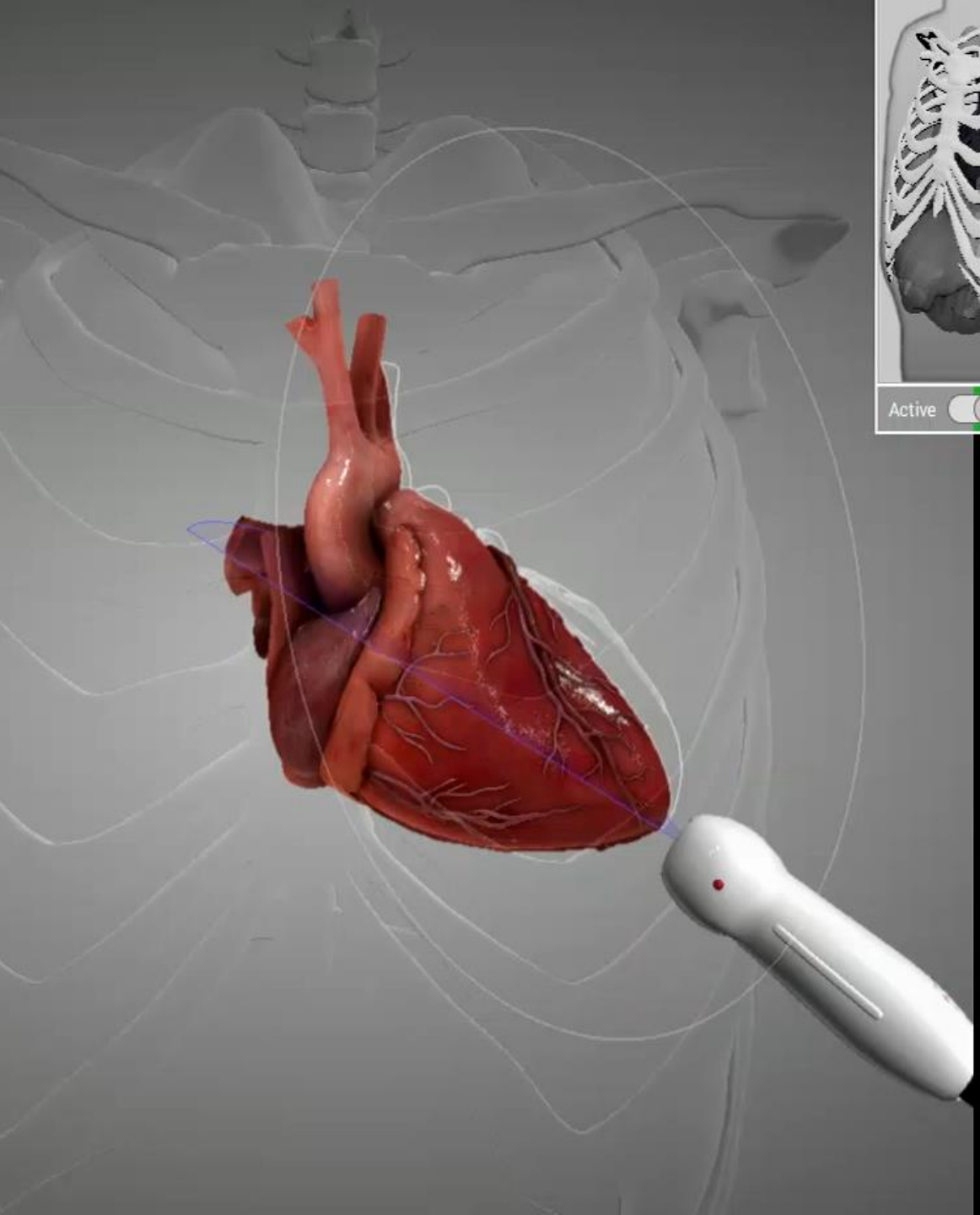


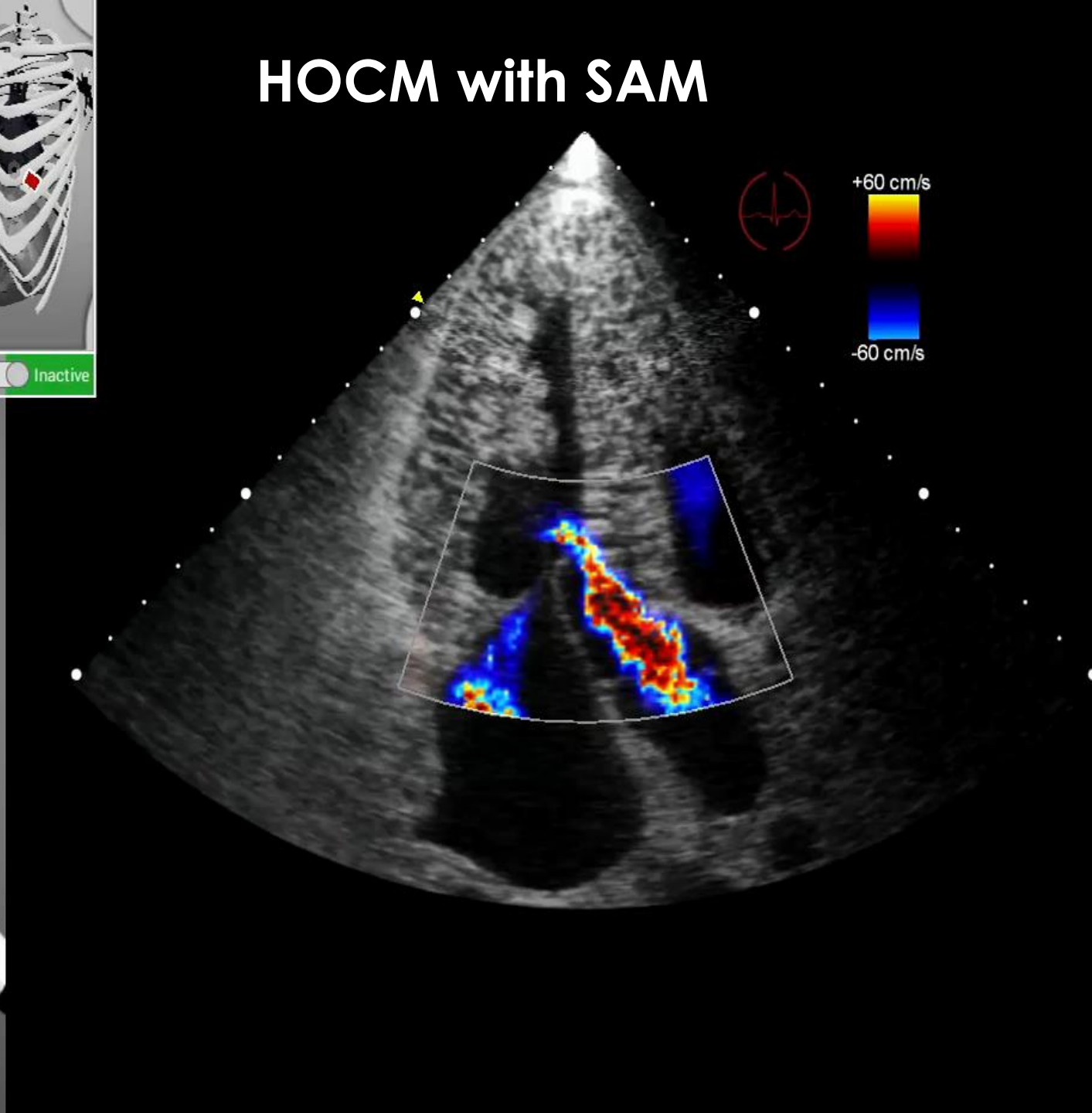
HOCM with SAM





HOCM with SAM

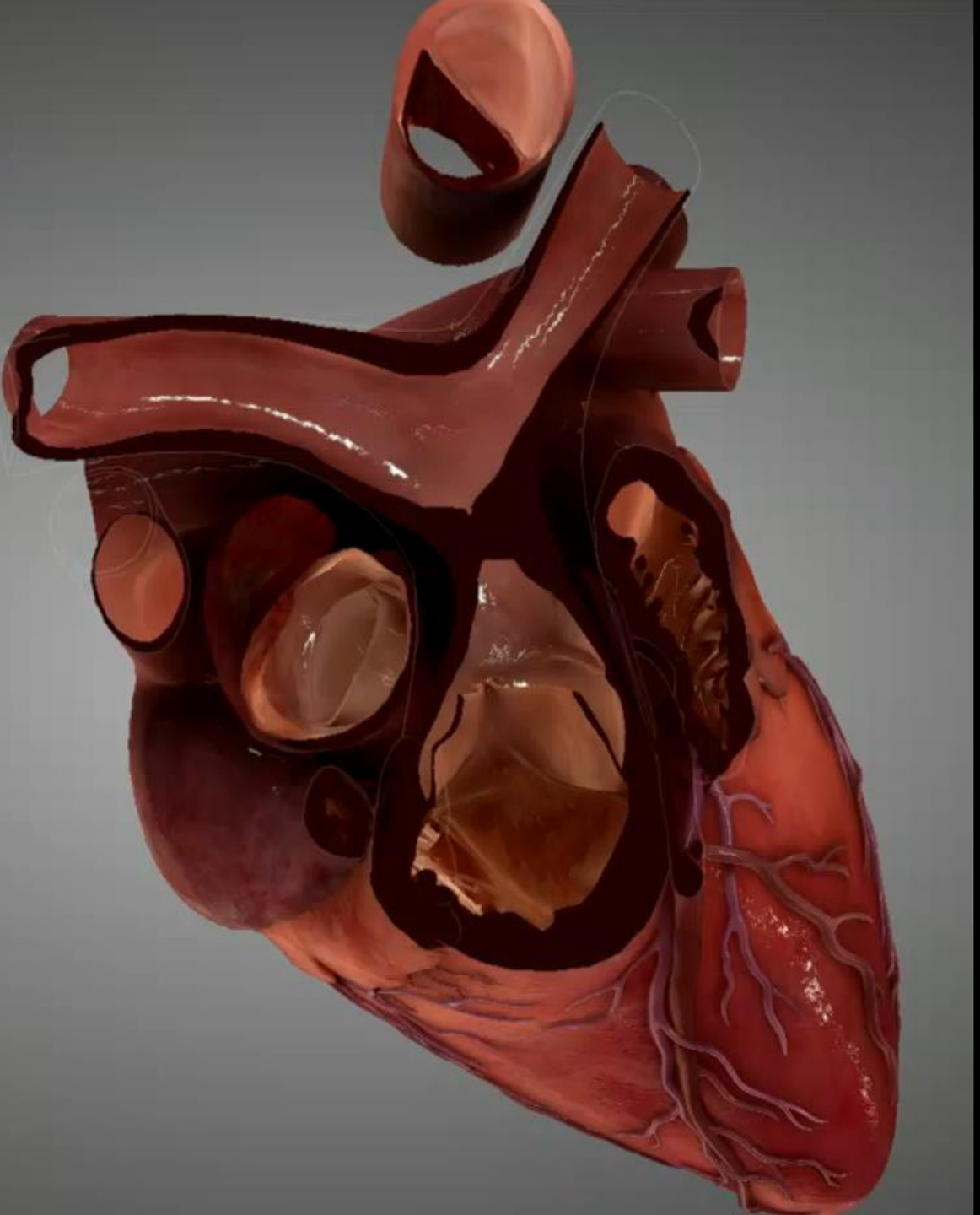


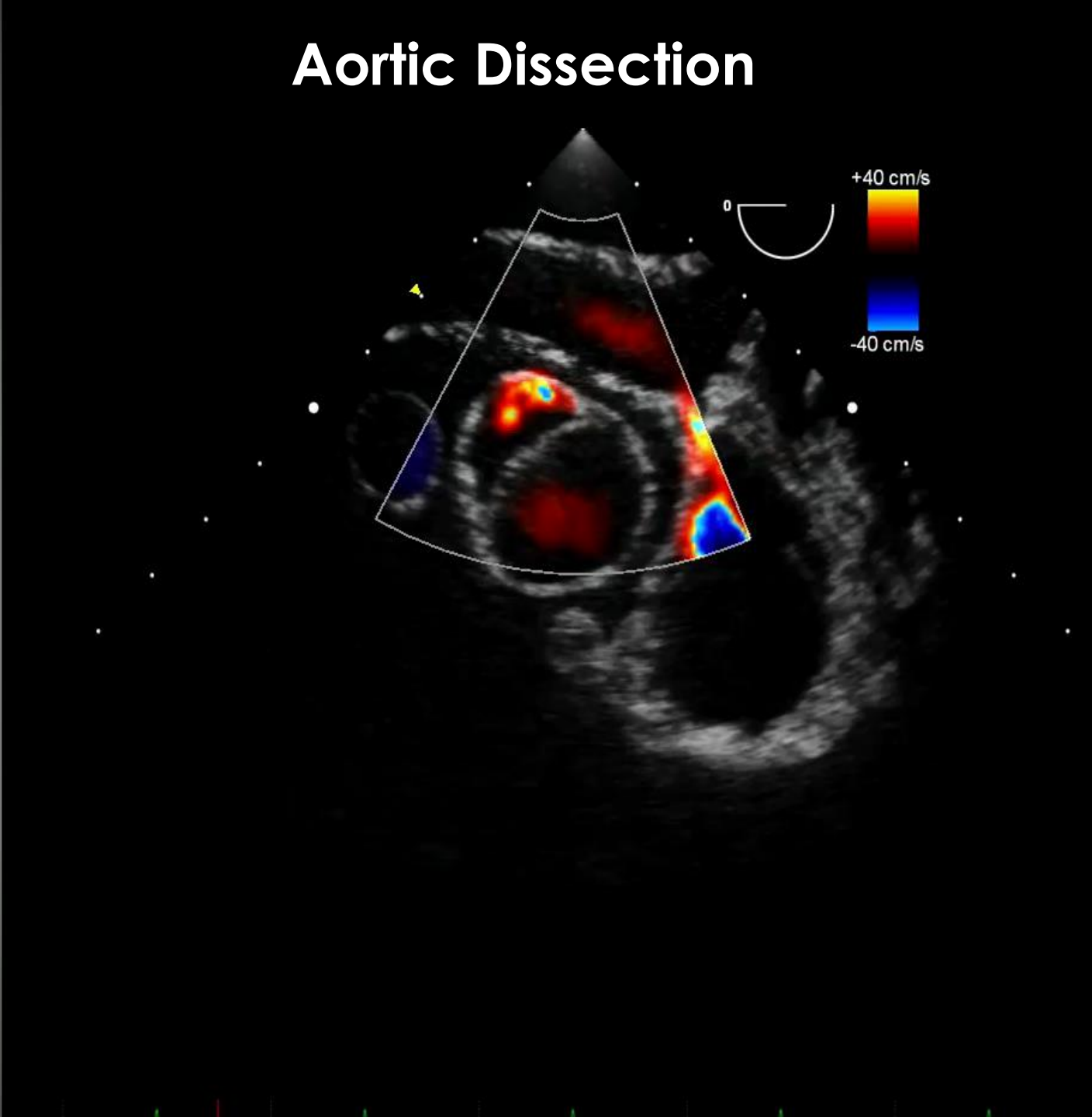


Aortic Dissection

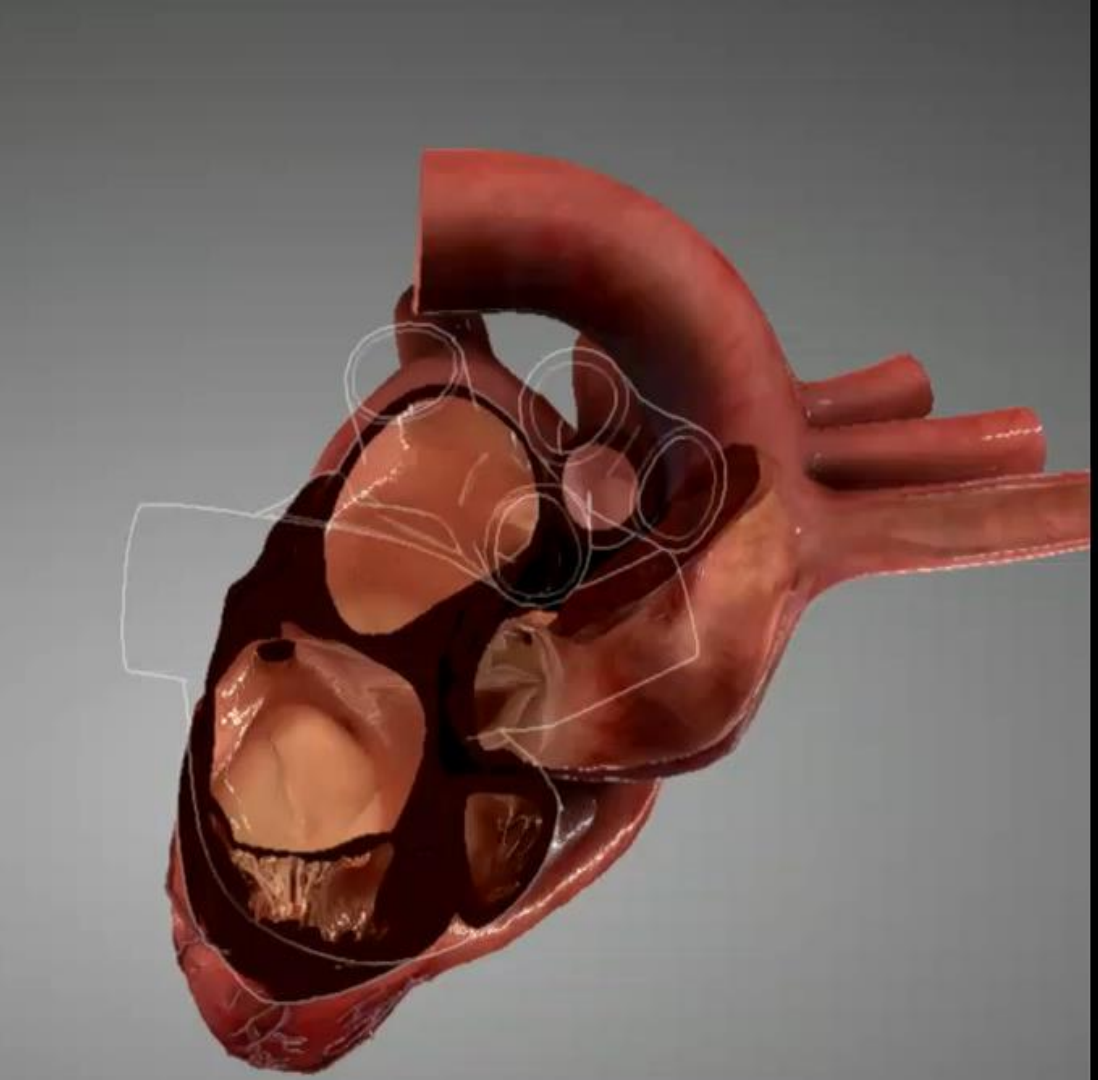
- Rescue TEE findings consistent with aortic injury may be found
- Aortic dissection or other injury is most commonly diagnosed by TEE in certain patients presenting to the ER
- Only limited visualization of the distal ascending aorta and proximal aortic arch is possible with TEE examination (TTE suprasternal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

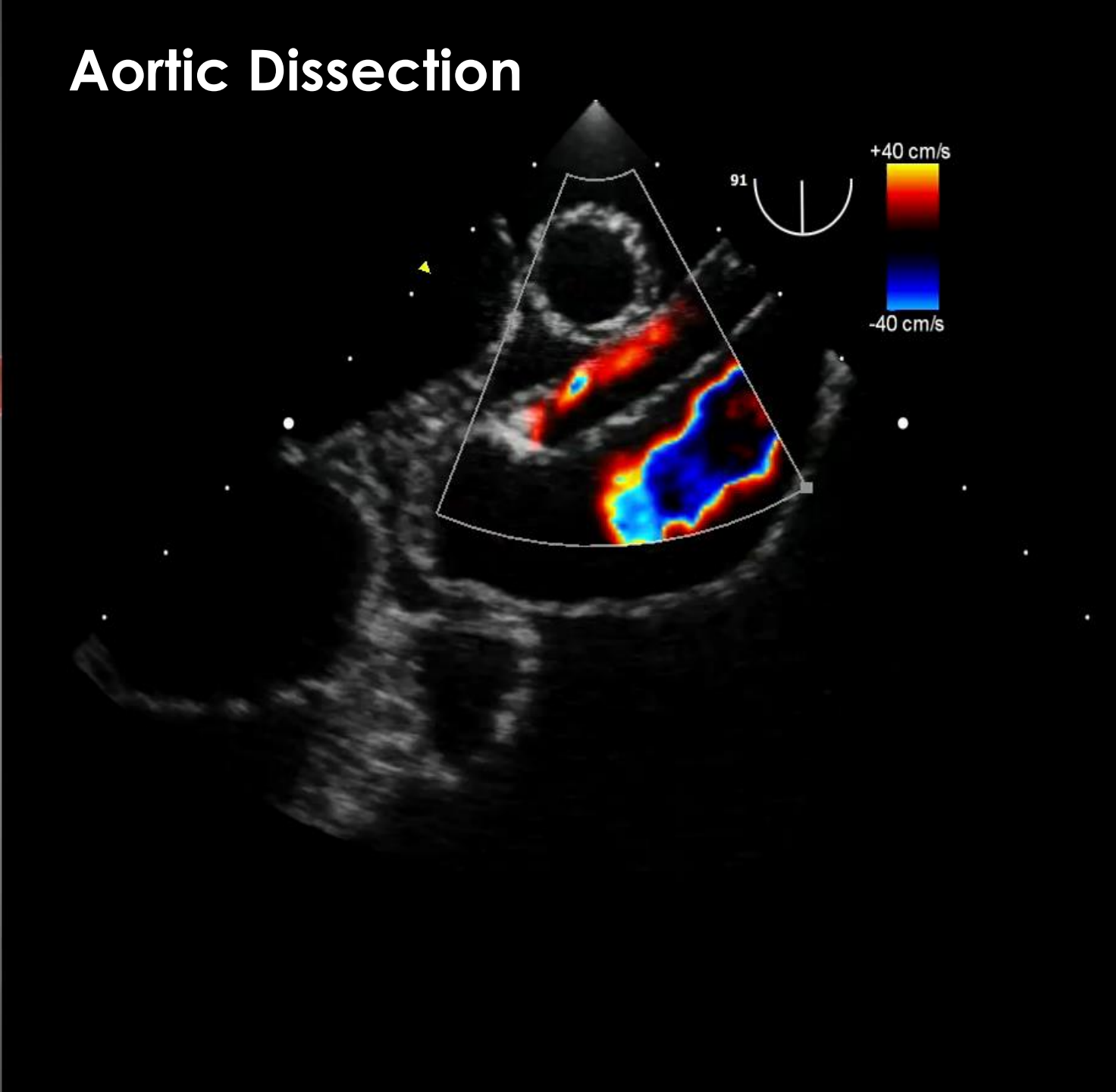
Aortic Dissection

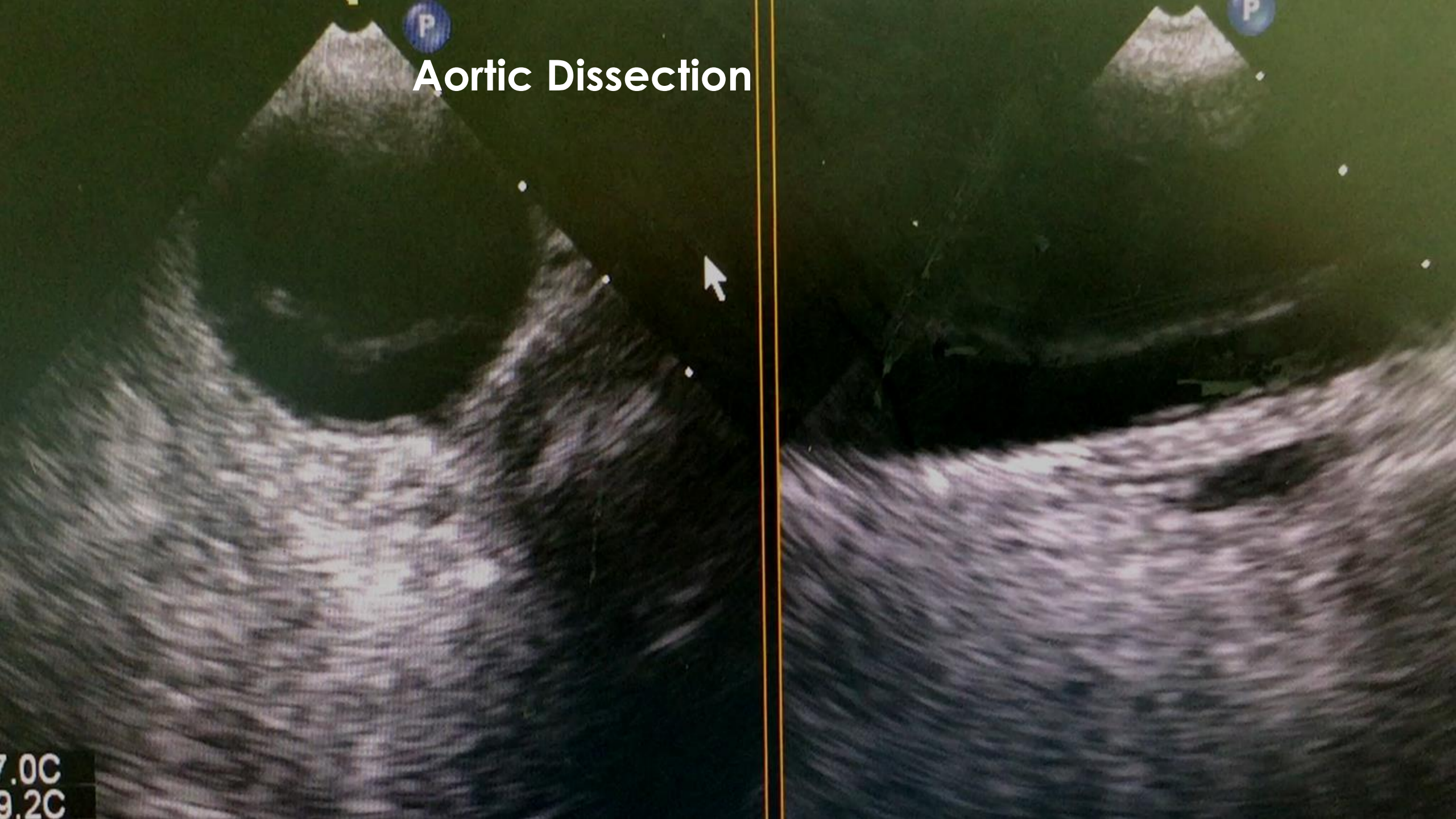




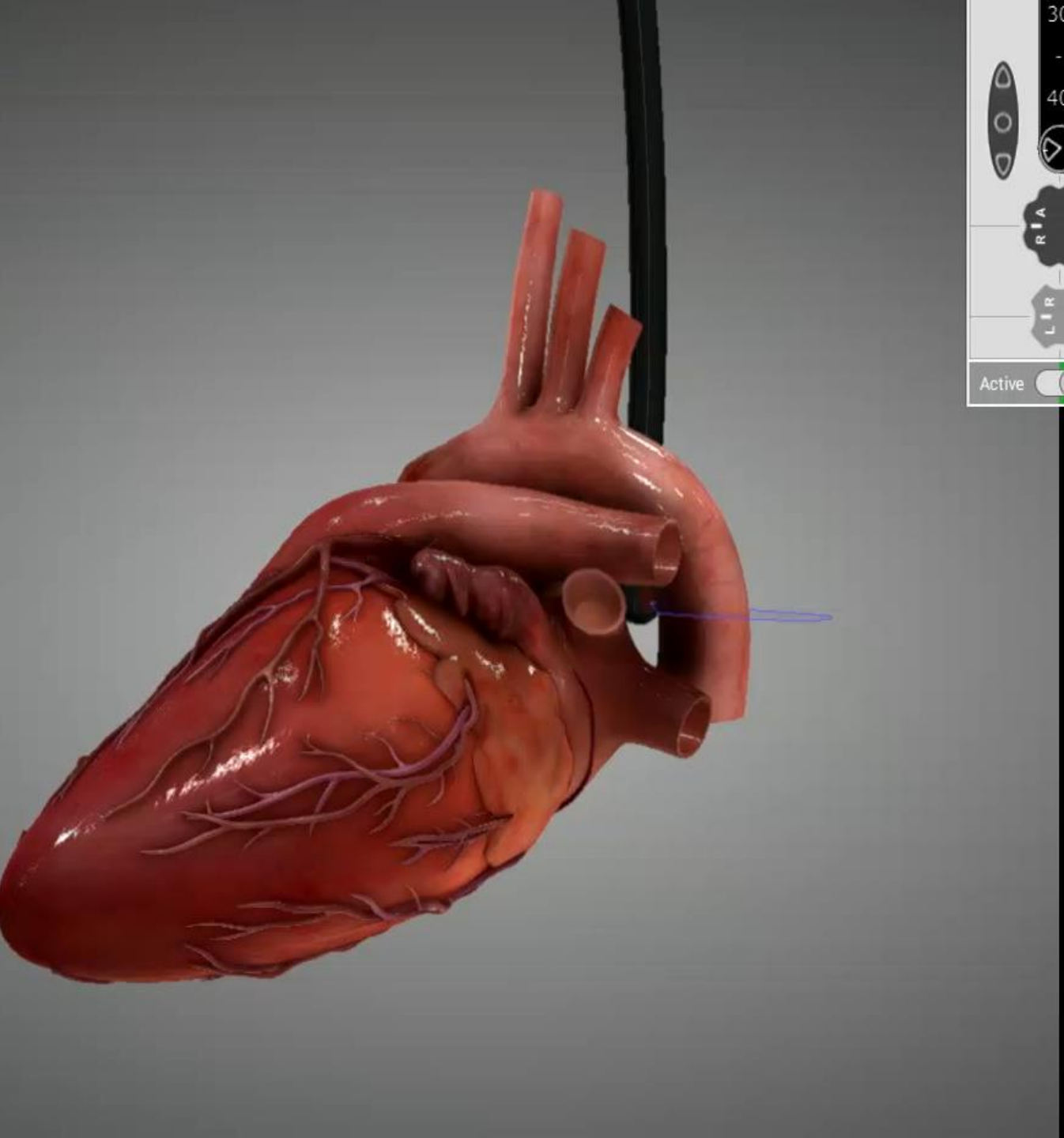
Aortic Dissection

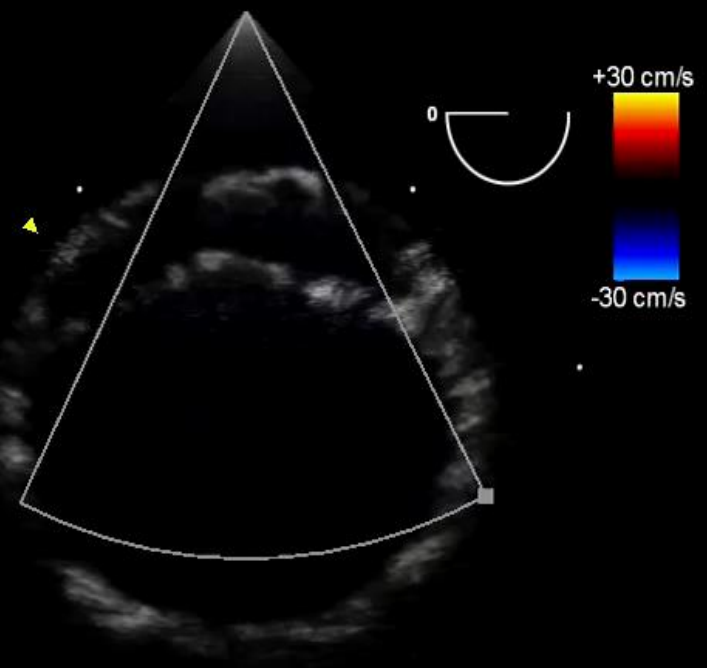




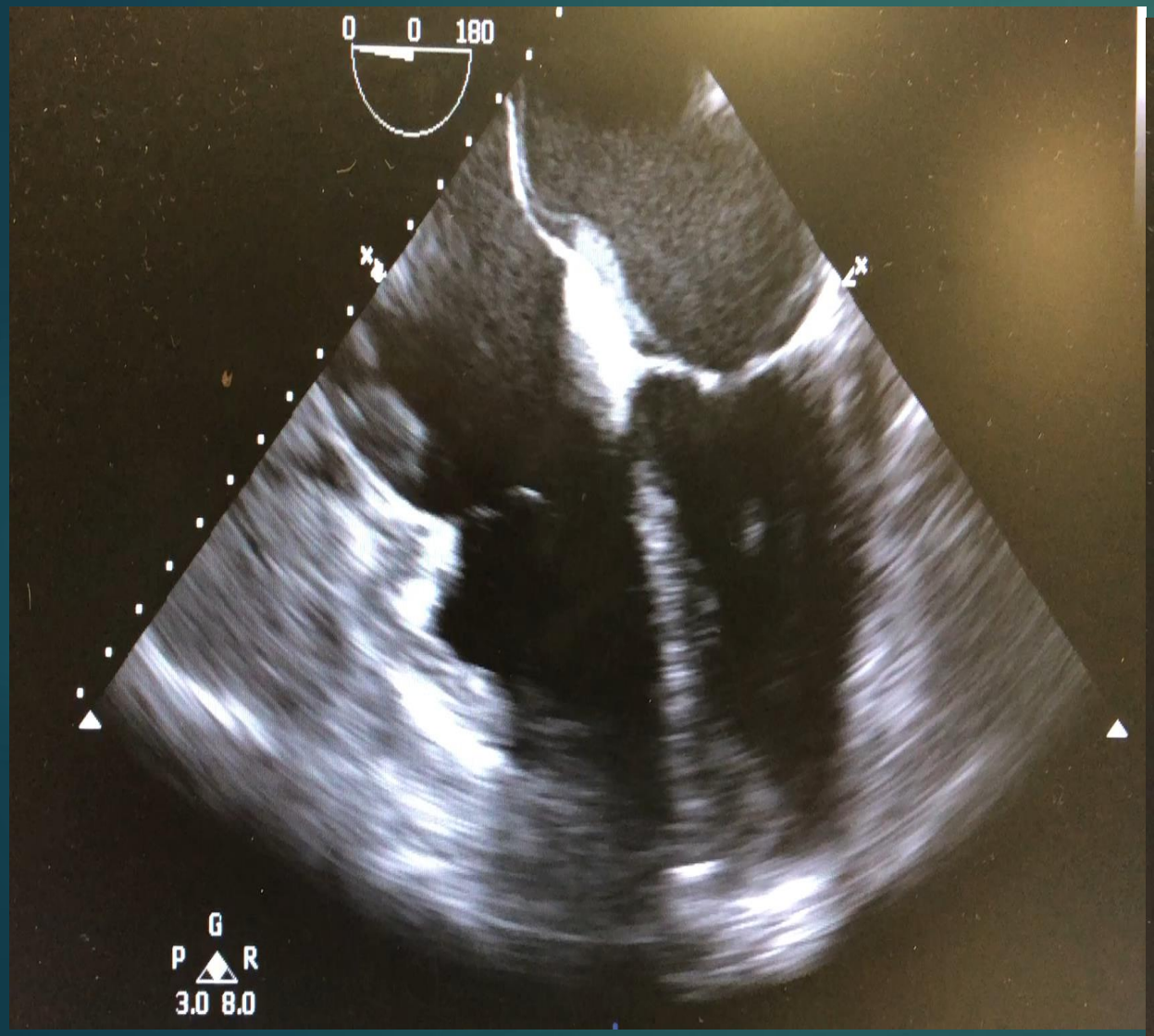

Aortic Dissection

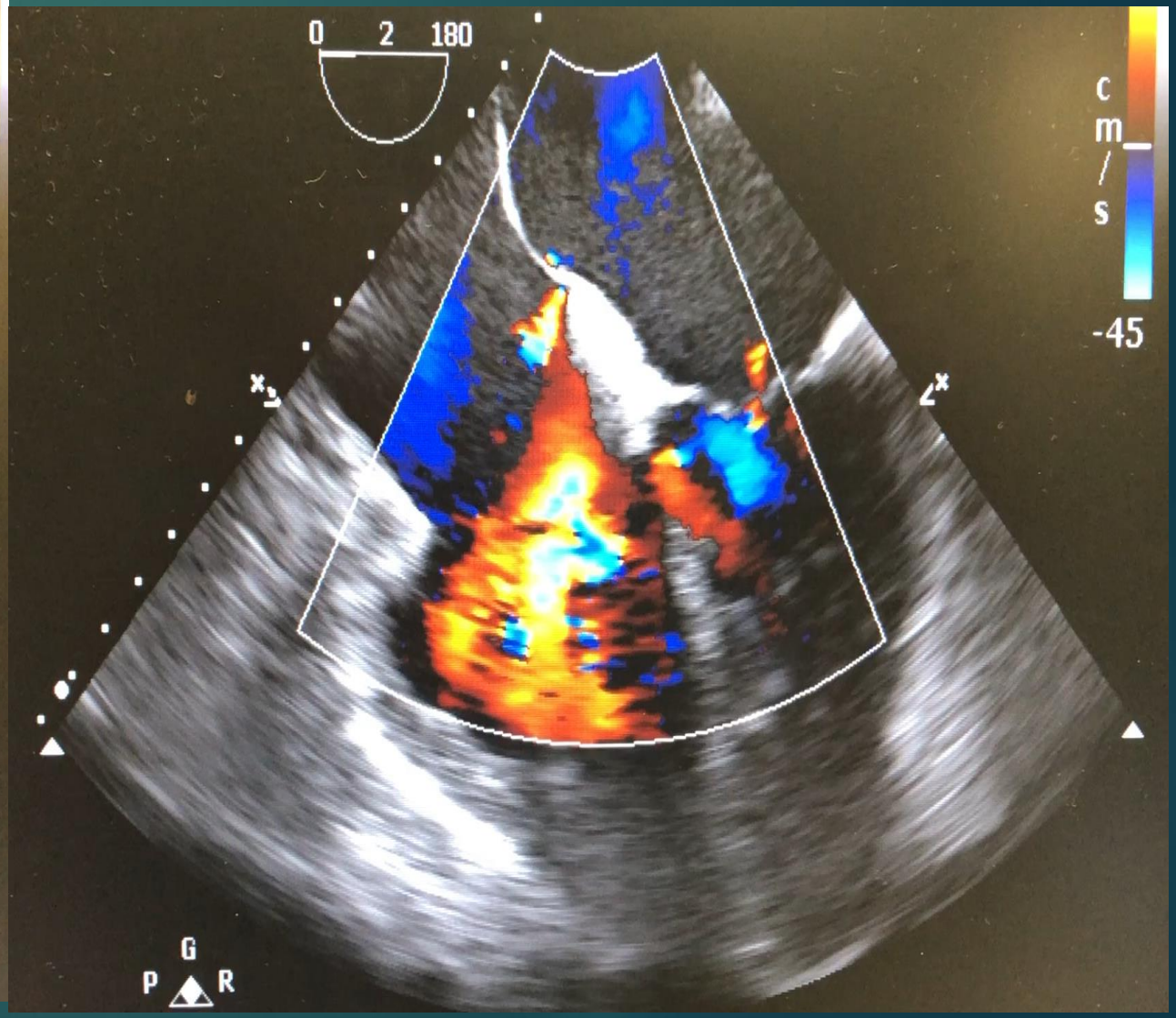
Aortic Dissection



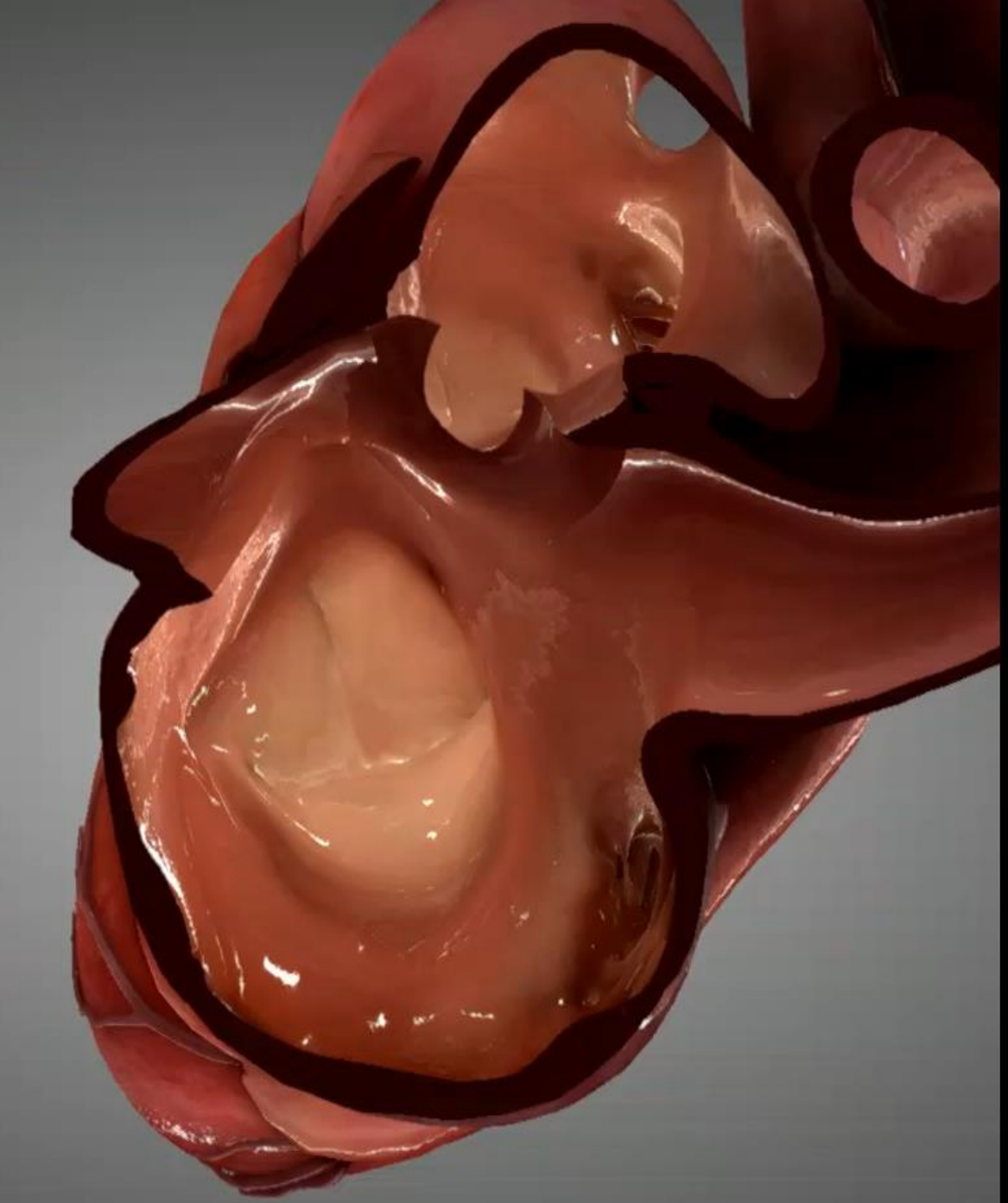


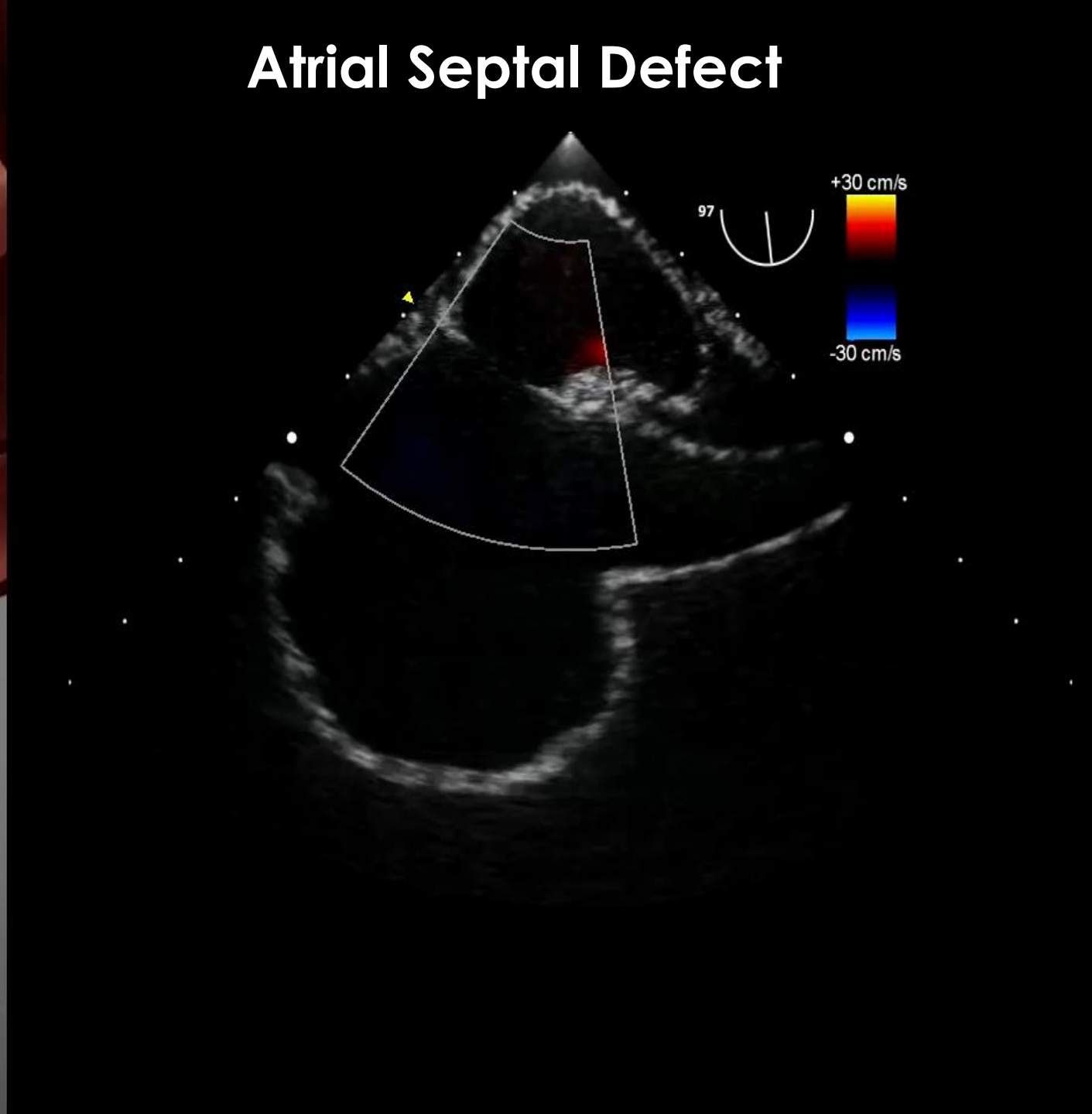
Atrial Septal Defect



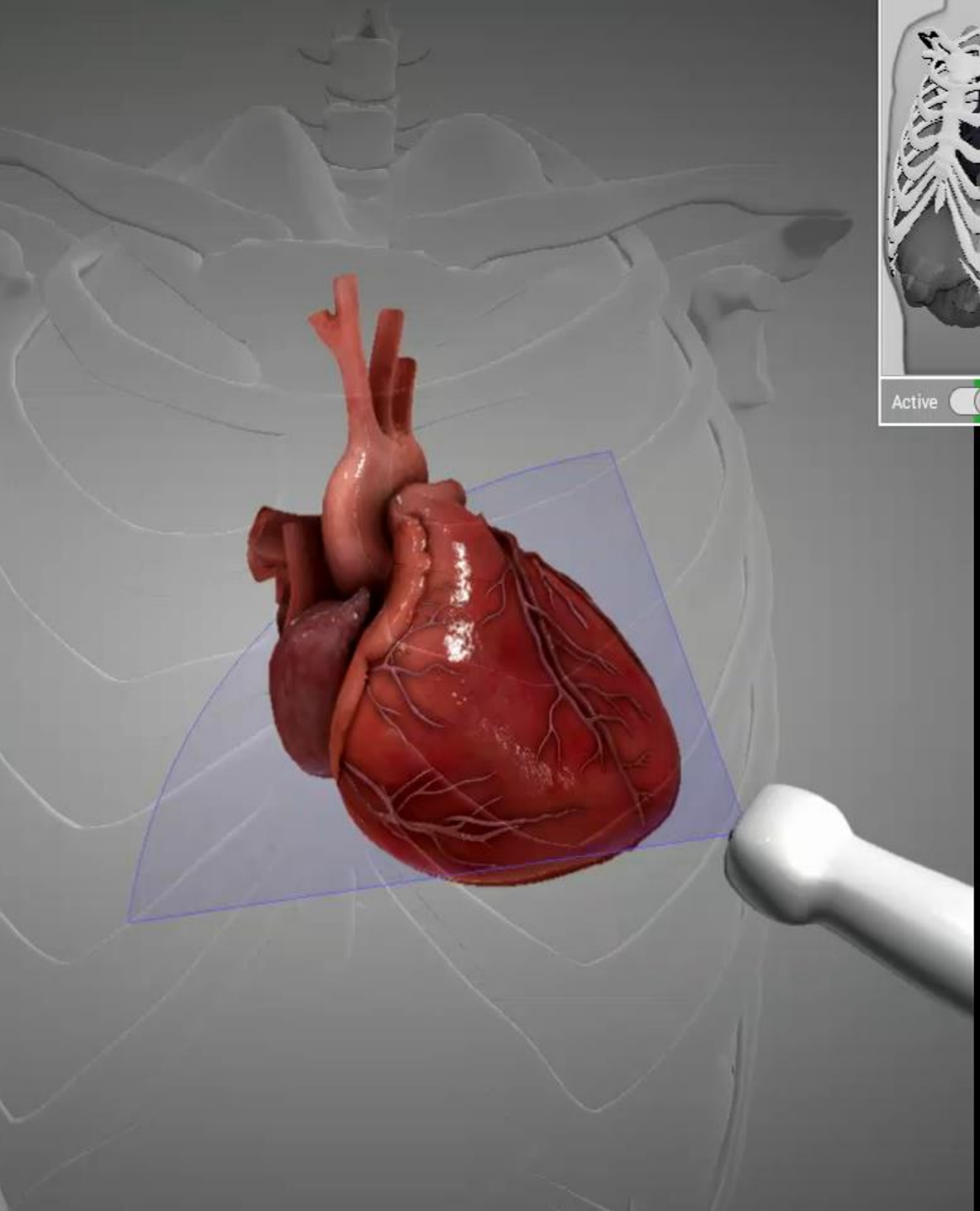


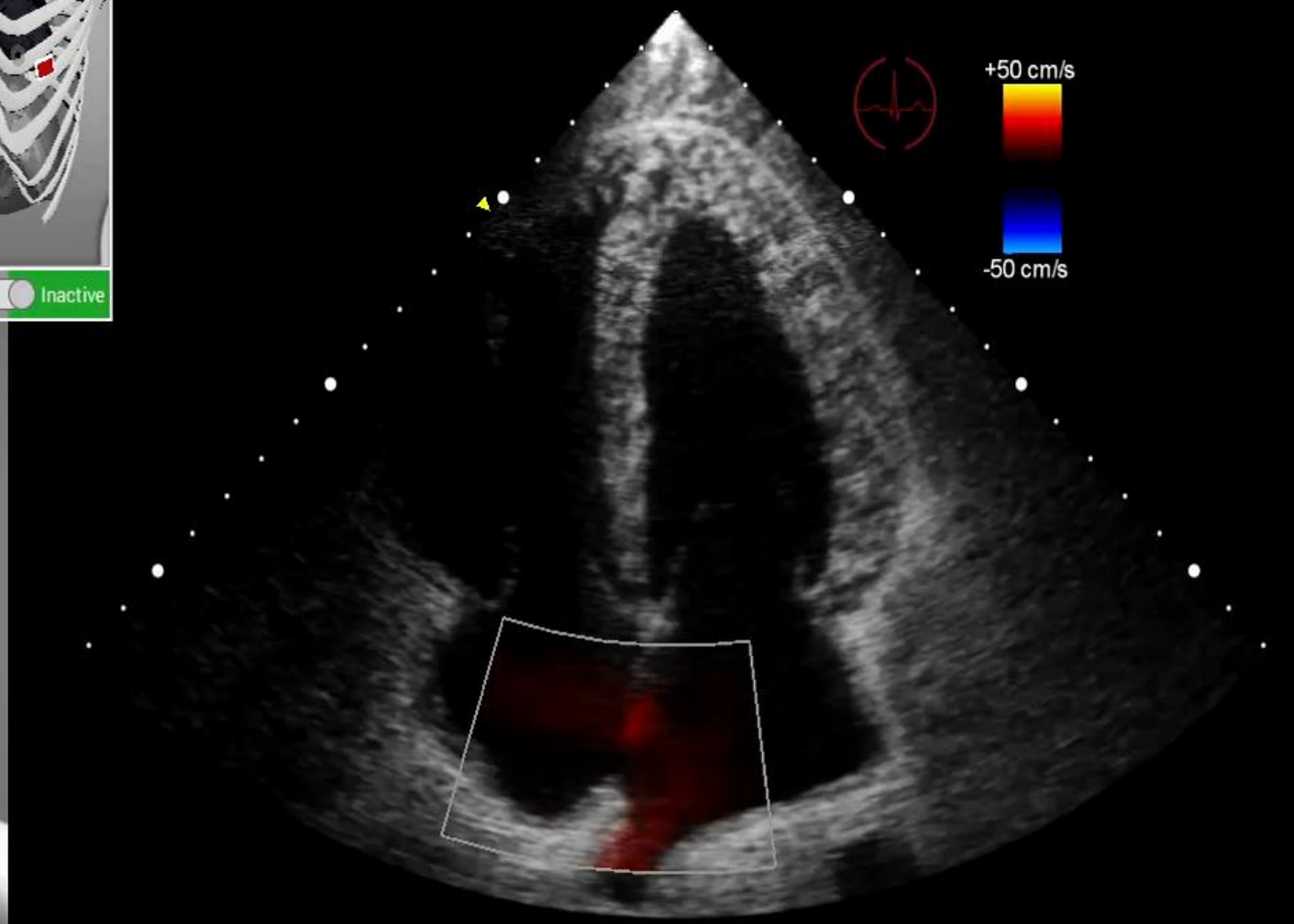
Atrial Septal Defect





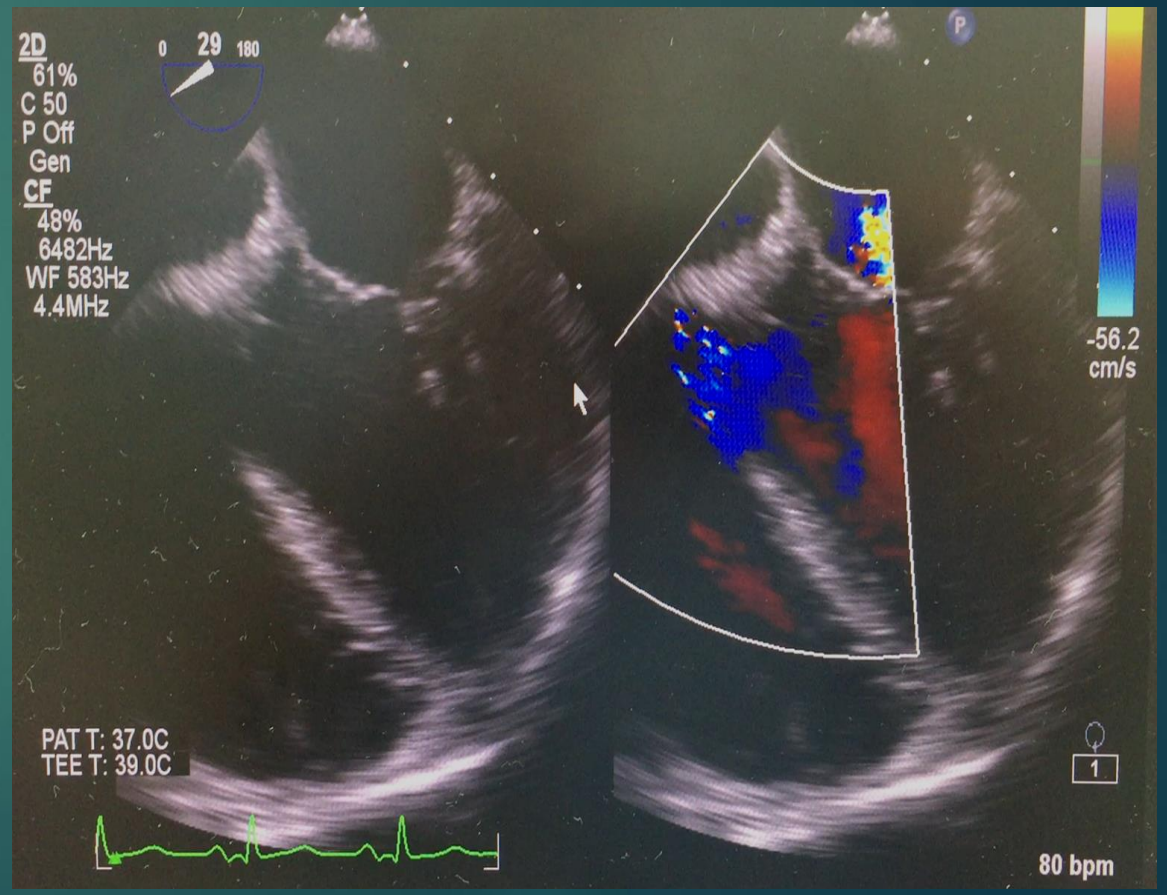
Atrial Septal Defect



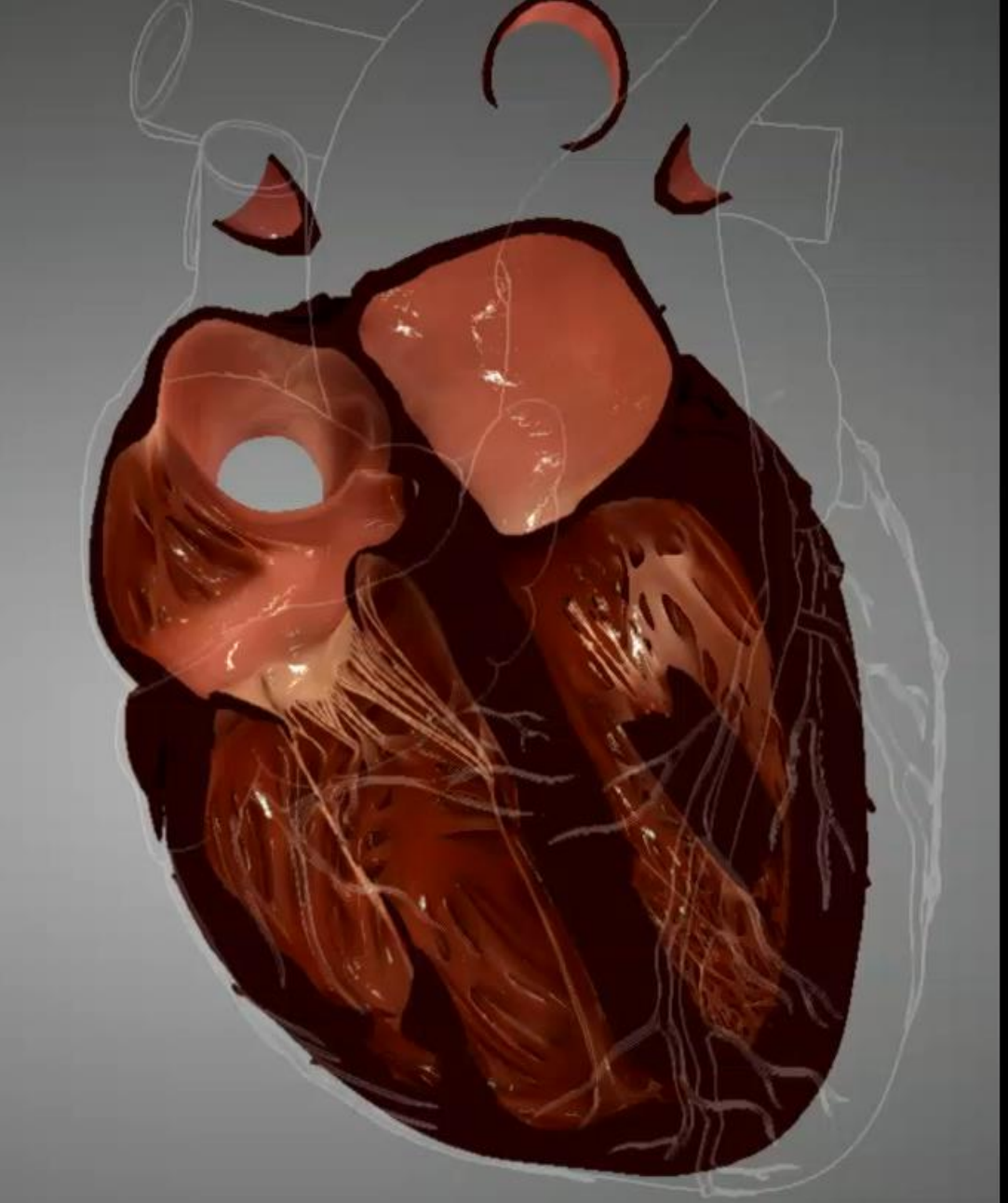


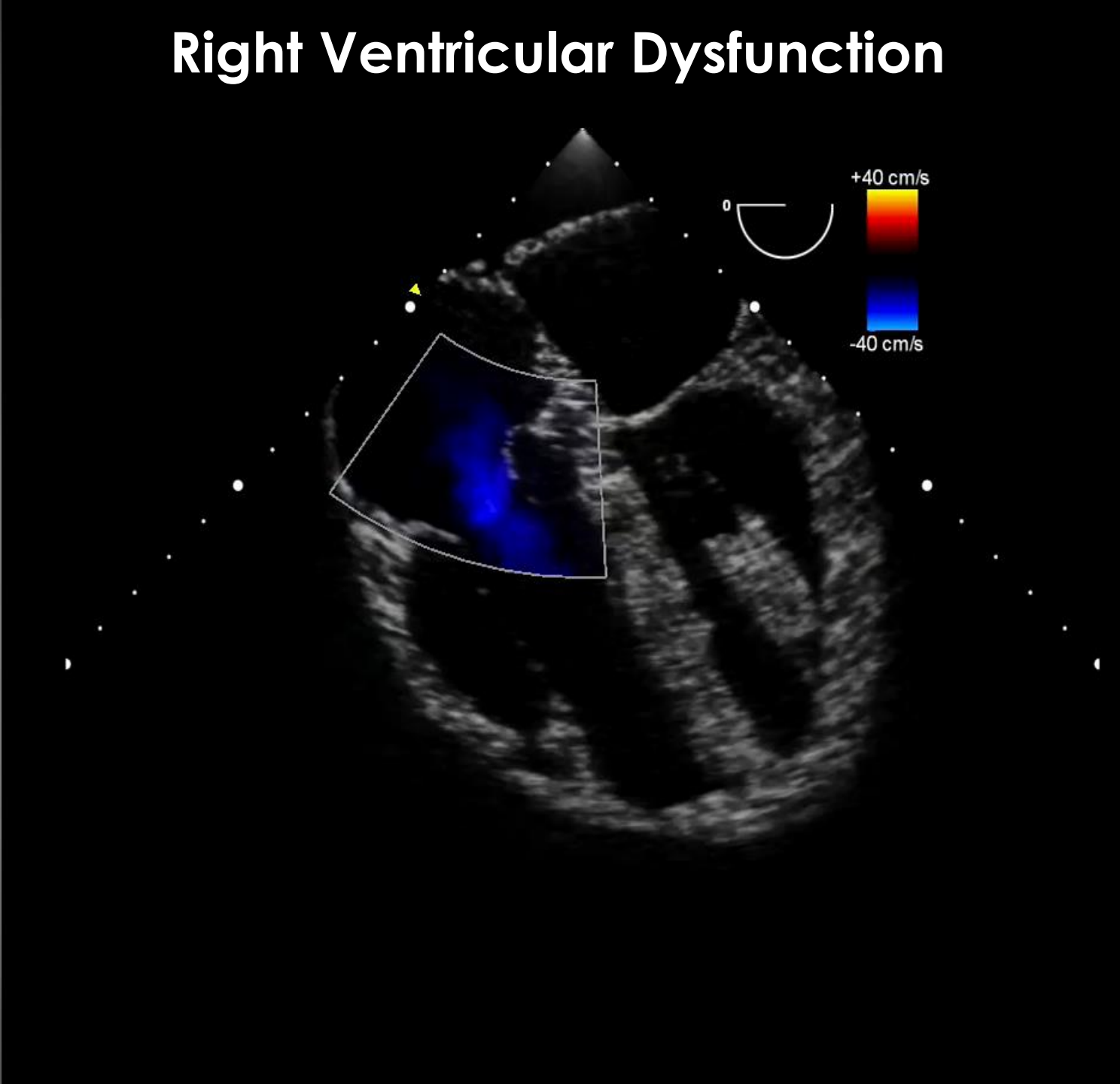
Ventricular Septal Defect

- 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

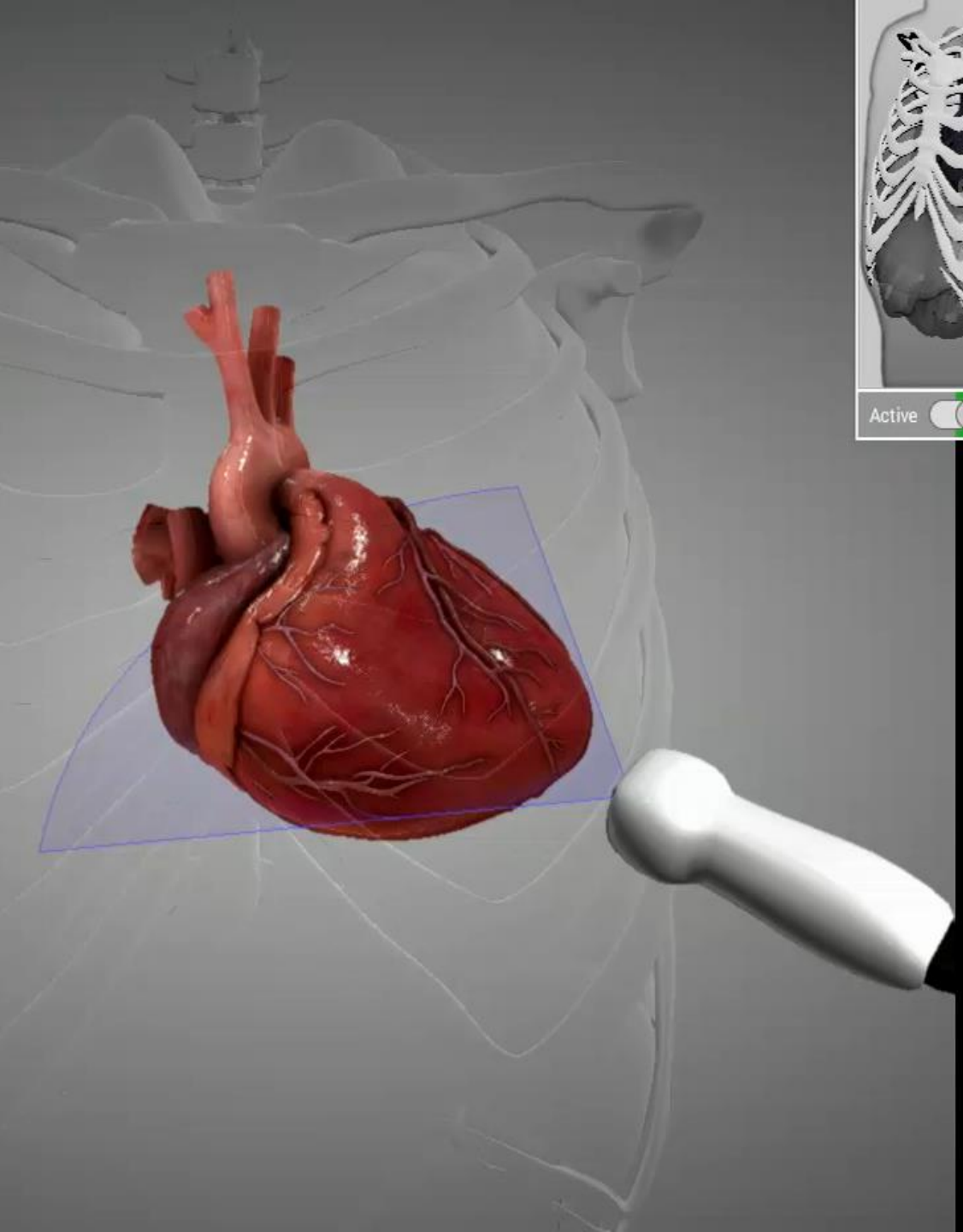


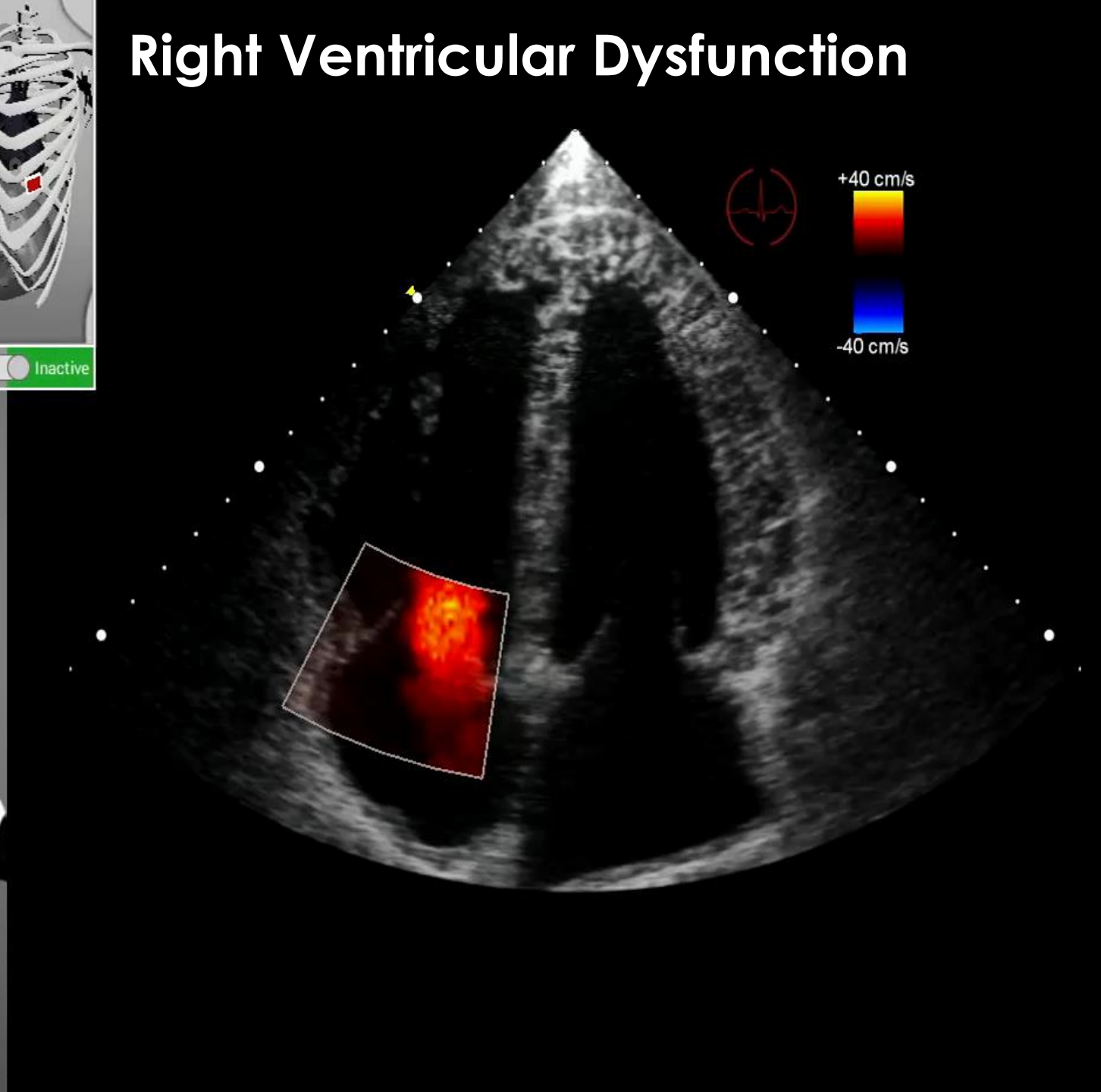
Right Ventricular Dysfunction

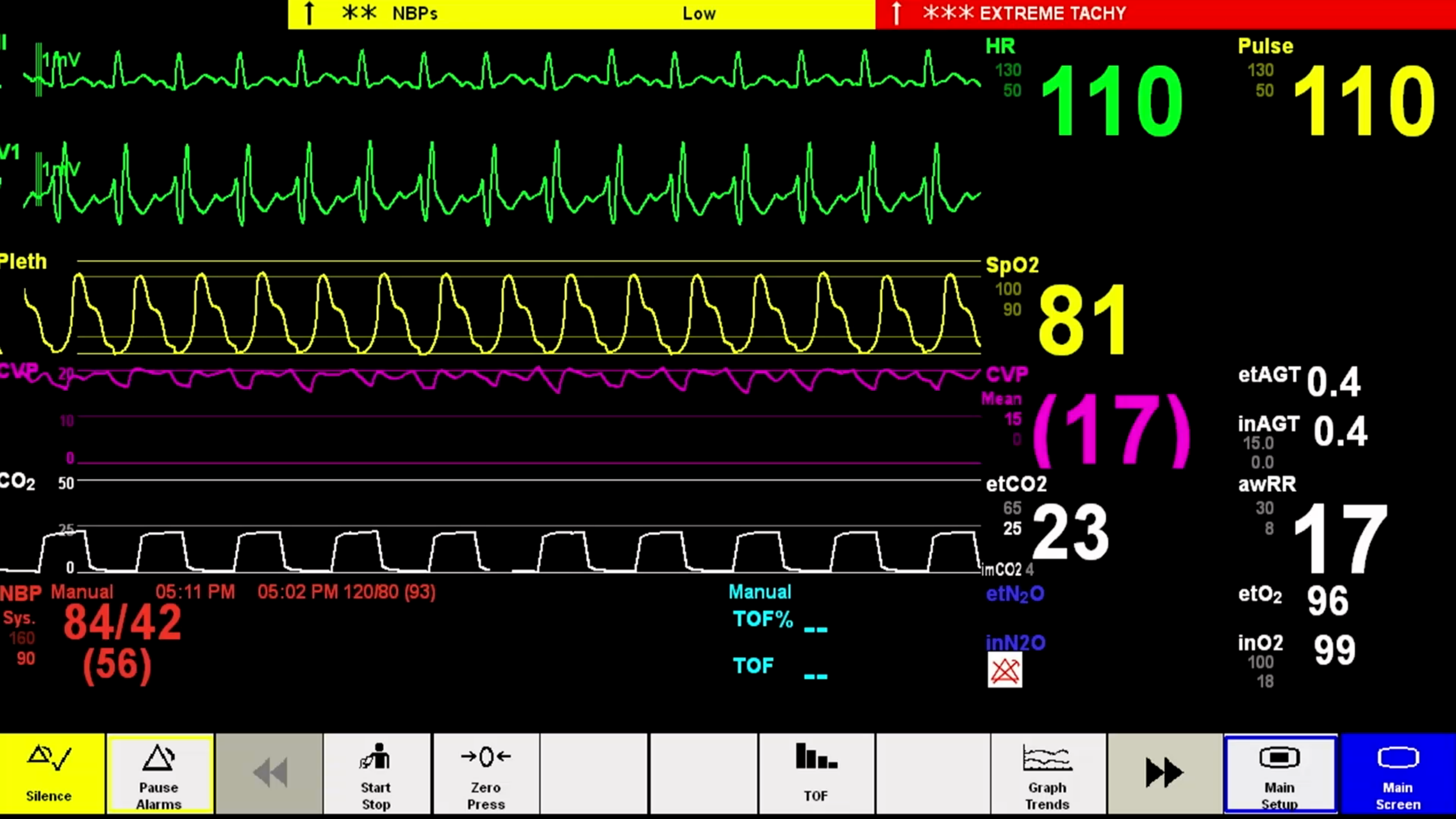




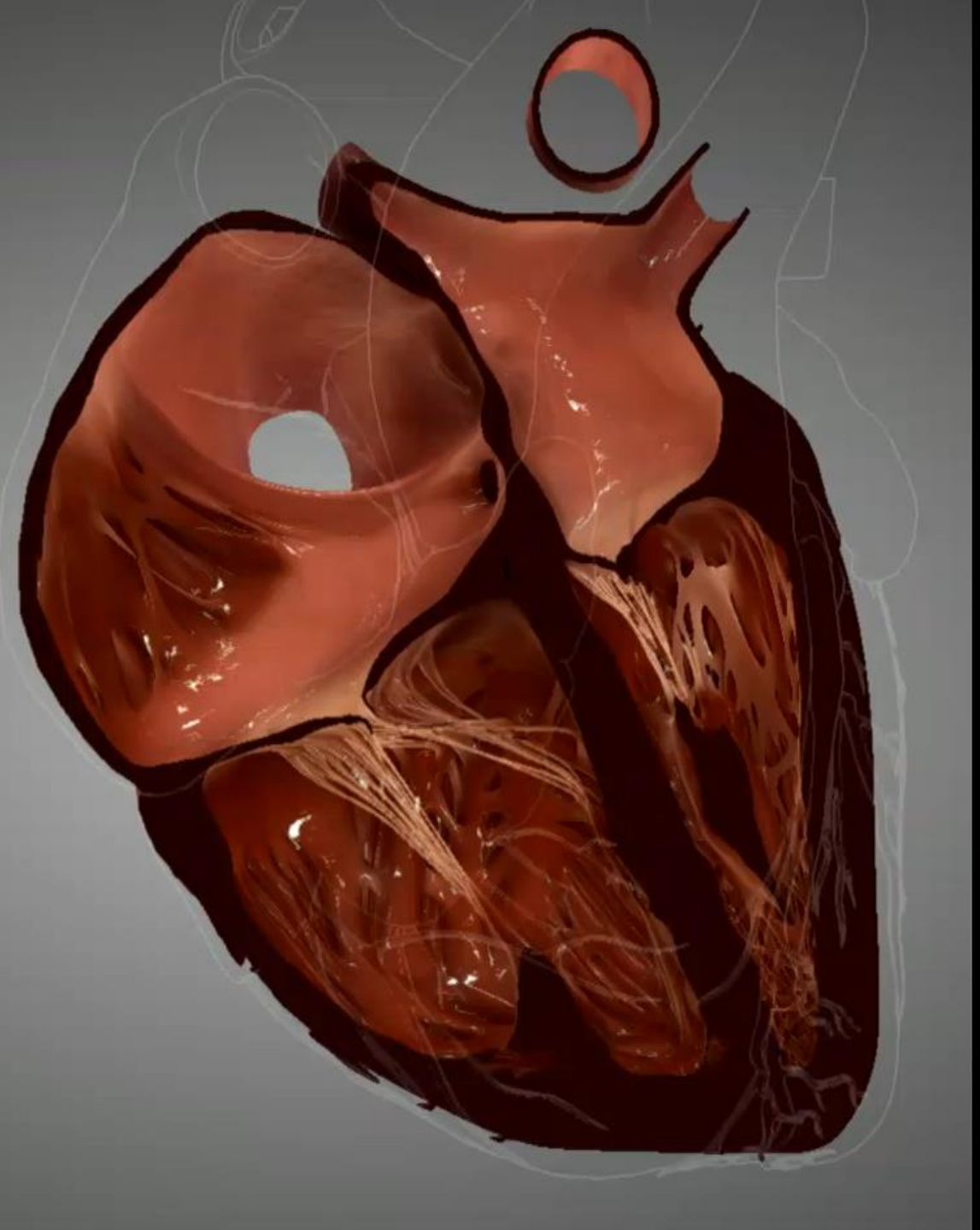
Right Ventricular Dysfunction

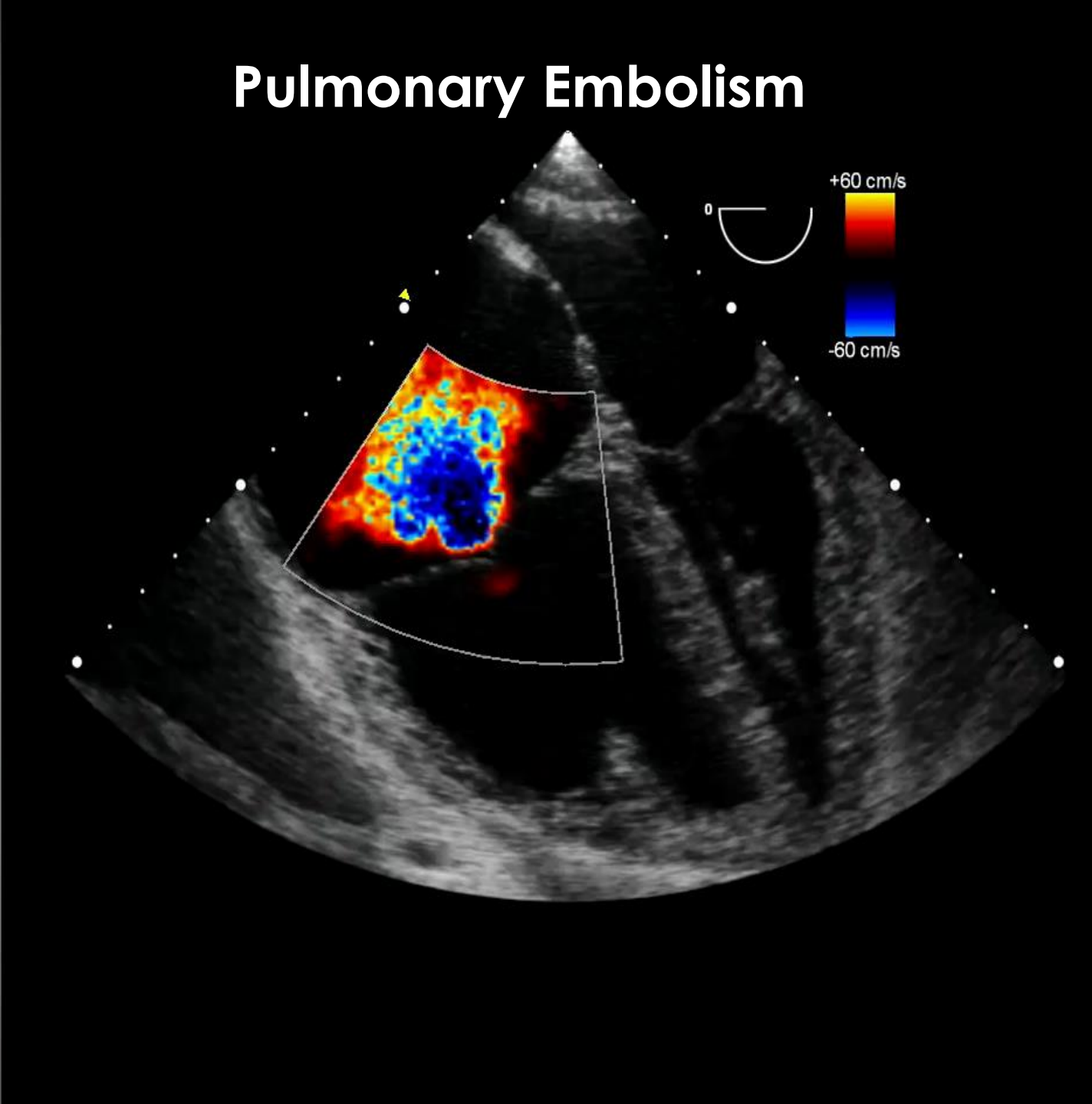




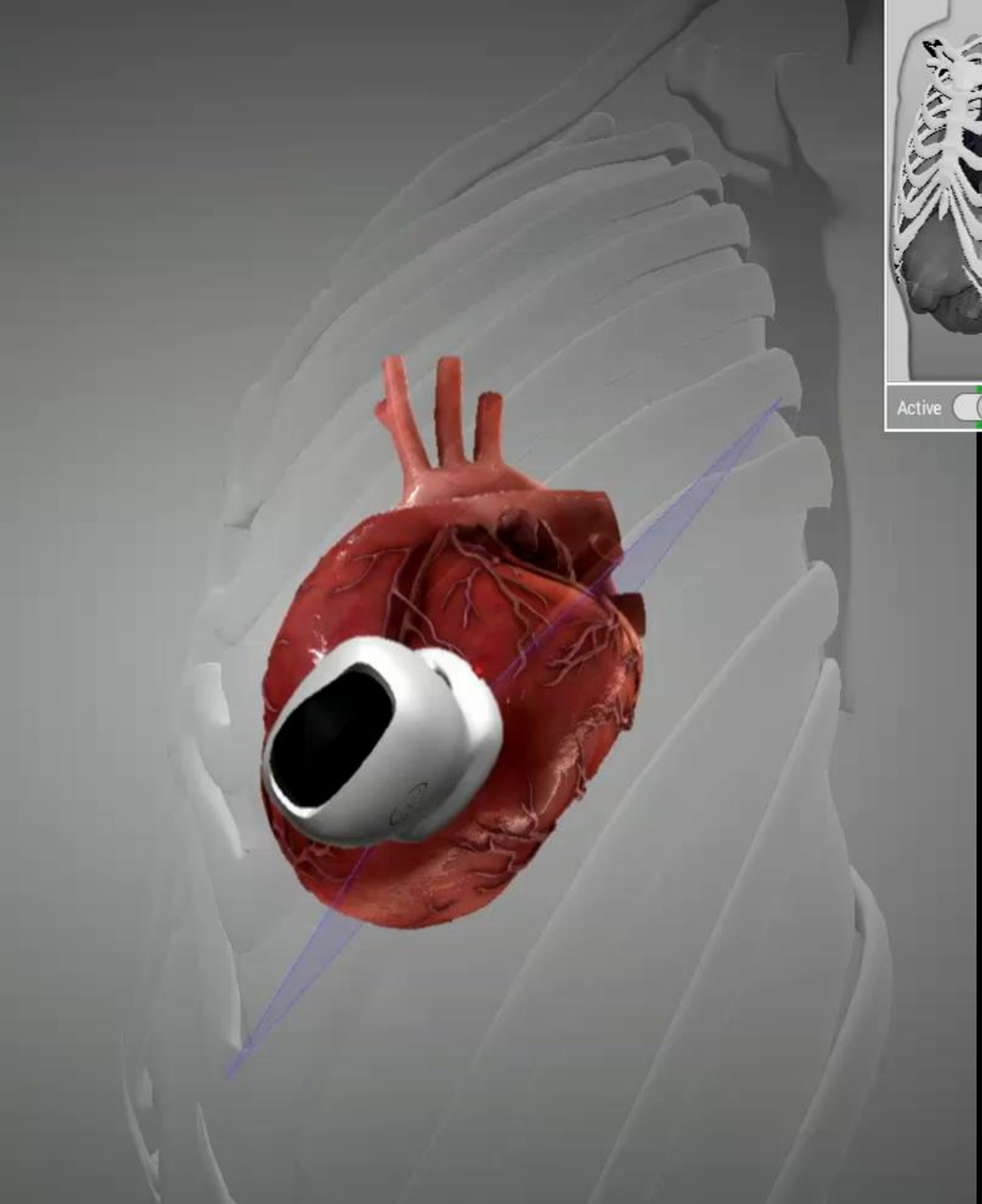

** NBPs
Low
*** EXTREME TACHY
HR
130
50
110
Pulse
130
50
110
II
1mV
V1
1mV
Pleth
SpO2
100
90
81
CVP
20
10
0
CVP
Mean
15
0
(17)
etAGT 0.4
inAGT
15.0
0.0
0.4
CO2
50
25
0
etCO2
65
25
23
awRR
30
8
17
imCO2 4
NBP Manual 05:11 PM 05:02 PM 120/80 (93)
Sys.
160
90
84/42
(56)
Manual
TOF% --
TOF --
etN2O
inN2O
etO2 96
inO2
100
18
99
Silence
Pause Alarms
Start Stop
Zero Press
TOF
Graph Trends
Main Setup
Main Screen

Pulmonary Embolism



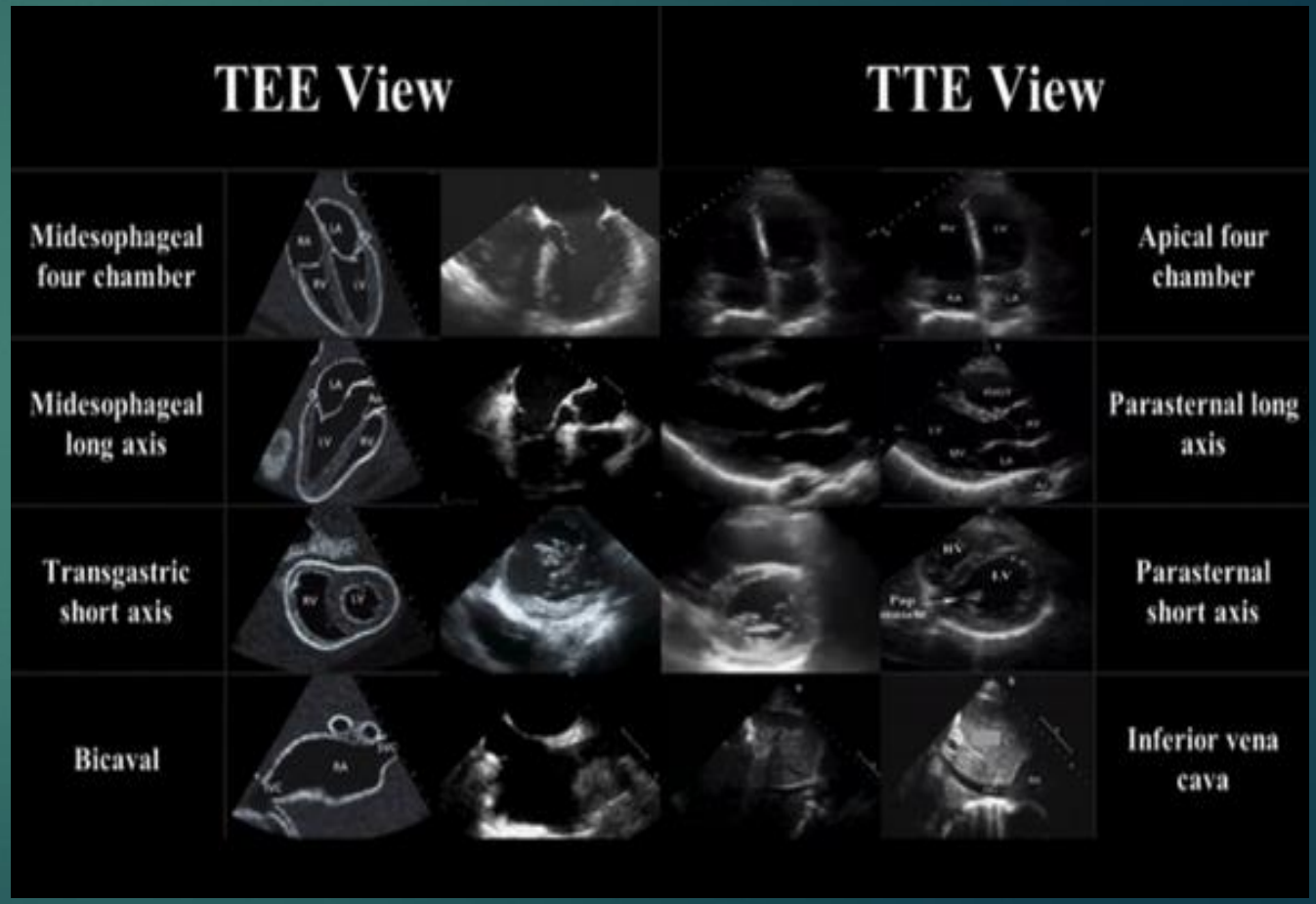


Pulmonary Embolism



General Indications for Rescue TEE

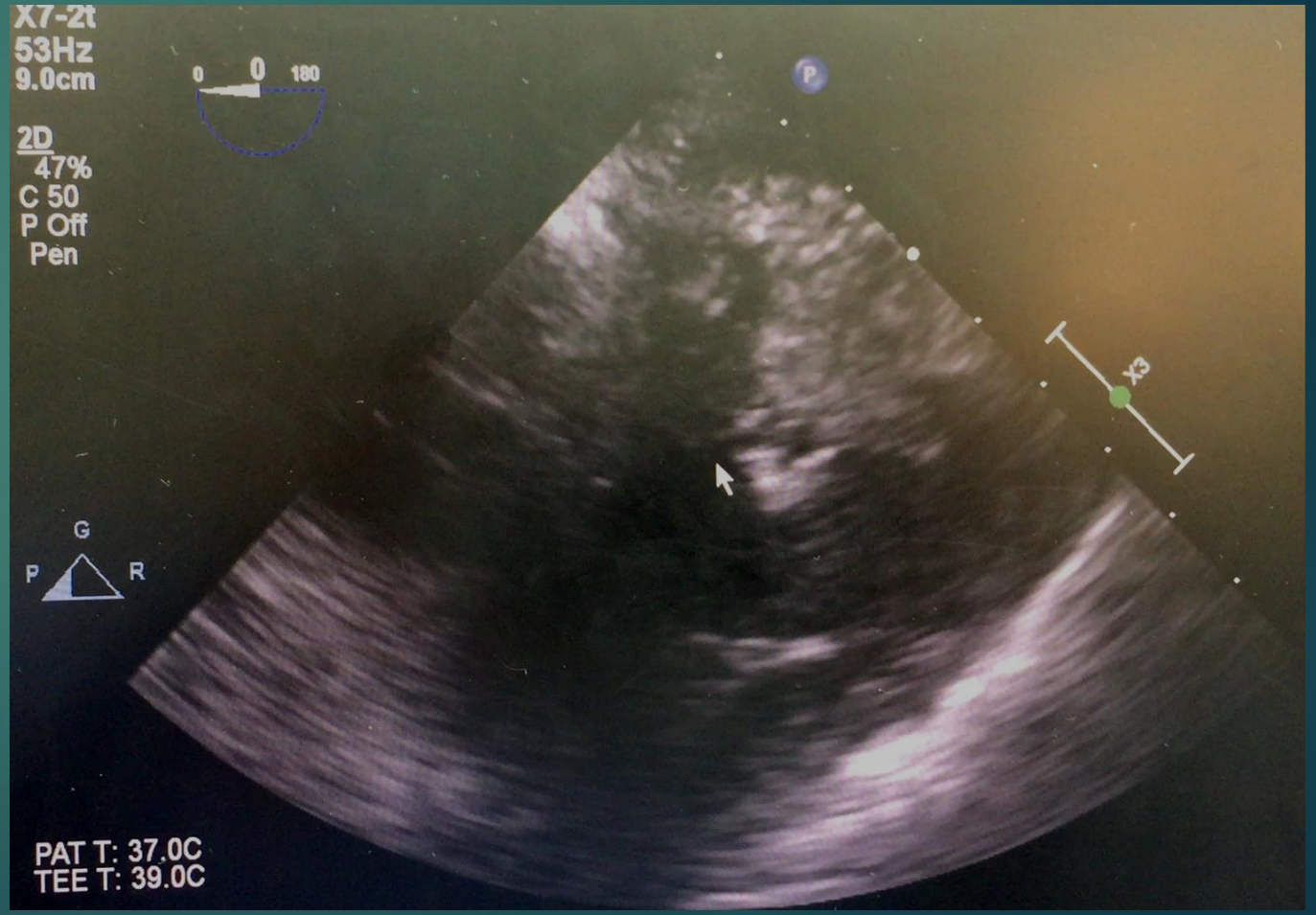
- Refractory hypotension
- Hypoxia
  - Patent foramen ovale
  - Atrial septal defect
- ECG changes/arrhythmias
- Shock/cardiac arrest
- Myocardial ischemia
- Tamponade
- Dissection
- Rescue TEE can provide a working diagnosis that led to **additional therapies in >80 percent** of patients



Memtsoudis SG et al. The usefulness of transesophageal echocardiography during intraoperative cardiac arrest in noncardiac surgery *Anesth Analg*. 2006;102(6):1653

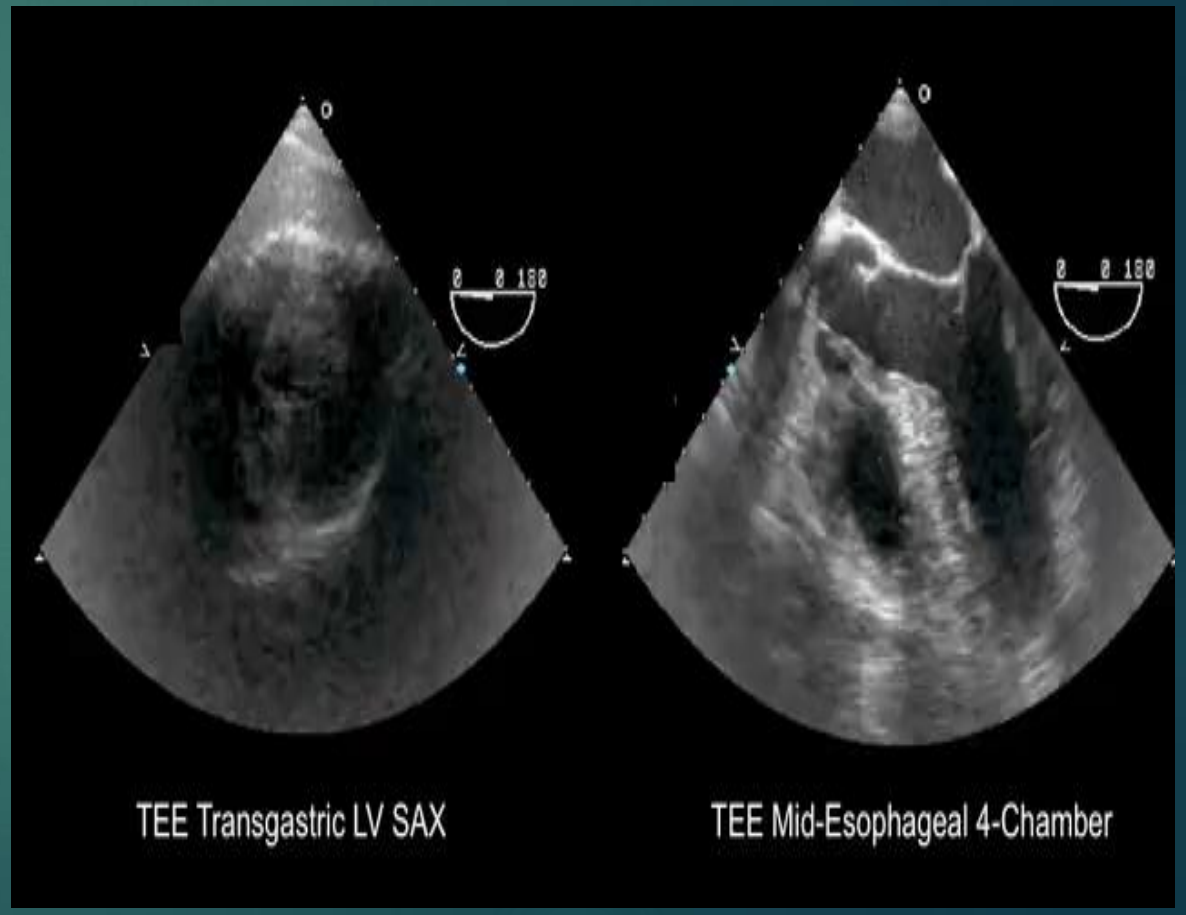
Instability due to Hypovolemia

- 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



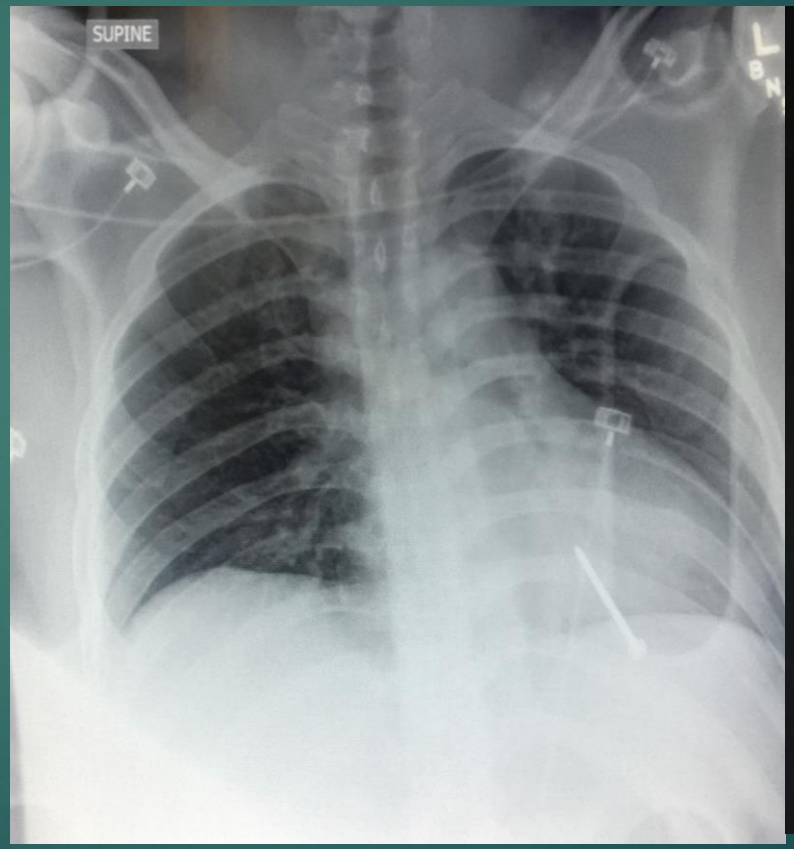
Instability due to Vasodilation

- 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



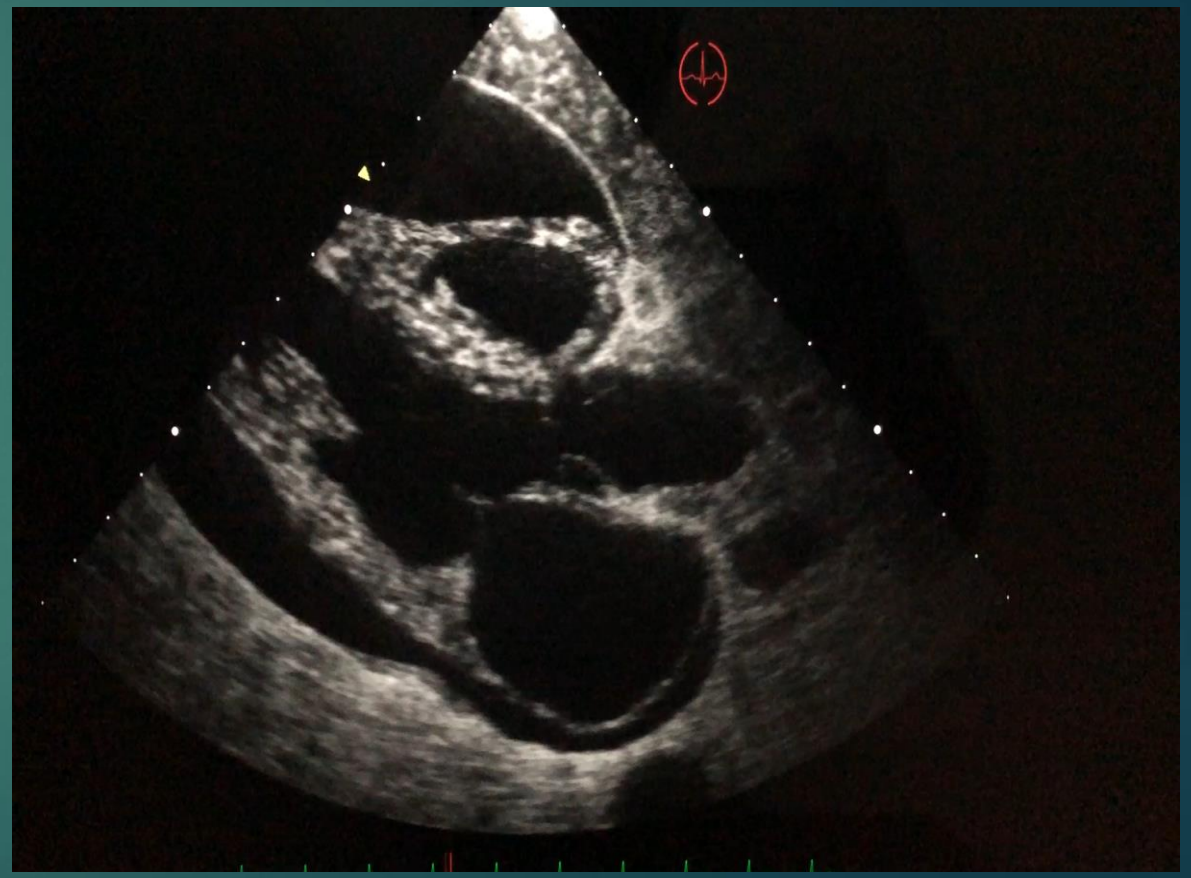
Instability due to Obstructive Shock

- 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)



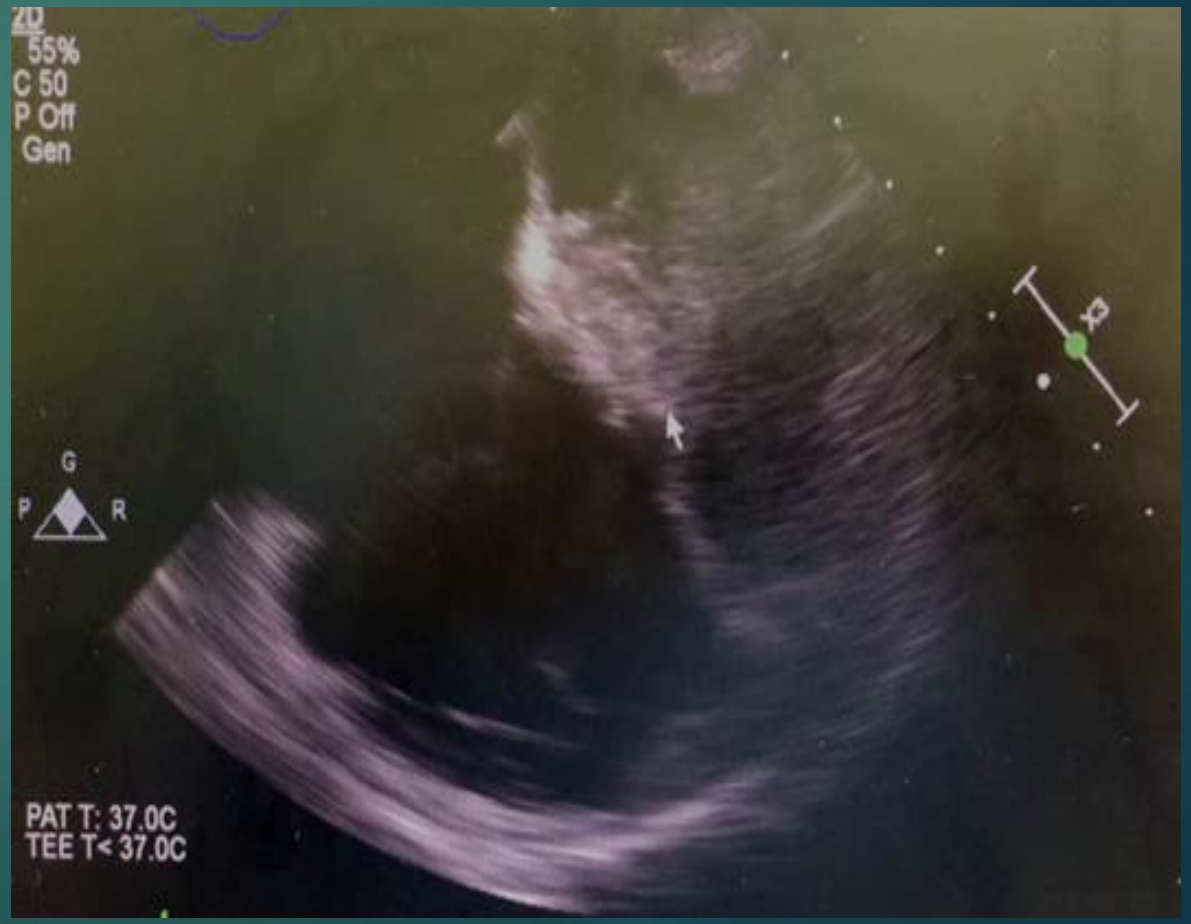
Cardiac Tamponade

- 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)



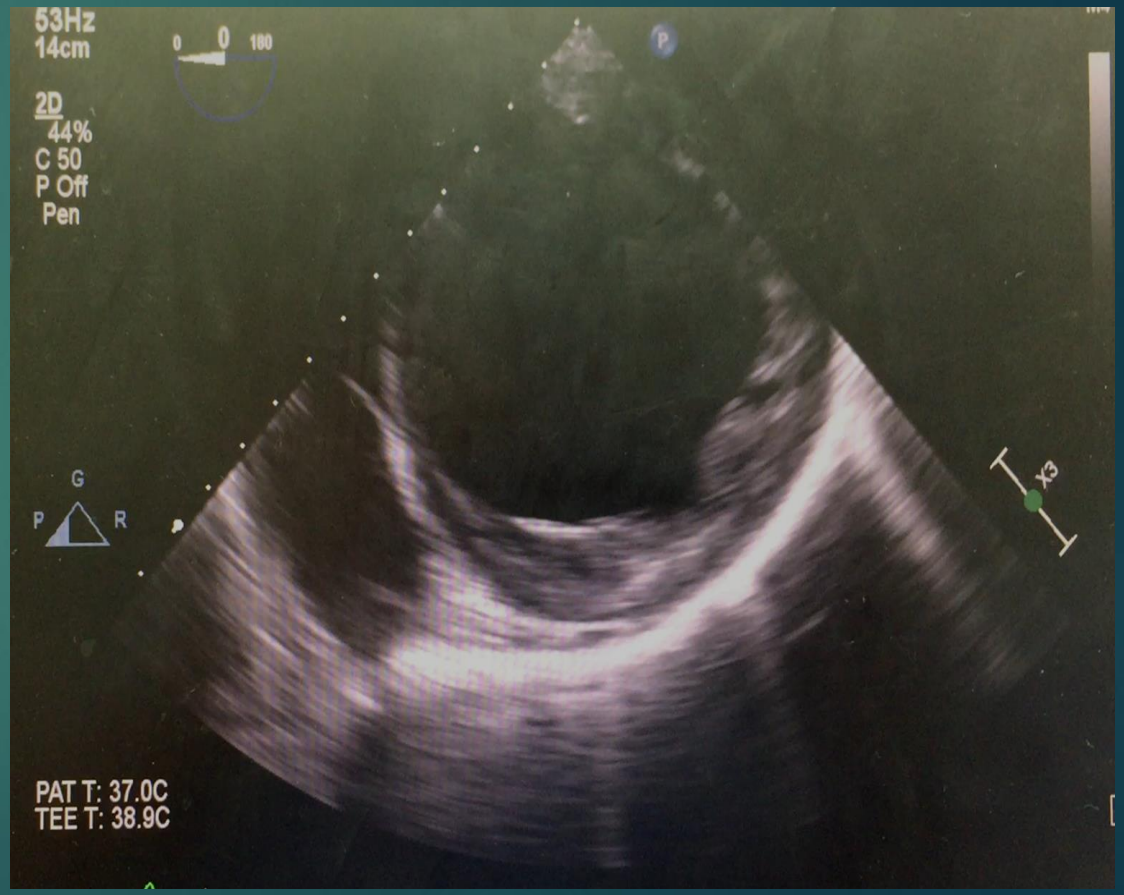
Pulmonary Embolism

- 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



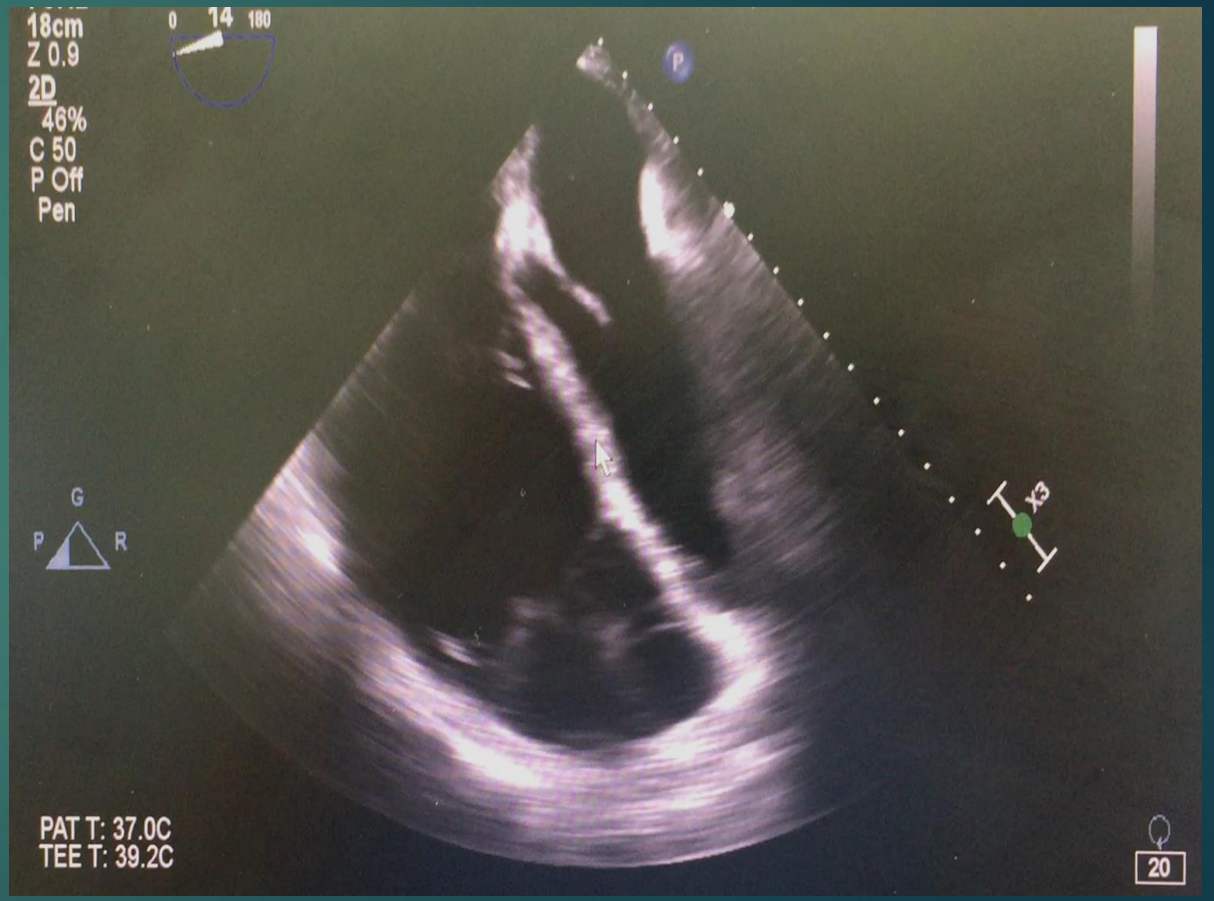
Cardiogenic Shock-LV Failure

- 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

Finding	%
Low EF	20.5%
RV Dysfunction	13.1%
Hypovolemia	32.2%
New Wall Motion Abnormality	10.2%
Pulmonary Embolism	5.8%
All other diagnoses	17.7%

Jasdavius et al: A systematic review of transthoracic and transesophageal echocardiography in non-cardiac surgery: implications for point-of-care ultrasound education in the operating room. Can J Anesth 2015

Most Common Findings in Rescue TEE (Shilcutt)

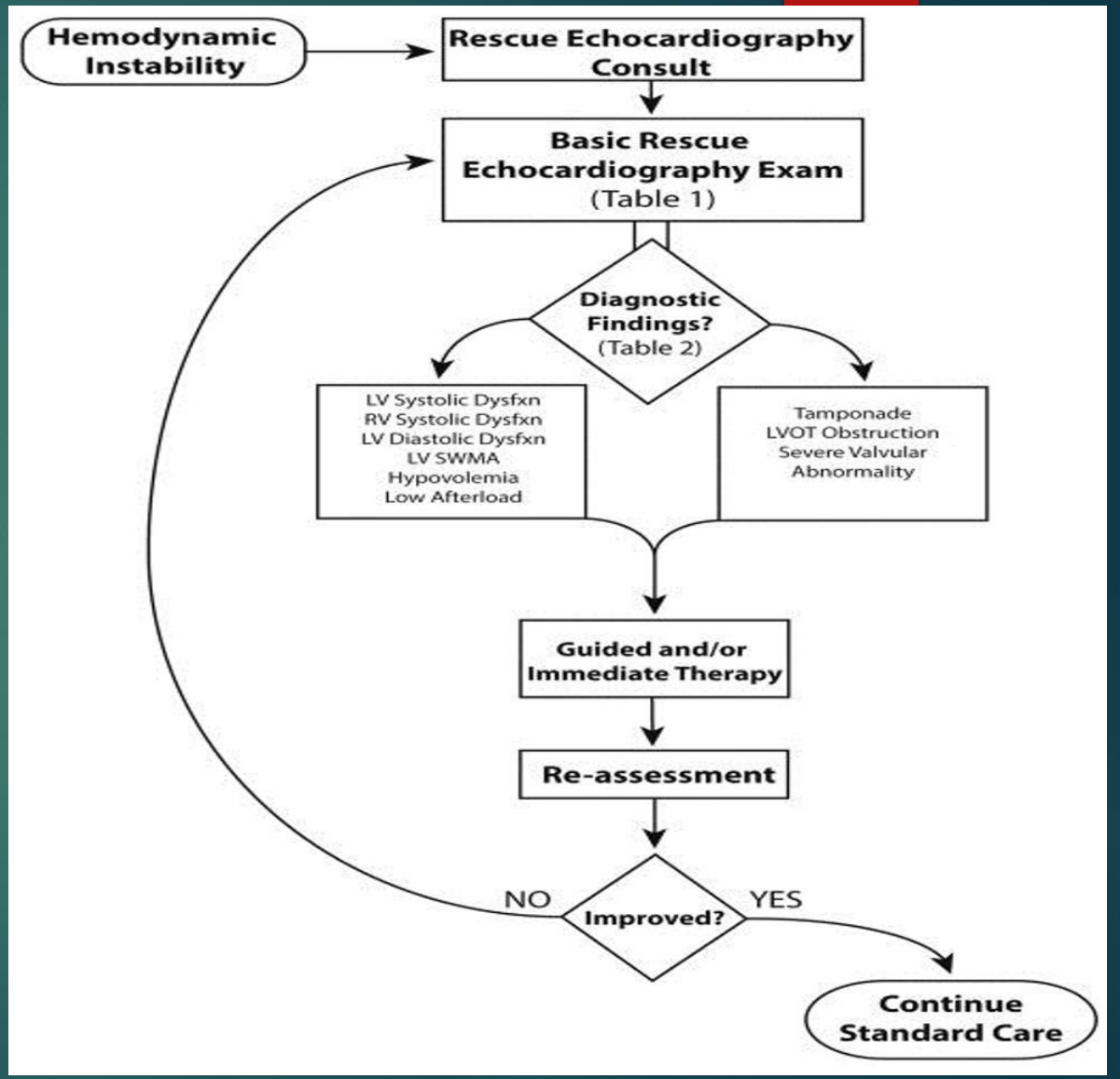
- TEE exam (8 of 11 PTE views)
- TTE exam (4 FATE and 3 other views)
- Impact was significant
  - Drug treatment change in 21 patients
  - Fluid or ventilator change in 10 patients

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

Shilcutt: Use of Rapid " Rescue " Perioperative Echocardiography to Improve Outcomes After Hemodynamic Instability in Noncardiac Surgical Patients. J Cardiothorac Vasc Anesth 2012; 26:362-70

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



Markin etal. A review of 364 perioperative rescue echocardiograms: findings of an anesthesiologist staffed perioperative echocardiography service J Cardiothorac Vasc Anesth. 2015 Feb;29(1):82-8

Management Impact of Interventions

Management Changes as a Result of Rescue Echocardiography Findings			
Management Changes N = 364	**Number of Rescue Echocardiograms Showing Management Change**		
	Total (%)	Intraoperative n = 202 n (%)	Postoperative n = 162 n (%)
All management changes	214 (58.8%)	126 (62.4%)	87 (53.7%)
Types of management changes:			
Fluid administration	113 (31.0%)	83 (41.1%)	30 (18.5%)
Inotropes	64 (17.6%)	34 (16.8%)	30 (18.5%)
Vasopressors	40 (11.0%)	25 (12.4%)	15 (9.3%)
Inhaled vasodilators	8 (2.2%)	3 (1.5%)	5 (3.1%)
Diuretics	5 (1.4%)	1 (0.5%)	4 (2.5%)
Surgical changes	27 (7.4%)	9 (4.5%)	17 (10.5%)
Other medical changes	18 (4.9%)	11 (5.4%)	7 (4.3%)

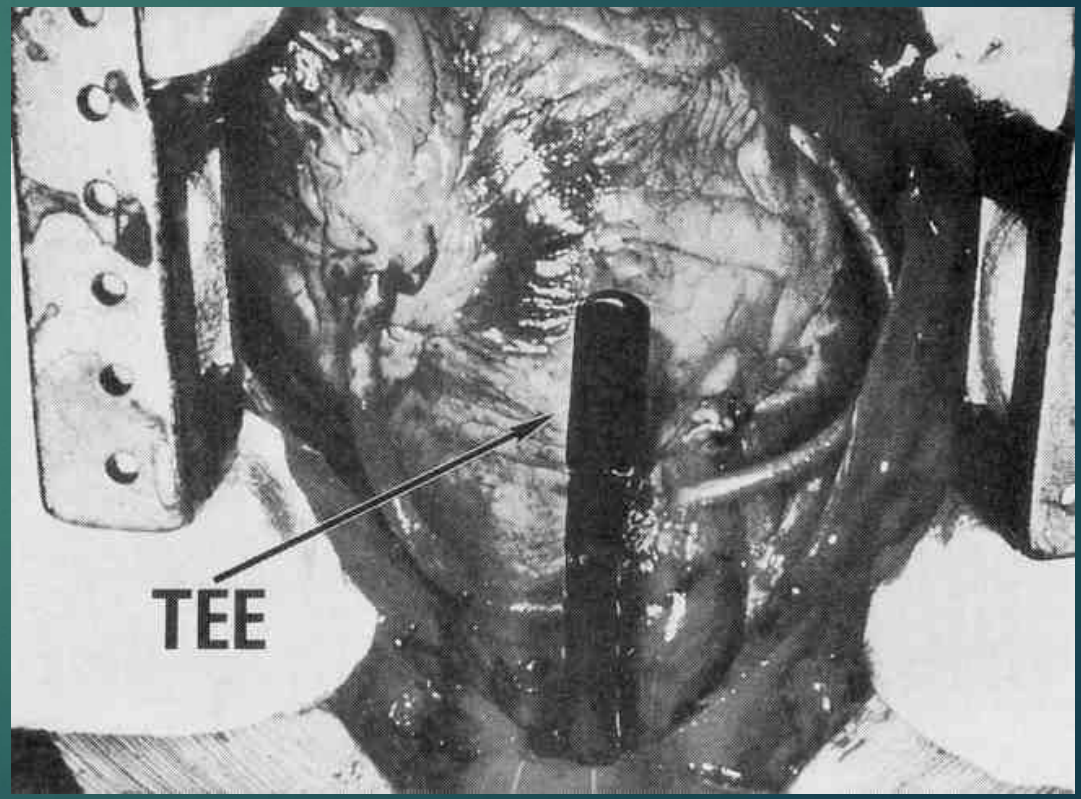
Markin et al J Cardiothorac Vasc Anesth. 2015;29:82-8

Rescue TEE-Diagnostic Targets

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

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