The “Standard” 3D Exam

Kent H. Rehfeldt, MD, FASE
Associate Professor of Anesthesiology
Mayo Clinic
Rochester, MN

No Disclosures

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Standard 3D Exam

Is 3D “standard” ?

Are certain 3D images required / recommended intraoperatively ?

If standard, how and when should we obtain them ?

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Goals / Objectives

- Examine guidelines for the use of 3D TEE in intraoperative / procedural settings
- Determine how / when 3D imaging should be employed during exam sequence

What should we do with 3D, and how should we do it?

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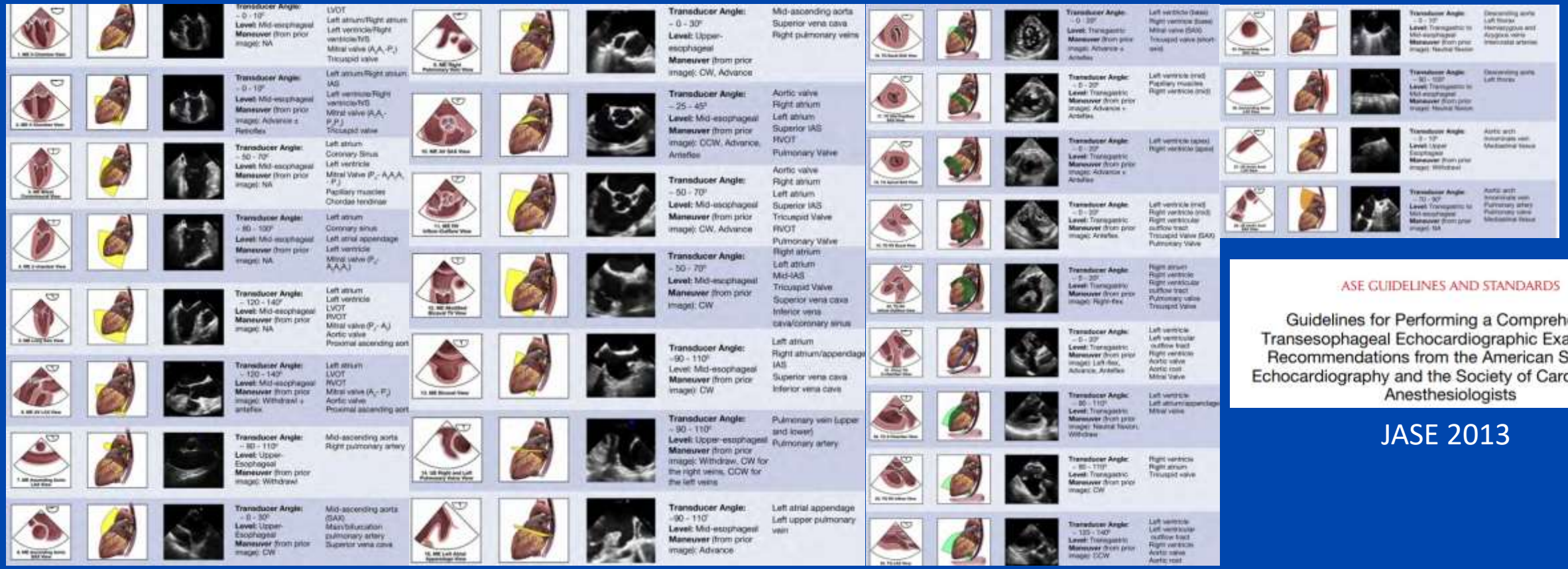
Comprehensive 2D TEE



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

JASE 2013

"The comprehensive imaging examination… presented in a suggested order."

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ASE GUIDELINES AND STANDARDS

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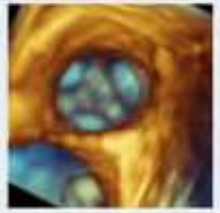
Protocol For Three-Dimensional Transesophageal Echocardiography Image Acquisition

Left Ventricle	1. Obtain a view of the left ventricle from the 0°, 60°, or 120° mid-esophageal positions 2. Use the biplane mode to check that the left ventricle is centered in a second view 90° to the original. 3. Acquire using wide-angle, multi-beat mode	
Right Ventricle	1. Obtain a view of the right ventricle from the 0° mid-esophageal position with the right ventricle tilted so that it is in the center of the image 2. Acquire using wide-angle, multi-beat mode	
Interatrial Septum	1. 0° with the probe rotated to the inter-atrial septum 2. Acquire using narrow-angle, single-beat or wide-angle, multi-beat modes	
Aortic Valve	1. Obtain a view of the aortic valve from either the 60° mid-esophageal, short-axis view or the 120° mid-esophageal, long-axis view 2. Acquire using either the narrow-angle, single-beat or the wide-angle, multi-beat modes	
Mitral Valve	1. Obtain a view of the mitral valve from the 0°, 60°, 90° or 120° mid-esophageal views 2. Use the biplane mode to check that the mitral valve annulus is centered with the acquisition plane in a second view 90° to the original. 3. Acquire using narrow-angle, single-beat mode	
Pulmonic Valve	1. Obtain a view of the pulmonic valve from either the 90° high-esophageal view or the 120° mid-esophageal, 3-chamber view rotated to center the pulmonic valve 2. Acquire using narrow-angle, single-beat mode	
Tricuspid Valve	1. Obtain a view of the tricuspid valve from either the 0° to 30° mid-esophageal, 4-chamber view tilted so that the valve is centered in the imaging plane or the 40° transgastric view with anteflexion 2. Acquire using a narrow-angle, single-beat	

"Recommended views…of cardiac structures."

Ventricles, atrial septum, valves

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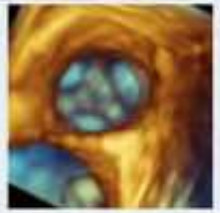
Pulmonic Valve	1. Obtain a view of the pulmonic valve from either the 90° high-esophageal view or the 120° mid-esophageal, 3-chamber view rotated to center the pulmonic valve 2. Acquire using narrow-angle, single-beat mode	
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Suggested approach to image acquisition

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GUIDELINES AND STANDARDS

EAE/ASE Recommendations for Image Acquisition and Display Using Three-Dimensional Echocardiography

(J Am Soc Echocardiogr 2012;25:3-46.)

5. MANAGEMENT AND WORK FLOW

Until 3D echocardiography is fully incorporated into daily clinical practice, protocols and techniques will remain focus oriented and vary according to disease process as well as institutional use.

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GUIDELINES AND STANDARDS

EAE/ASE Recommendations for Image Acquisition and Display Using Three-Dimensional Echocardiography

(J Am Soc Echocardiogr 2012;25:3-46.)

ical decision making.[14,16-24] Although a systematic approach to performing a comprehensive 3D TEE examination is recommended, it is recognized that not all views may be optimally obtained in all patients and that additional unconventional views may be required to obtain additional detailed information in patients with complex pathologies.

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Ventricles, atrial septum, valves

Table 3 Protocol for transesophageal 3D echocardiography

Protocol For Three-Dimensional Transesophageal Echocardiography		
Aortic Valve	**Left Ventricle/Right Ventricle**	**Pulmonic Valve**
60° mid-esophageal, short-axis view with and without color (zoomed or full-volume acquisition)	Left ventricle - 0° to 120° mid-esophageal views encompassing the entire ventricle (full-volume acquisition)	90° high-esophageal view with and without color (zoomed acquisition)
120° mid-esophageal, long-axis view with and without color (zoomed or full-volume acquisition)	Right ventricle - 0° to 120° mid-esophageal views with the right ventricle tilted to be in the center of the image (full-volume acquisition)	120° mid-esophageal, 3-chamber view with and without color (zoomed acquisition)
Mitral Valve	**Interatrial Septum**	**Tricuspid Valve**
0° to 120° mid-esophageal views with and without color (zoomed acquisition)	0° with the probe rotated to the interatrial septum (zoomed or full- volume acquisition)	0° to 30° mid-esophageal, 4-chamber view with and without color (zoomed acquisition)
		40° transgastric view with anteflexion with or without color (zoomed acquisition)

Standard 3D exam ?

GUIDELINES AND STANDARDS

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Exam protocol

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		40° transgastric view with anteflexion with or without color (zoomed acquisition)

VS

Recommendations

Table 7 Summary of indications for 3D echocardiography

	Recommended for Clinical Practice	Promis Clinic Studie		
Left Ventricle Functional Assessment				
Volume	✔			
Shape			✔	
Ejection Fraction	✔			
Dyssynchrony			✔	
Mass		✔		
Right Ventricle Functional Assessment				
Volume		✔		
Shape				✔
Ejection Fraction		✔		
Left Atrial Assessment				
Volume			✔	
Right Atrial Assessment				
Volume				✔
Mitral Valve Assessment				
Anatomy	✔			
Stenosis	✔			
Regurgitation			✔	
Tricuspid Valve Assessment				
Anatomy				✔
Stenosis				✔
Regurgitation				✔
Pulmonic Valve Assessment				
Anatomy				✔
Stenosis				✔
Regurgitation				✔
Aortic Valve Assessment				
Anatomy		✔		
Stenosis		✔		
Regurgitation				✔
Infective Endocarditis				✔
Prosthetic Valves			✔	
Guidance of Transcatheter Procedures*	✔			

* mitral clips, mitral valvuloplasty, transcatheter aortic valve implantation, paravalvular leak closure, atrial septal defect closure, ventricular septal defect closure and left atrial appendage closure.

Not TEE specific

GUIDELINES AND STANDARDS

EAE/ASE Recommendations for Image Acquisition and Display Using Three-Dimensional Echocardiography

(J Am Soc Echocardiogr 2012;25:3-46.)

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Standard 3D exam ?

Table 7 Summary of indications for 3D echocardiography

	Recommended for Clinical Practice	Promising Clinical Studies	Areas of Active Research	Unstudied
Left Ventricle Functional Assessment				
Volume	✔			
Shape			✔	
Ejection Fraction	✔			
Dyssynchrony			✔	
Mass		✔		
Right Ventricle Functional Assessment				
Volume		✔		
Shape				✔
Ejection Fraction		✔		
Left Atrial Assessment				
Volume			✔	
Right Atrial Assessment				
Volume				✔
Mitral Valve Assessment				
Anatomy	✔			
Stenosis	✔			
Regurgitation			✔	
Tricuspid Valve Assessment				
Anatomy				✔
Stenosis				✔
Regurgitation				✔
Pulmonic Valve Assessment				
Anatomy				✔
Stenosis				✔
Regurgitation				✔
Aortic Valve Assessment				
Anatomy		✔		
Stenosis		✔		
Regurgitation				✔
Infective Endocarditis				✔
Prosthetic Valves			✔	
Guidance of Transcatheter Procedures*	✔			

*Mitral clips, mitral valvuloplasty, transcatheter aortic valve implantation, paravalvular leak closure, atrial septal defect closure, ventricular septal defect closure and left atrial appendage closure.

2012

"…opinions of the writing group…"

3D Recommended for:

- LV volume, EF
- Mitral
- Catheter procedures

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What is a “standard” 3D Exam?

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A Practical Approach to an Intraoperative Three-Dimensional Transesophageal Echocardiography Examination

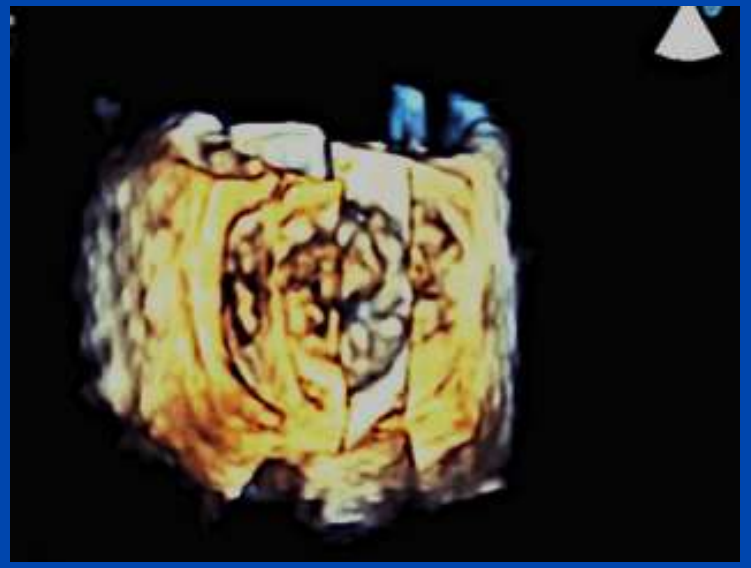
Feroze Mahmood, MD,* Jelliffe Jeganathan, MBBS,* Rabya Saraf, BA,† Sajid Shahul, MD,‡
Madhav Swaminathan, MD,§ G. Burkhard Mackensen, MD, PhD,‖ Ziyad Knio, BS,† and Robina Matyal, MD*

J Cardiothor Vasc Anesth Vol30,No2(April),2016:pp470

- "…the requirements for the perioperative arena are different … and time limited"
- "Intraoperative 3D imaging is performed as a supplement to 2D imaging."
- "There is no standardized sequence for conducting an intraoperative 3D examination."

2016

The standard 3D exam:



- *Individualized*
- *Driven by specific clinical situation*

3D TEE:

- Time consuming
- Often incompatible with ongoing surgery

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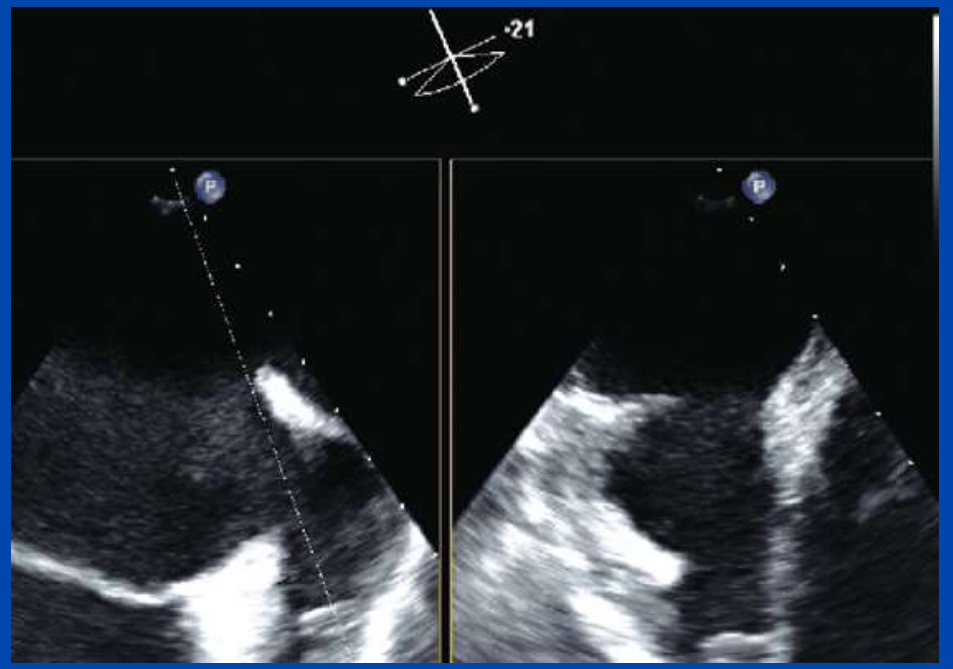
Decisions:

- What structure(s) to image with 3D
- What 3D mode to use

…and when ?



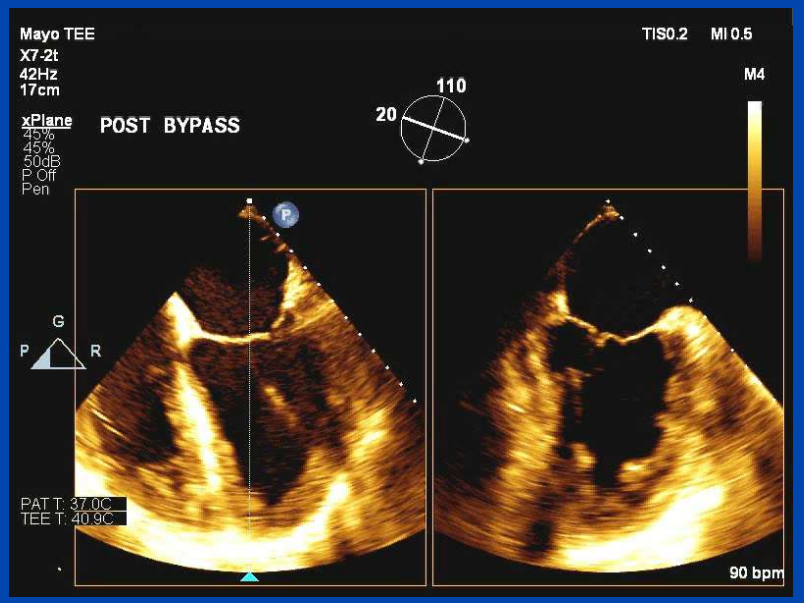
Quick Review: Modes of 3D

"Live"

"Zoom"

"Full volume"

Quick Review: Modes of 3D



Simultaneous orthogonal

"Live" or single – beat, probe responsive

ECG-gated, reconstructed multi-beat

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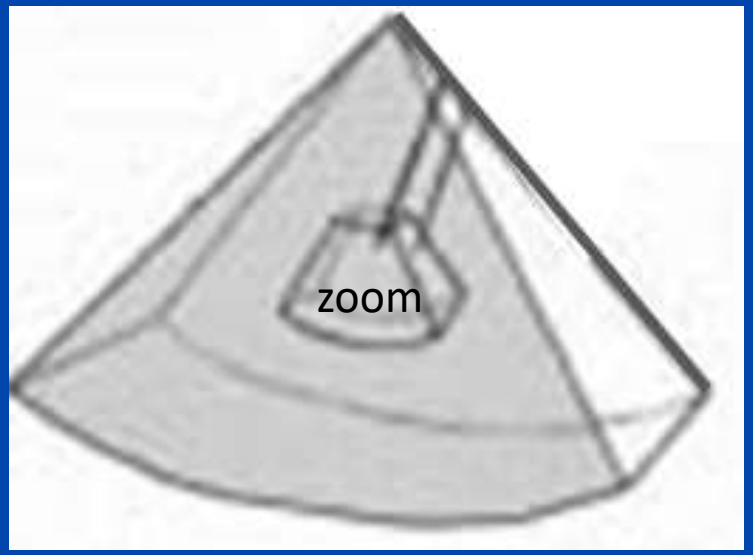
Wide sector “zoom” vs full volume

- Different volume format
- Zoom may default to single beat
- Both can be single beat (“live”) or multi beat gated



Modest improvement in resolution with smaller sector

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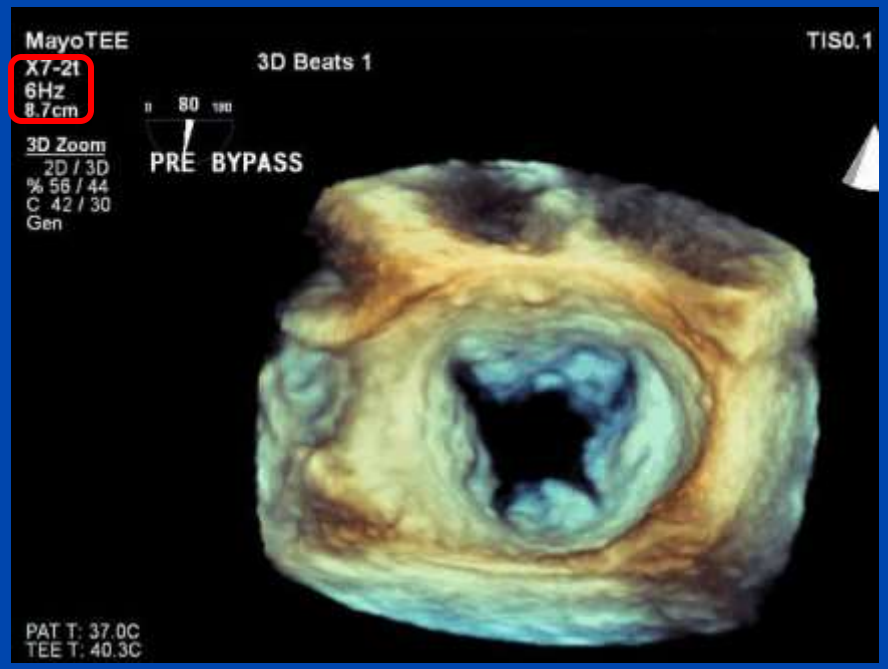
“Live” 3D : Single beat, probe responsive

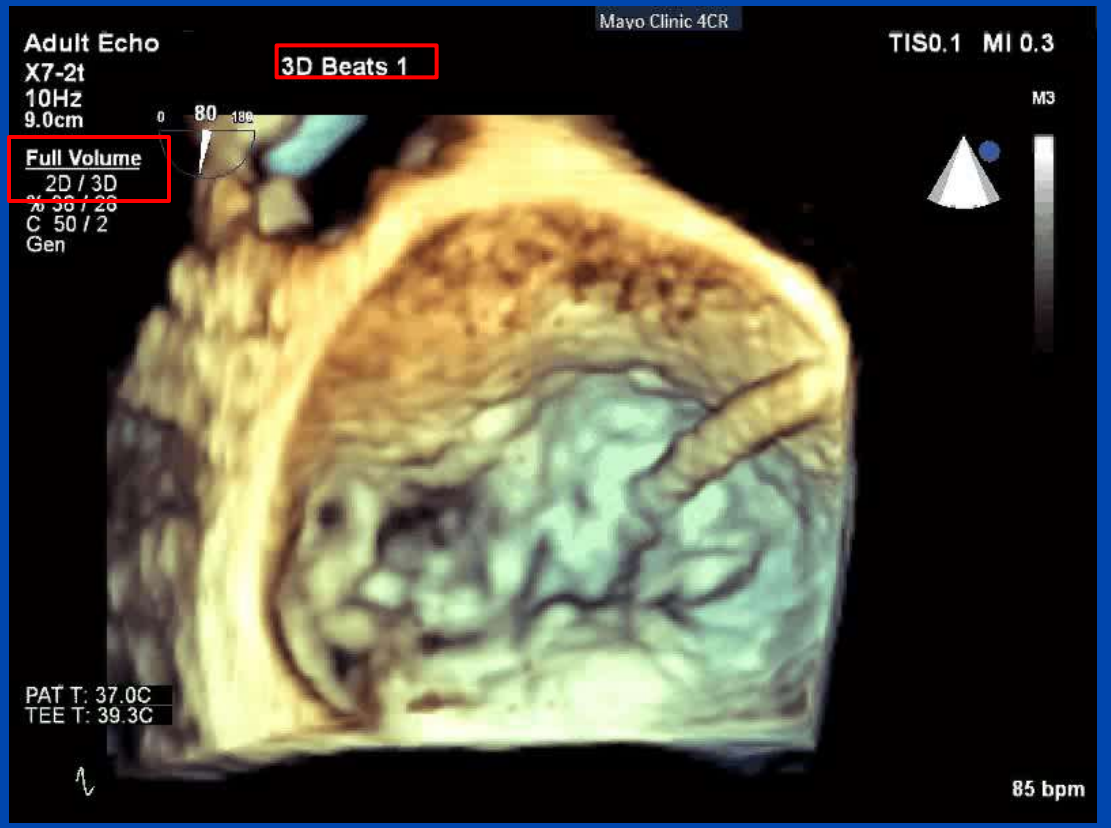
- Movement of probe = movement of image, real-time
- Can be:
  - *Narrow sector*
  - *“Zoom” = focused wide sector*
  - *Full volume, single beat*

Increased sector size decreases temporal resolution

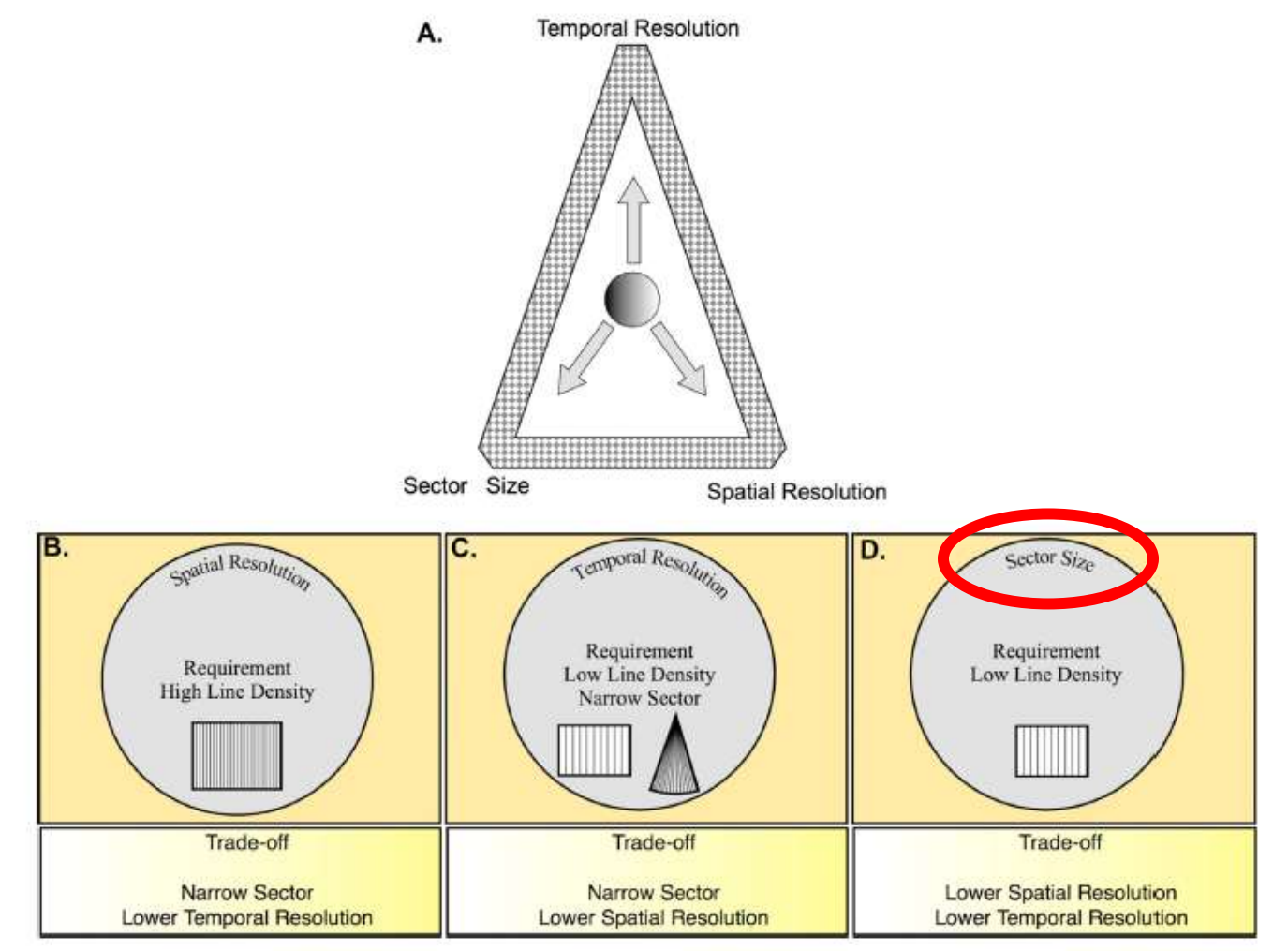


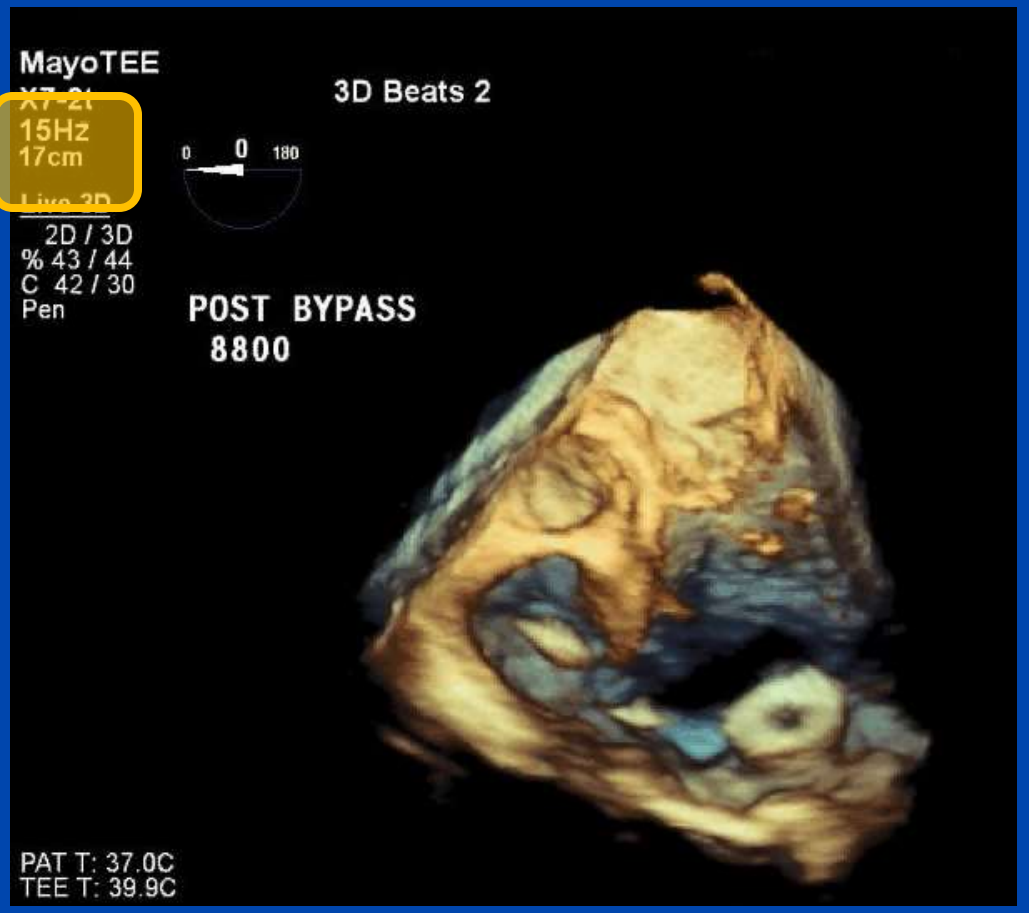
“Live” 3D : Single beat, probe responsive

- Why choose live / single beat?
  - ECG-gated not feasible (interference, motion, irregular rhythm)
  - Higher temporal resolution (narrow sector)
  - Monitor real-time procedures



The Trade Off





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Clinical Scenarios: When is 3D “standard”?

Debatable, but…

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Catheter based procedures

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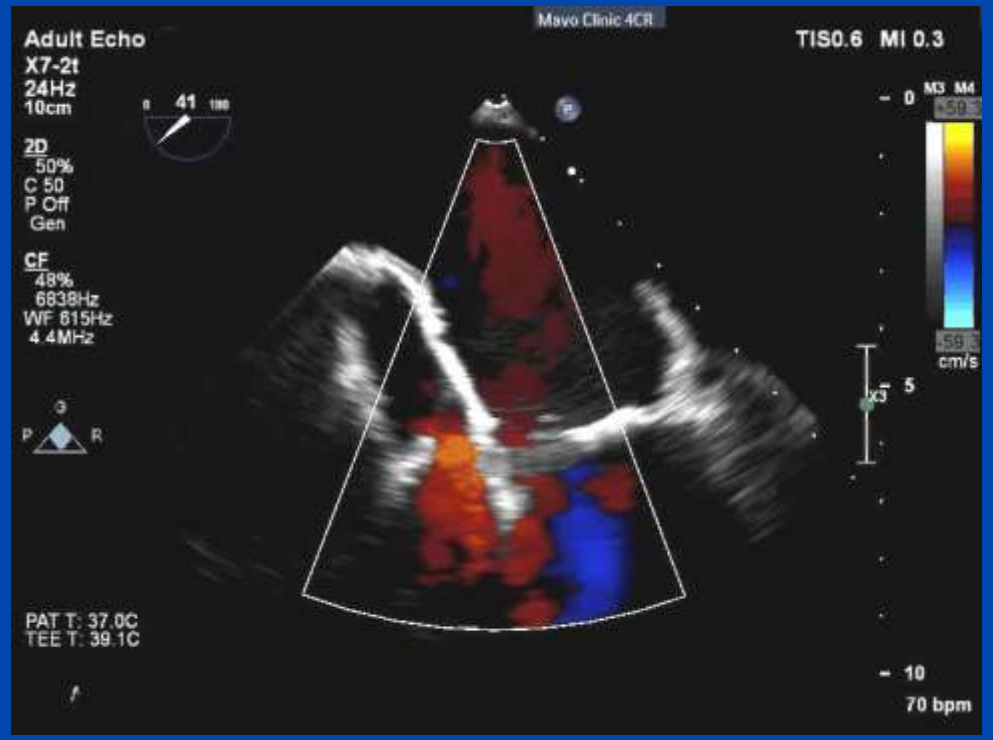
3D capability of high value

- Visual devices in multiple planes simultaneously (A-P, M-L)
  - *Simultaneous orthogonal / narrow / focused wide (zoom)*
  - *Familiar image orientation facilitates communication*



Echocardiographic Procedural Guidance

Before the procedure, labeled representative still frame images from the preprocedure TEE are printed for display in the catheterization laboratory. The procedure is performed under general anesthesia using TEE guidance. Four key standard TEE views (Figure 2) are used for basic procedural guidance:

1. A midesophageal short-axis view (multiplane angle of approximately 30–60 degrees) at the base of the heart is used to perform transseptal catheterization, guide catheter manipulation, monitor system translation, and avoid contact with the lateral structures such as the lateral left atrial wall and left atrial appendage.
2. A midesophageal commissural or "2-chamber" view (multiplane angle of approximately 60 degrees) is used for medial lateral and axial adjustments of the system.
3. A mid esophageal long axis (LVOT) (multiplane angle of approximately 120–150 degrees) is used for anterior–posterior system adjustments.
4. A transgastric short axis (multiplane angle 0–30 degrees) at the mitral valve level and in the left ventricle is used for alignment of the clip arms perpendicular to the line of coaptation.

Echocardiographic Guidance and Assessment of Percutaneous Repair for Mitral Regurgitation With the Evalve MitraClip: Lessons Learned From EVEREST I

Frank E. Silvestry, MD, FASE, L. Leonardo Rodriguez, MD, Howard C. Herrmann, MD, Sameer Rohatgi, MD, Stuart J. Weiss, MD, PhD, William J. Stewart, MD, FASE, Shunichi Homma, MD, Neil Goyal, MD, Todd Pulerwitz, MD, Alan Zunamon, MD, Andrew Hamilton, MD, John Merlino, MD, Randolph Martin, MD, FASE, Kimberly Krabill, MD, Peter C. Block, MD, Pat Whitlow, MD, E. Murat Tuzcu, MD, Samir Kapadia, MD, William A. Gray, MD, Mark Reisman, MD, Hal Wasserman, MD, Allan Schwartz, MD, Elyse Foster, MD, Ted Feldman, MD, and

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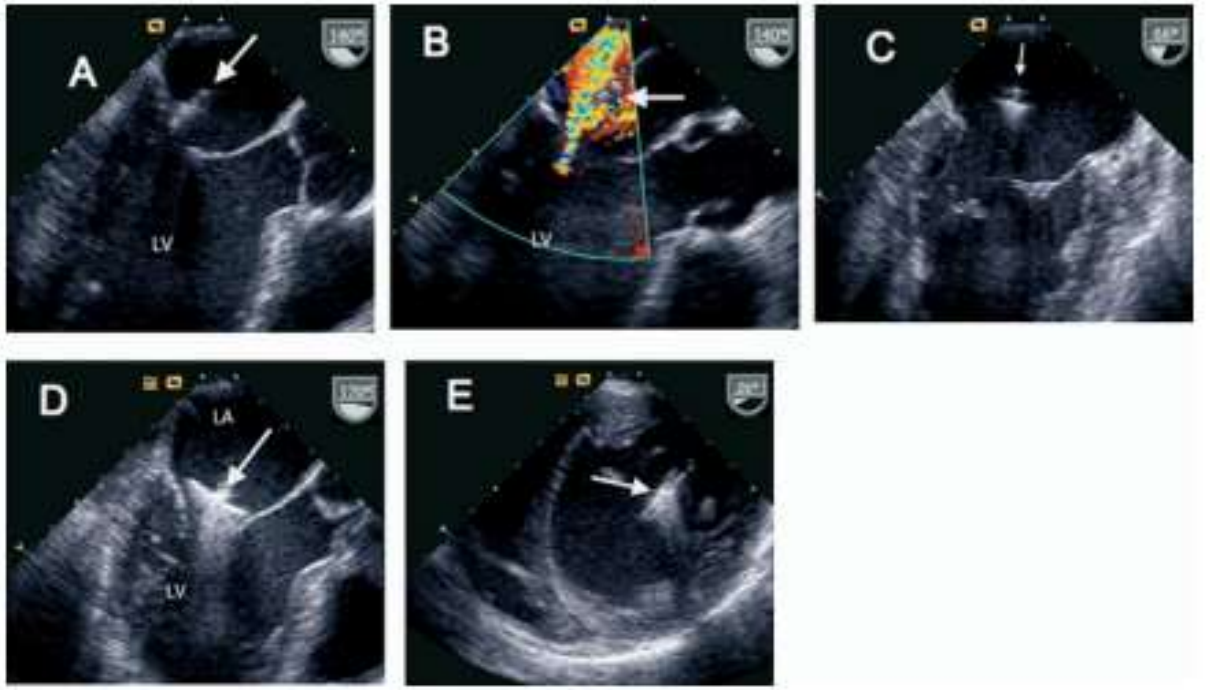
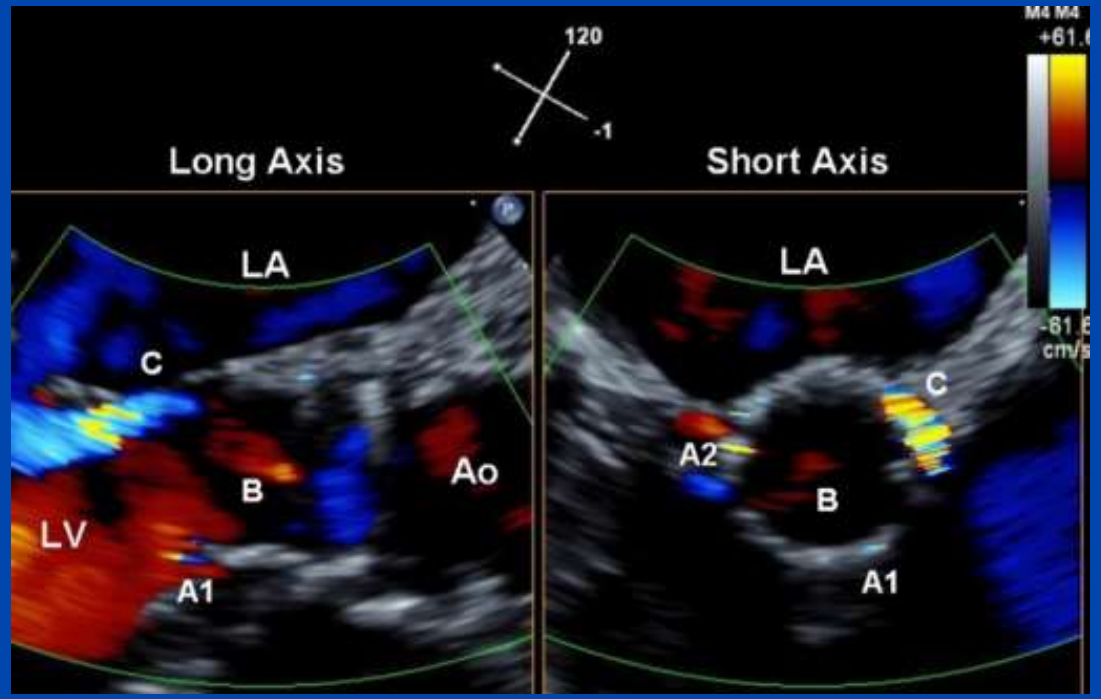
J Am Soc Echocardiogr 2007;20:1131-1140.



ACC CLINICAL DOCUMENT

2017 ACC Expert Consensus Decision Pathway for Transcatheter Aortic Valve Replacement in the Management of Adults With Aortic Stenosis

- Pre-op: TTE and CT, +/- TEE
- Procedural: TTE vs TEE
  - 3D recommended for paravalvular leak detection (simultaneous orthogonal or single-beat / live)



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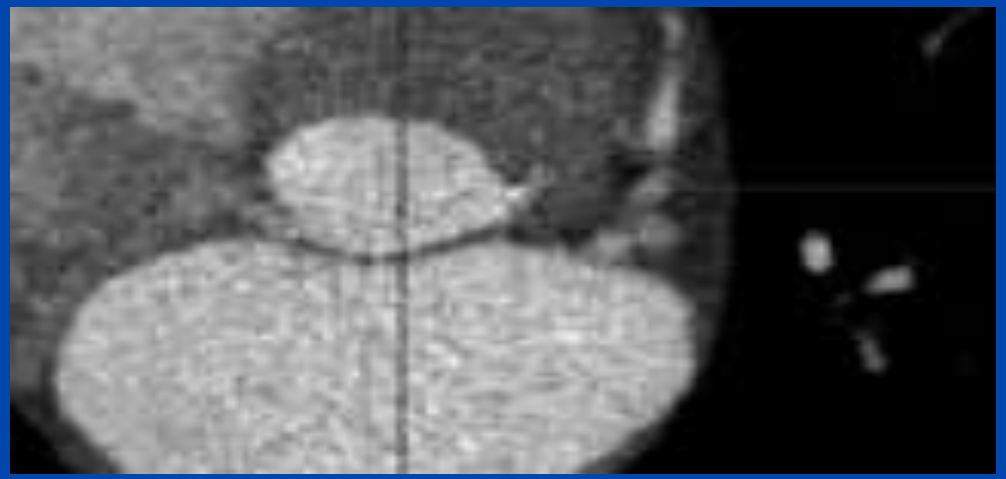
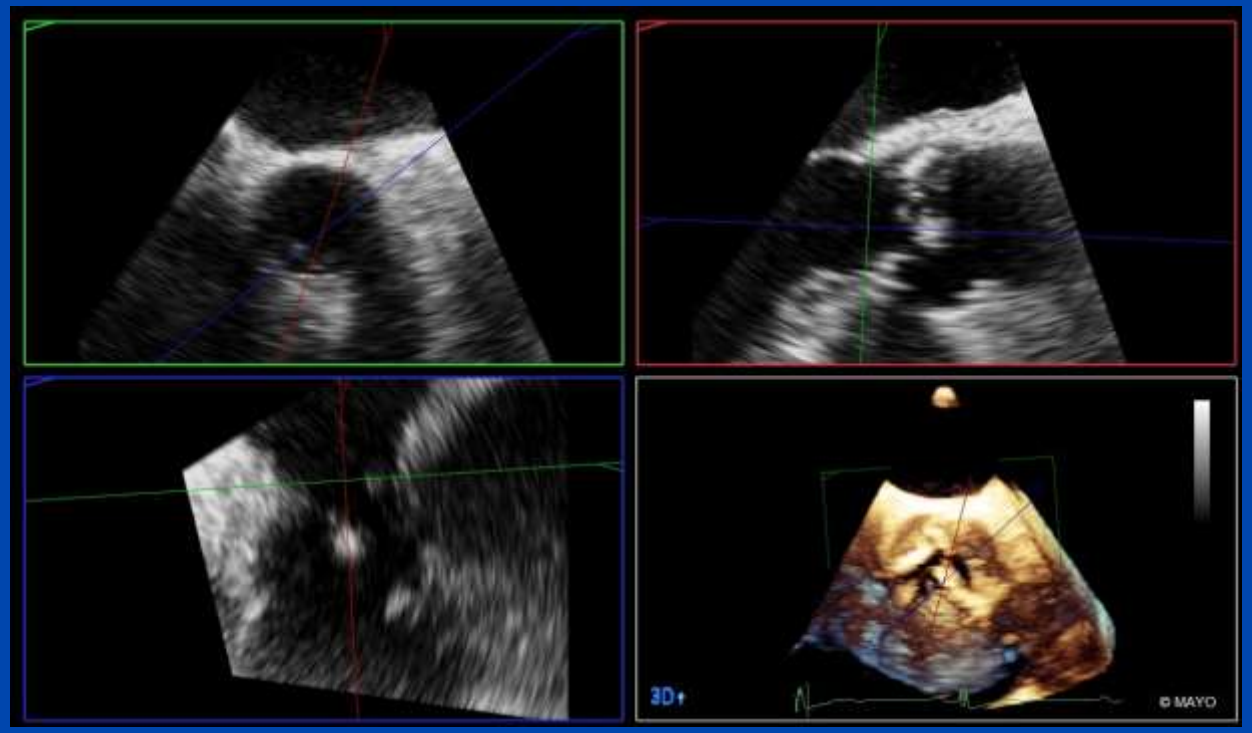
TAVR





"TTE annulus or outflow tract measurements are not accurate for selection of prosthetic valve size. TEE, especially with 3D imaging techniques, provides better anatomic delineation of the shape of the aortic annulus."

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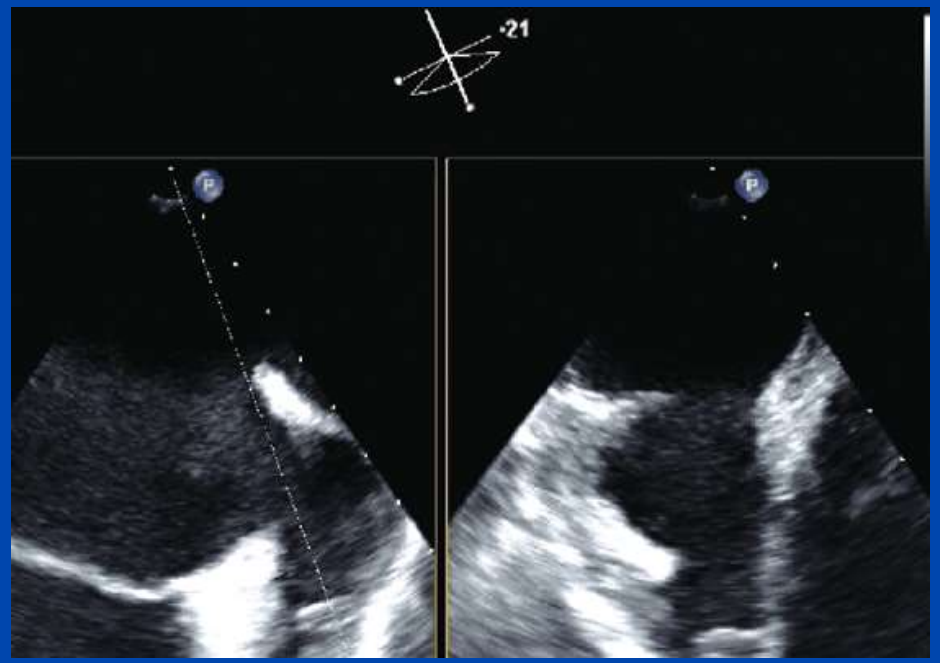
EXPERT CONSENSUS DOCUMENT

2016

SCAI/ACC/HRS Institutional and Operator Requirements for Left Atrial Appendage Occlusion

TEE needed at some point to exclude thrombus.



1. Echocardiography
2. An echocardiography laboratory with the full array of transthoracic and TEE capabilities should be on site.
3. A TEE-capable machine and probe should be available in the procedure room.
4. Appropriate staff should be present during the procedure, which may include a cardiologist or cardiac anesthesiologist familiar with the procedural steps and subtleties of invasive echocardiography.
5. Three-dimensional echocardiography capability is helpful but not required.

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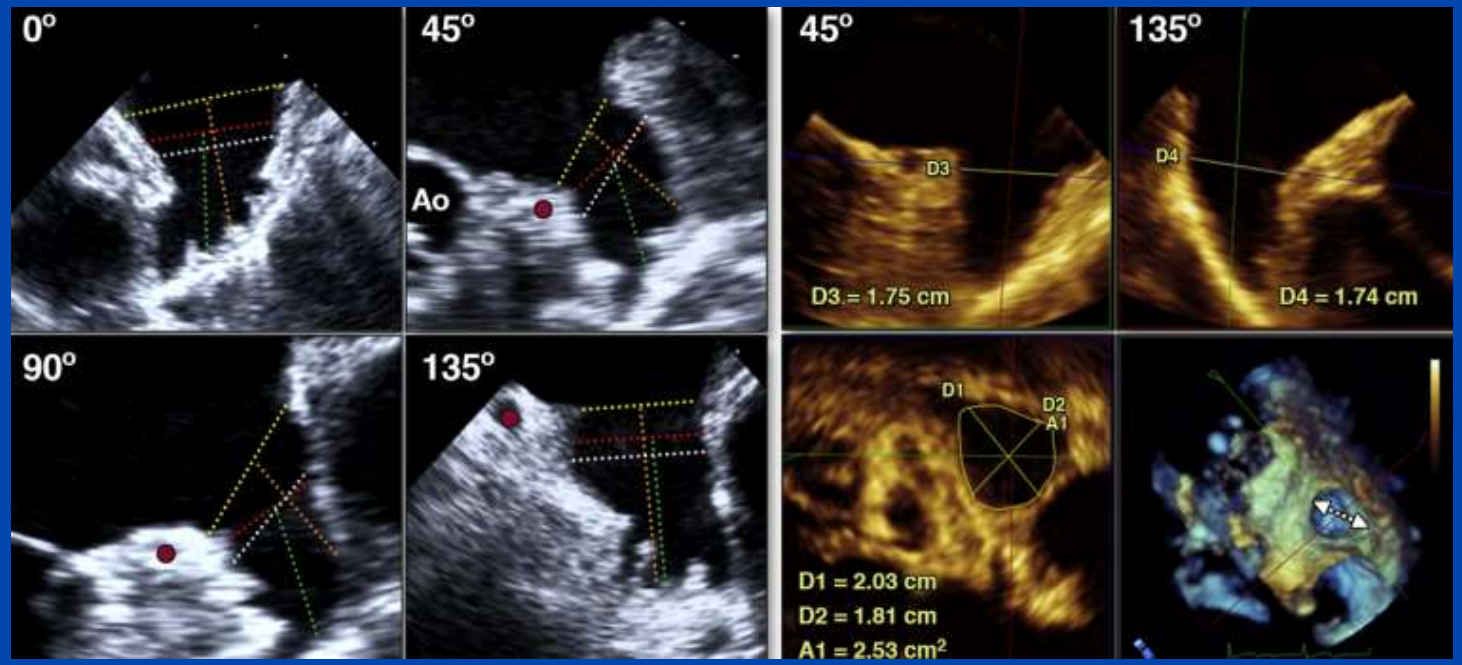
Percutaneous Interventions for Left Atrial Appendage Exclusion

Options, Assessment, and Imaging Using 2D and 3D Echocardiography

Nina C. Wunderlich, MD,* Roy Beigel, MD,†‡ Martin J. Swaans, MD, PhD,§ Siew Yen Ho, MD,‖ Robert J. Siegel, MD†

3D TEE with MPR more accurately sizes LAA



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EXPERT CONSENSUS DOCUMENT

2016

SCAI/AATS/ACC/STS Operator and Institutional Requirements for Transcatheter Valve Repair and Replacement. Part II. Mitral Valve

2. Non-invasive imaging
   a. Echocardiographic laboratory. Transthoracic and transesophageal echocardiographic capabilities with sonographers and echocardiographers experienced in valvular heart disease. Access to 3D echocardiography is necessary.

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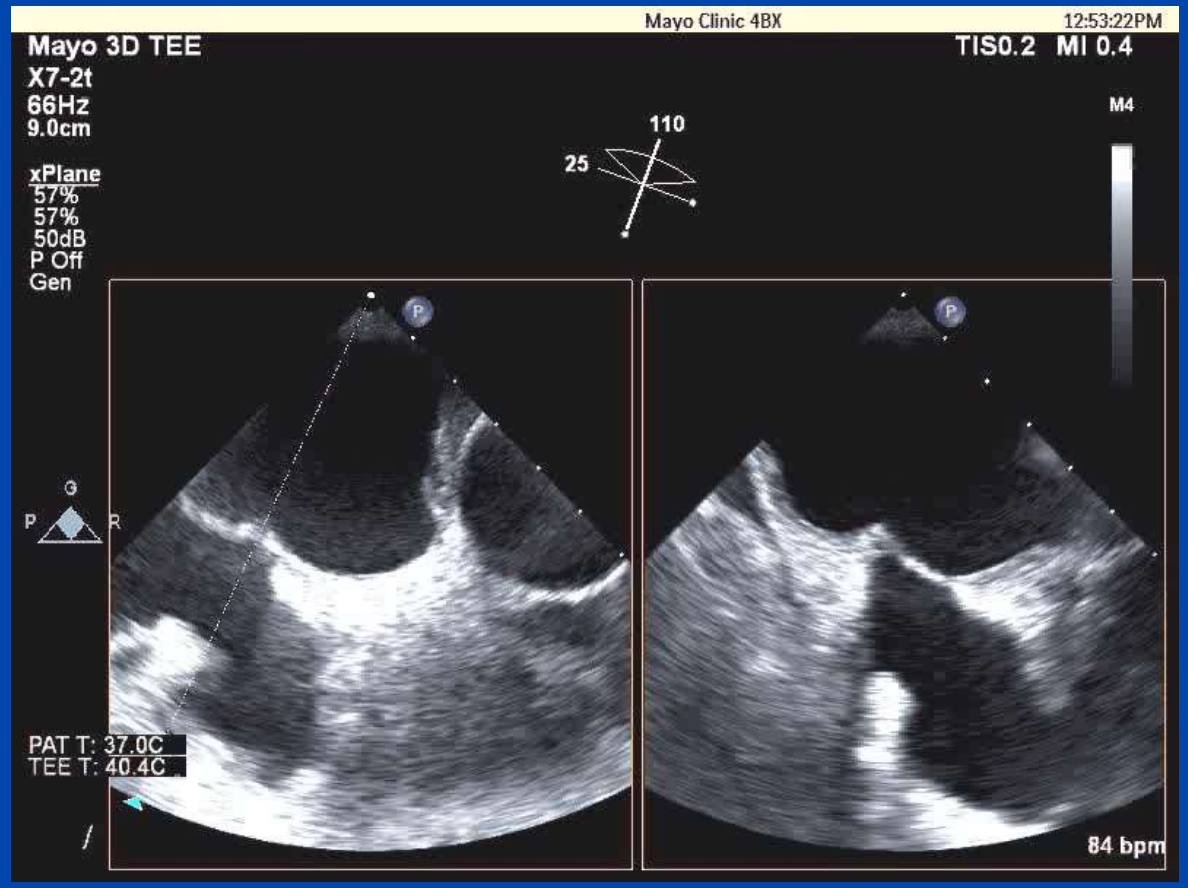
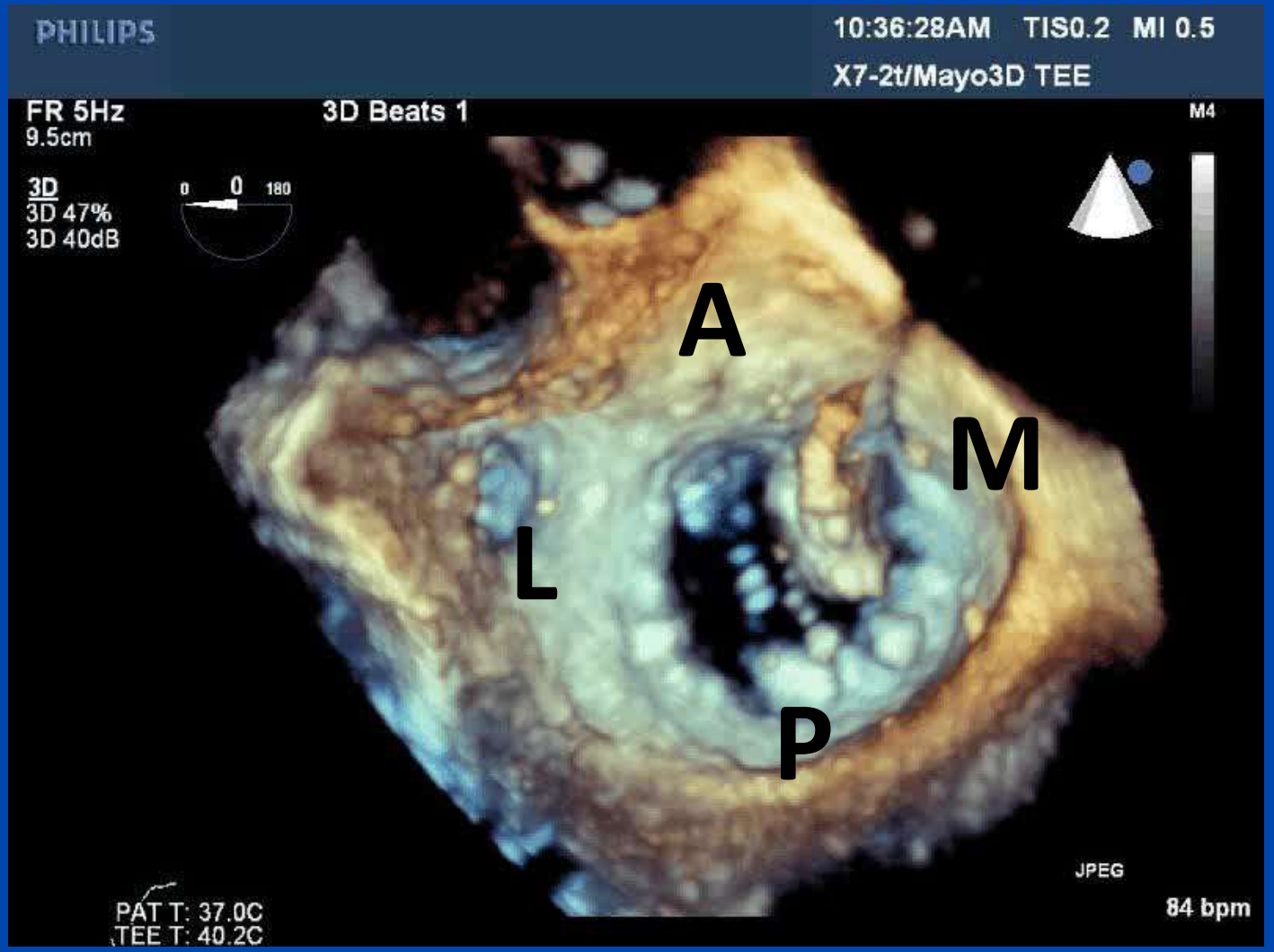
Percutaneous Mitral Procedures



Live, probe-responsive mode to monitor catheter movement

Trans-septal puncture

Percutaneous Mitral Procedures



- Live, probe-responsive mode to monitor catheter movement
- Adequate sector to encompass the valve

- Single-beat
- Either wide sector/zoom or full-volume

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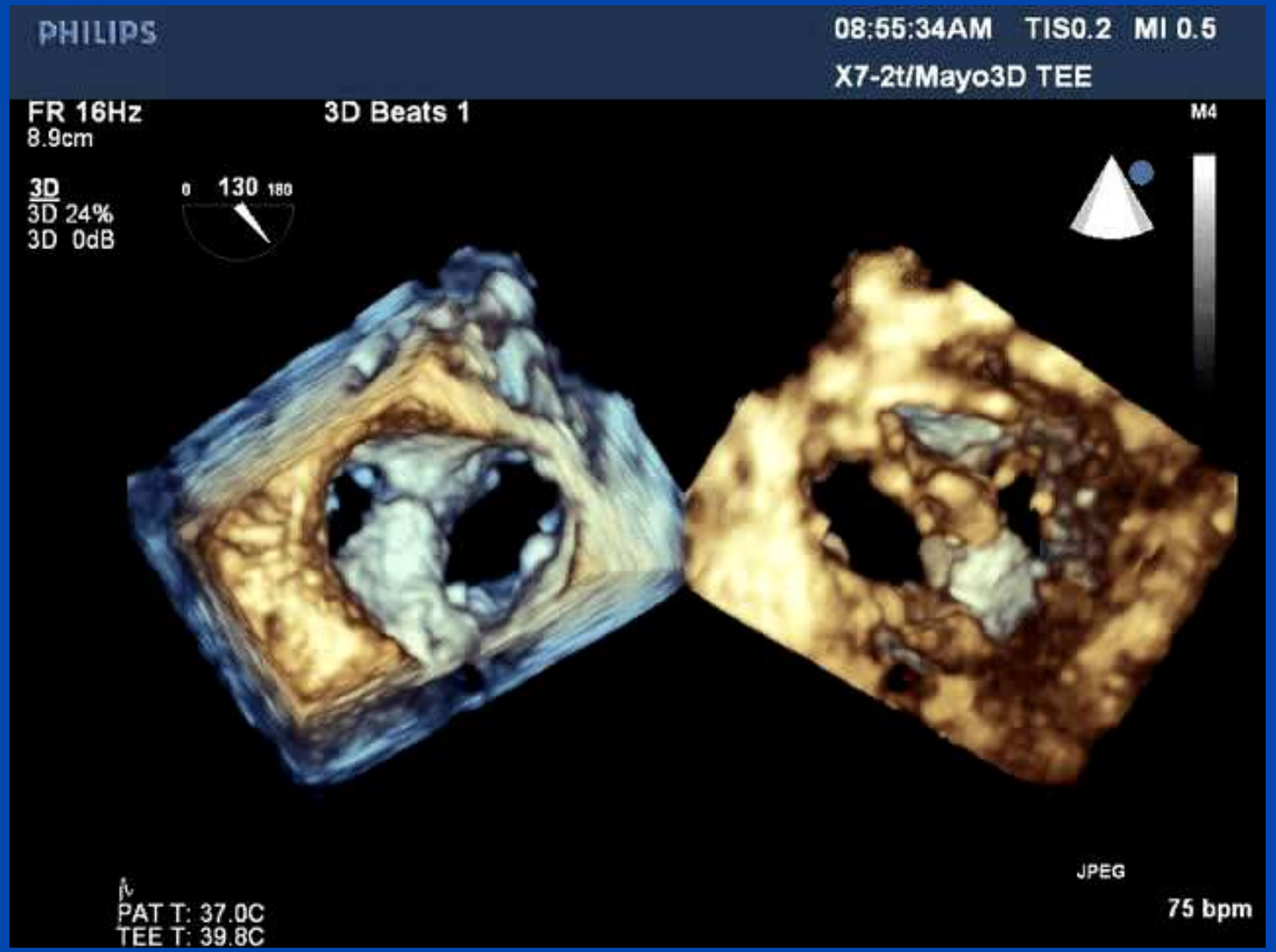
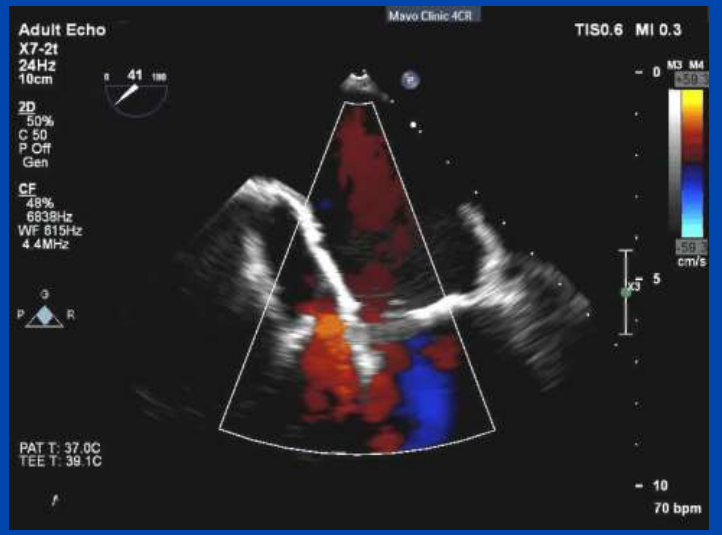
Percutaneous Mitral Procedures



Dual image format. Both LA and LV perspectives.



Percutaneous Mitral Procedures

At completion, consider multi-beat mode for better spatial, temporal resolution.

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Valve Pathology, Repair, and Replacement

Valve Repair / Replacement

Pre-bypass Diagnostic Exam

Narrow sector not ideal: piece-meal exam

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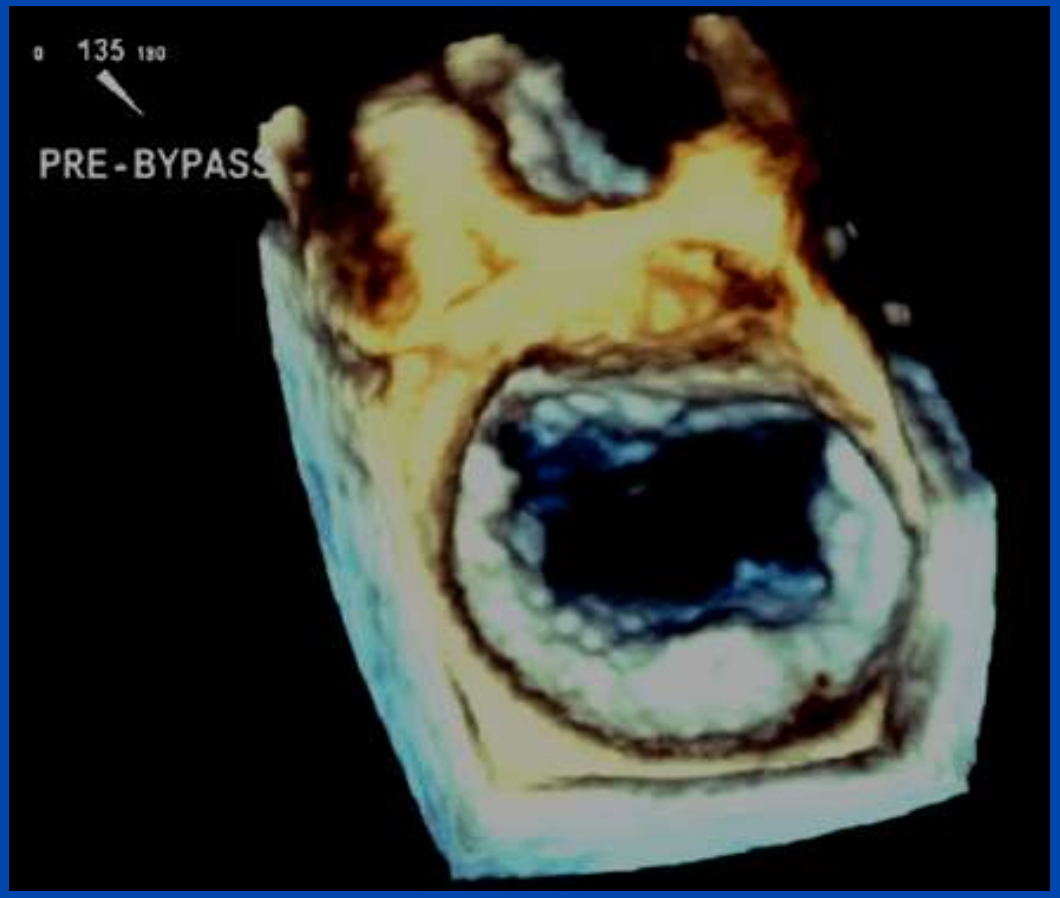
Valve Repair / Replacement

Pre-bypass Diagnostic Exam



- Wide sector/zoom or full volume to encompass valve
- ECG-gated for best temporal and spatial resolution

MAYO CLINIC

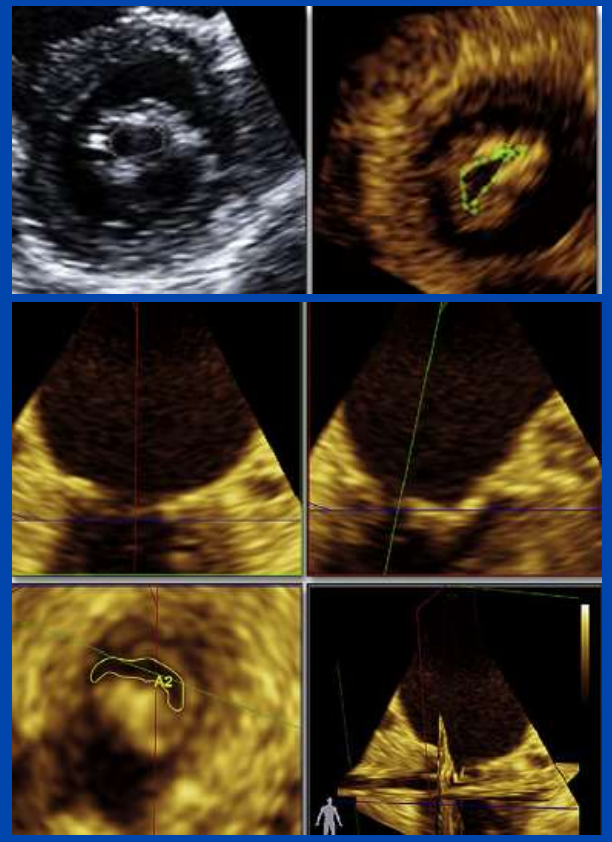
Valve Repair / Replacement

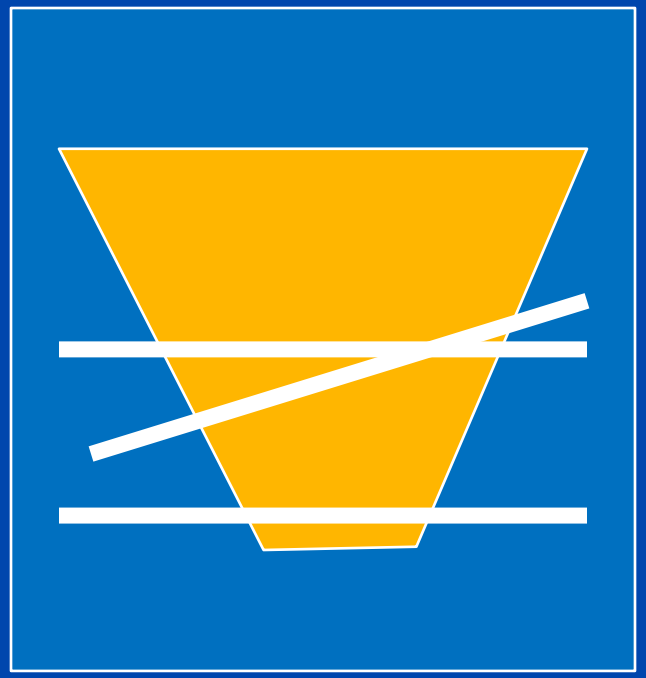
Pre-bypass Diagnostic Exam

Narrow sector reasonable for AV SAX

Value of 3D Multi-planar Review

- Ability to adjust planes simultaneously ensures location of measurements





Gated, full volume

Need adequate temporal and spatial resolution
- Pick diastolic frame
- Trace orifice

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3D Assessment of Regurgitant Orifice

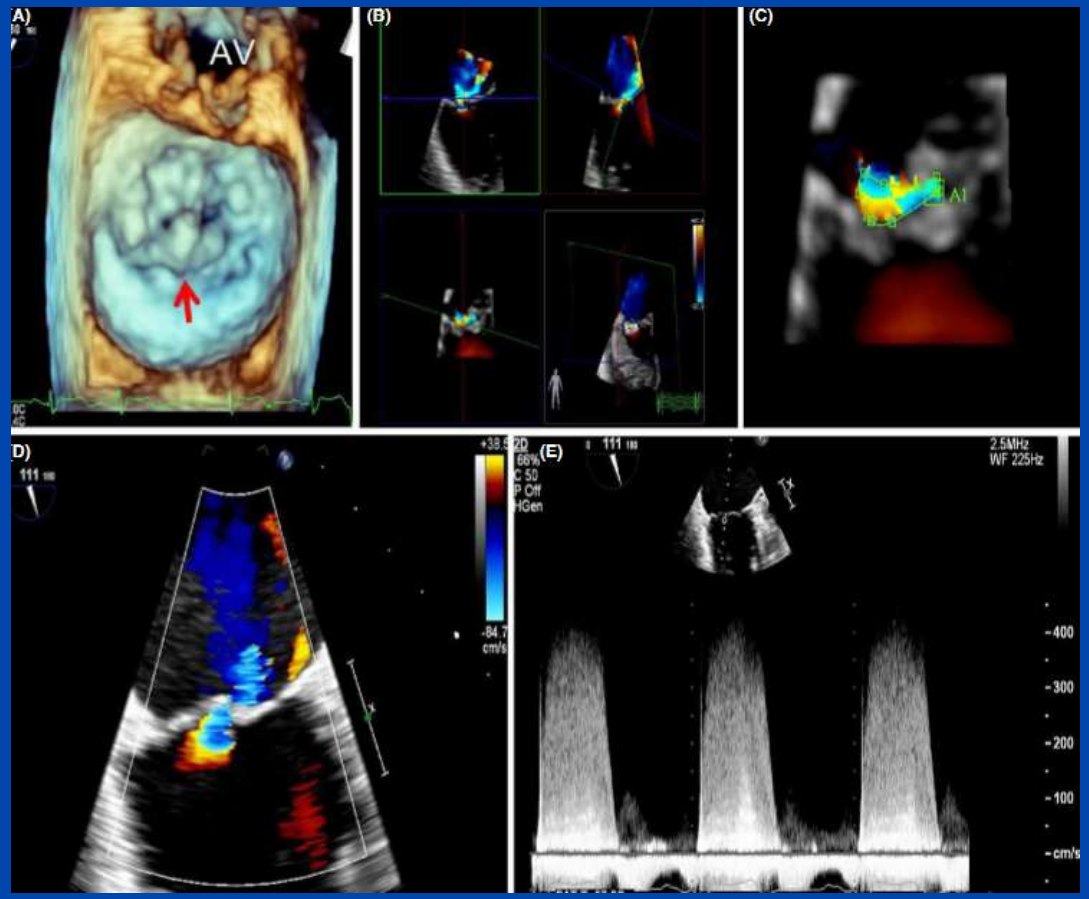
- Not always as circular as we think
  - Defeats geometric assumptions, calculations

ORIGINAL INVESTIGATION

WILEY Echocardiography

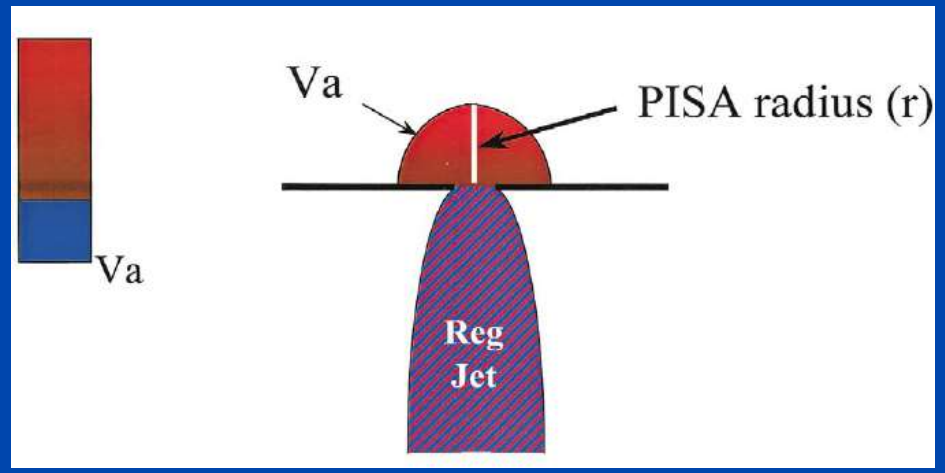
Quantitation of valve regurgitation severity by three-dimensional vena contracta area is superior to flow convergence method of quantitation on transesophageal echocardiography

Echocardiography. 2017;1–10

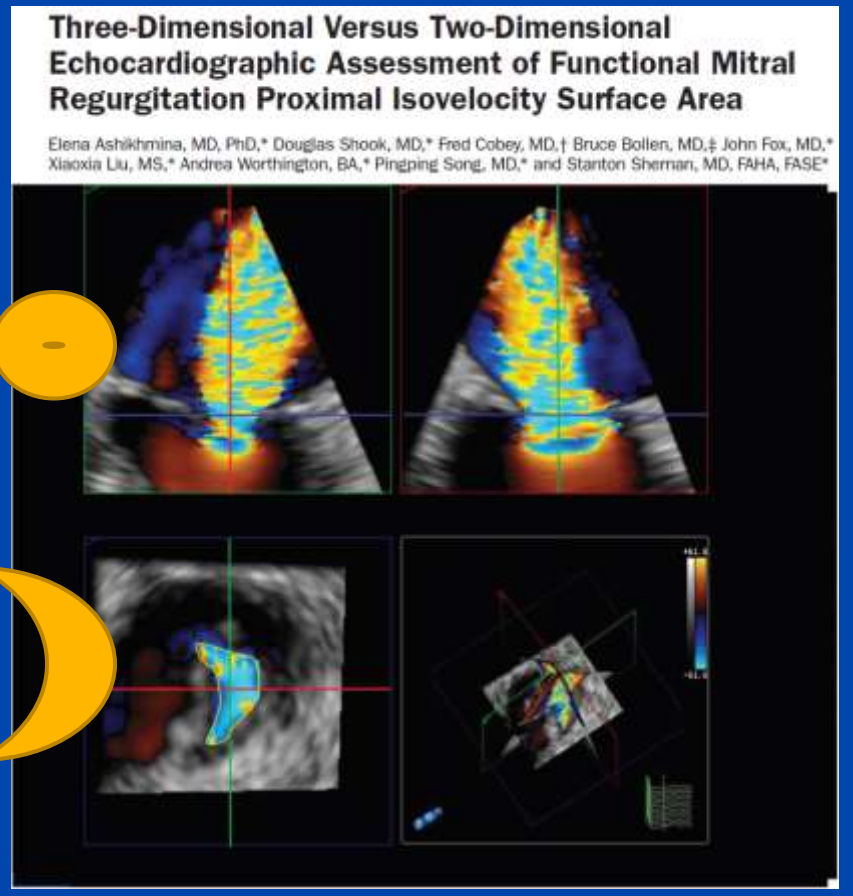


3D Assessment of Regurgitant Orifice

- Re-thinking regurgitant orifice by 3D

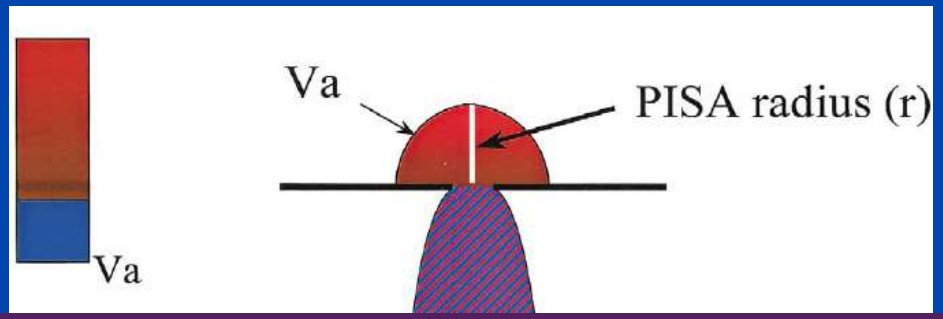


VS

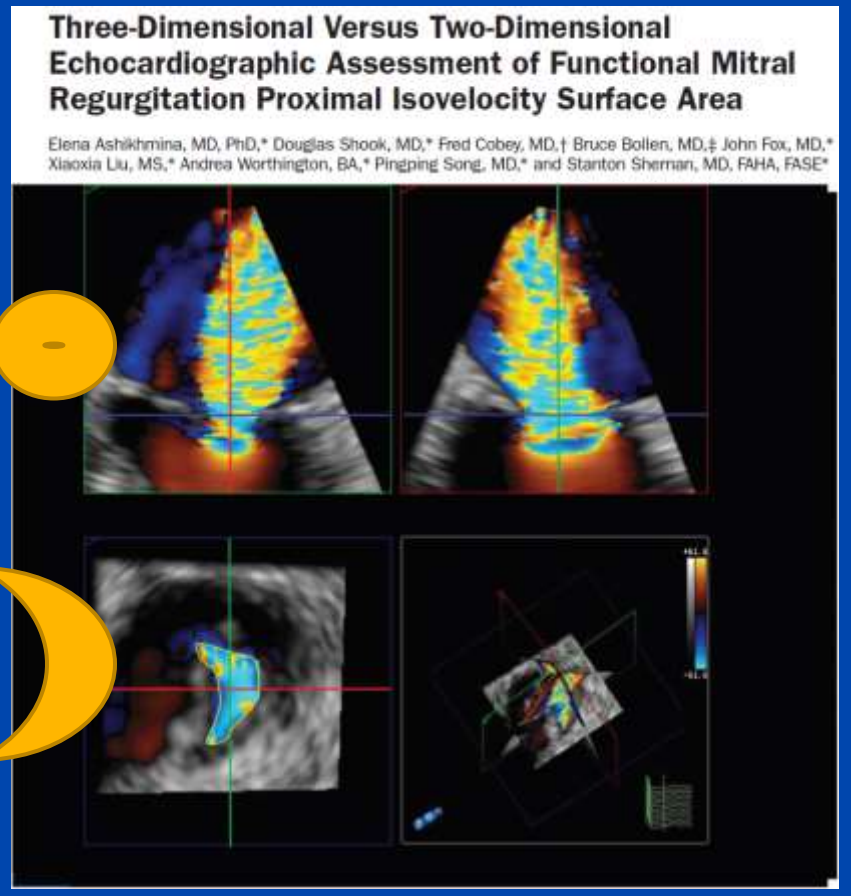


3D Assessment of Regurgitant Orifice

- Re-thinking regurgitant orifice by 3D



VS



Need adequate temporal and spatial resolution

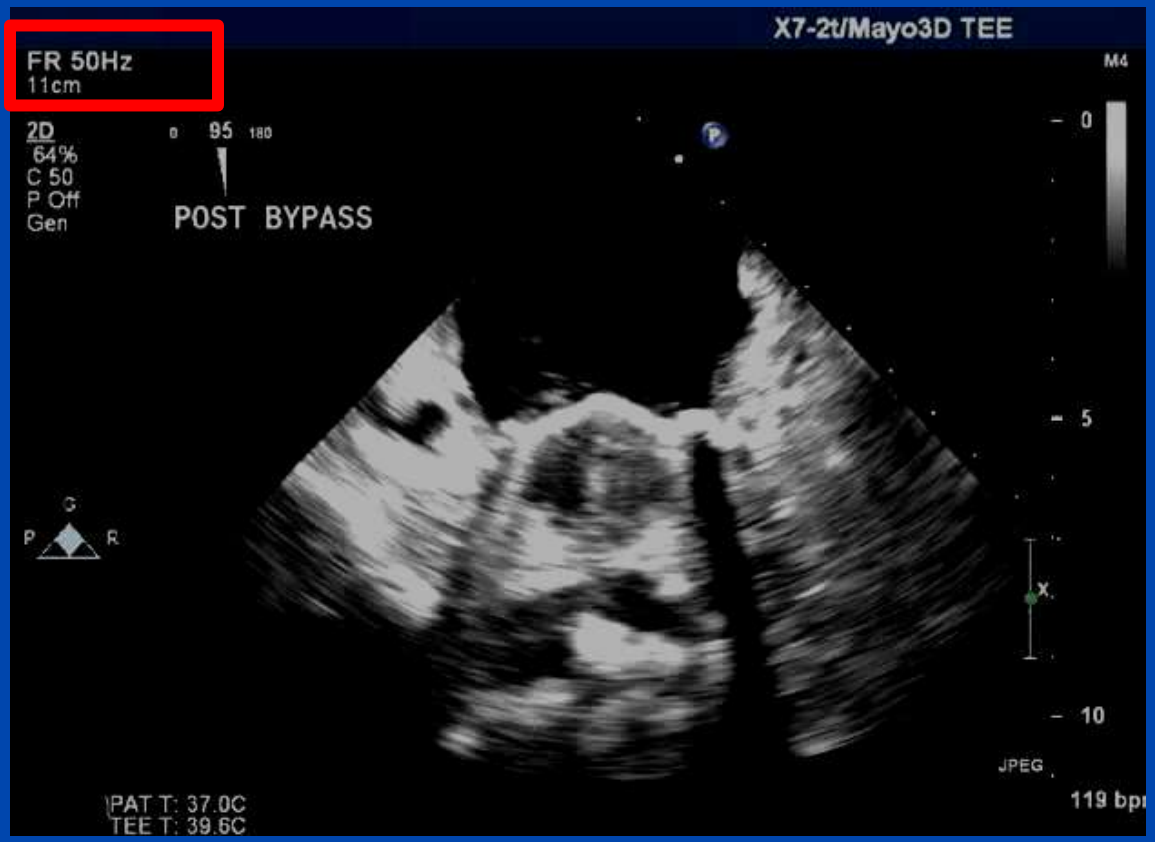
- Pick systolic frame
- Trace orifice

Gated, full volume

Post valve intervention

3D imaging options

- Challenging environment post-CPB (single beat?)
- Adequate temporal and spatial resolution + encompass valve



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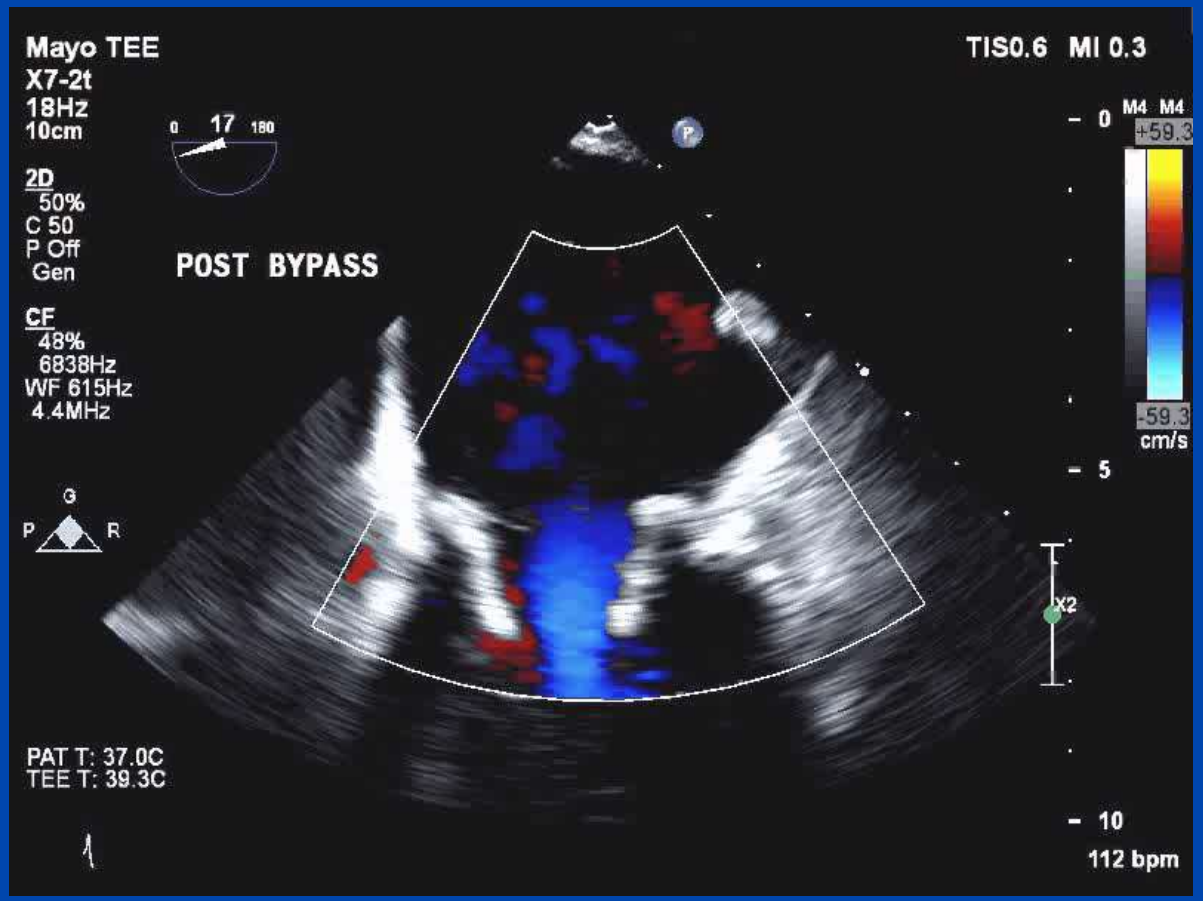
Post Valve Intervention

3D imaging options

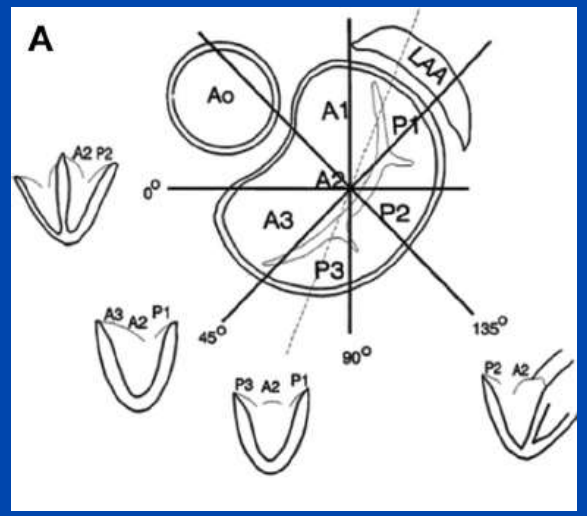
- Challenging environment post-CPB
- Adequate temporal and spatial resolution + encompass valve

Mitral Replacement

Paravalvular regurgitation



4 chamber



Ability to translate 2D images into 3D mental picture

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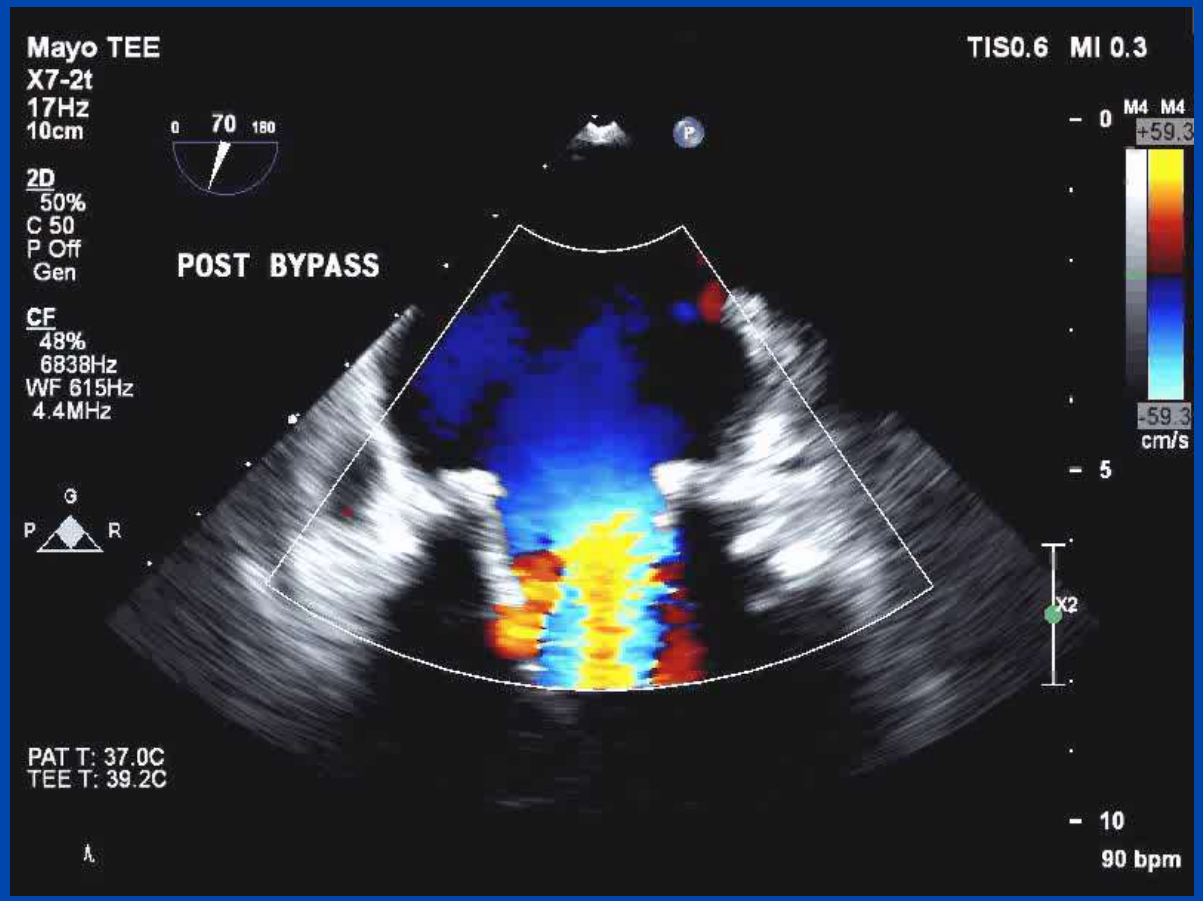
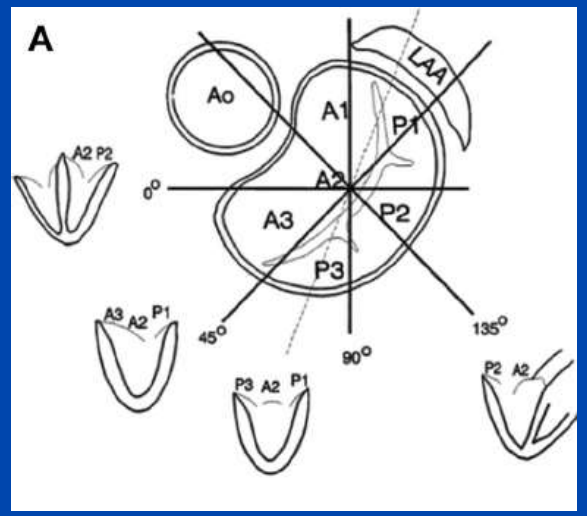
Mitral Replacement

Paravalvular regurgitation

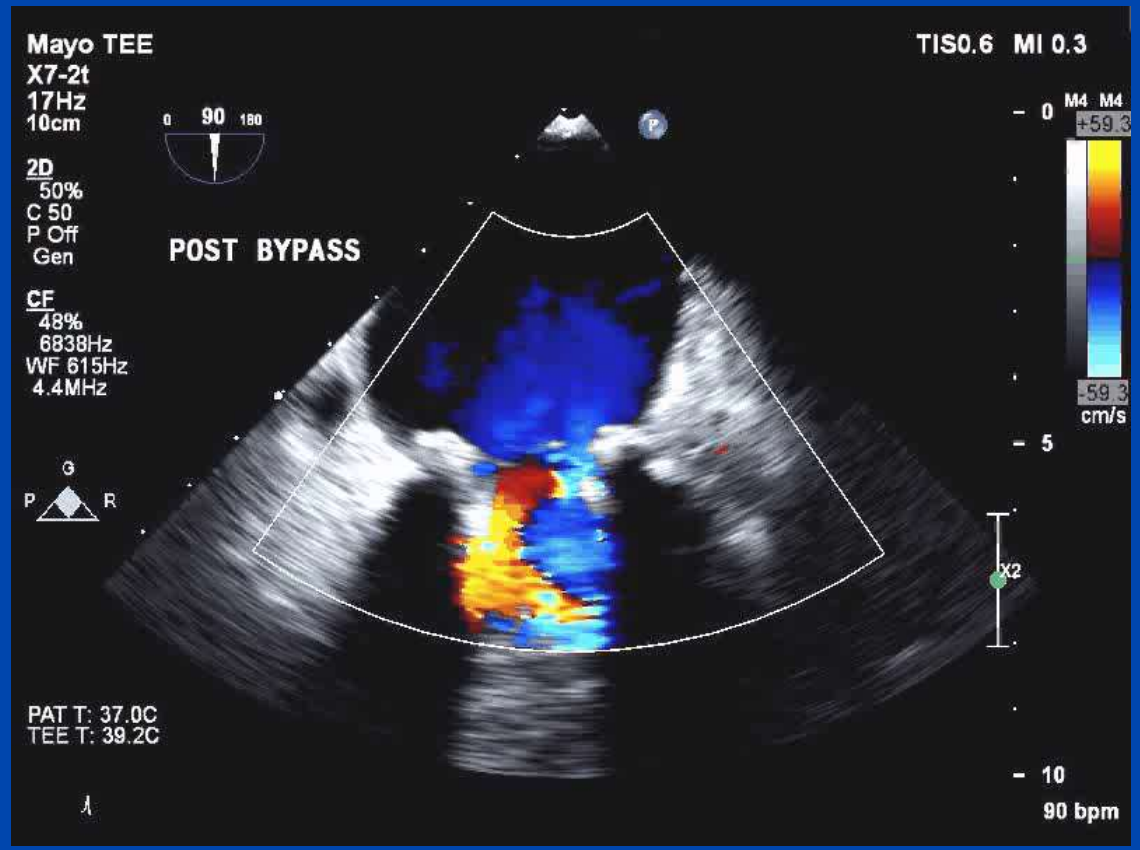


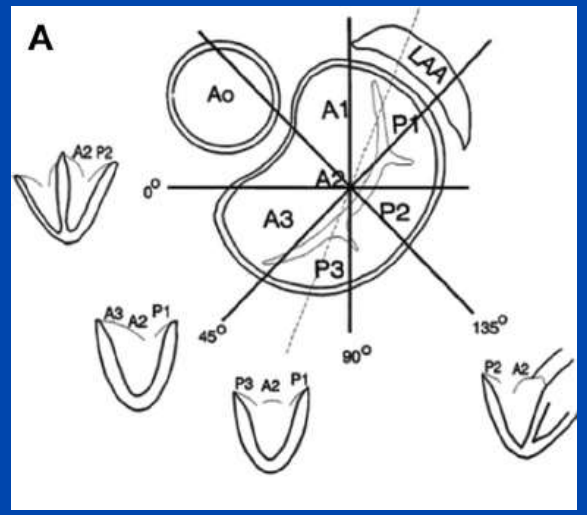


Commissural

Mitral Replacement

Paravalvular regurgitation



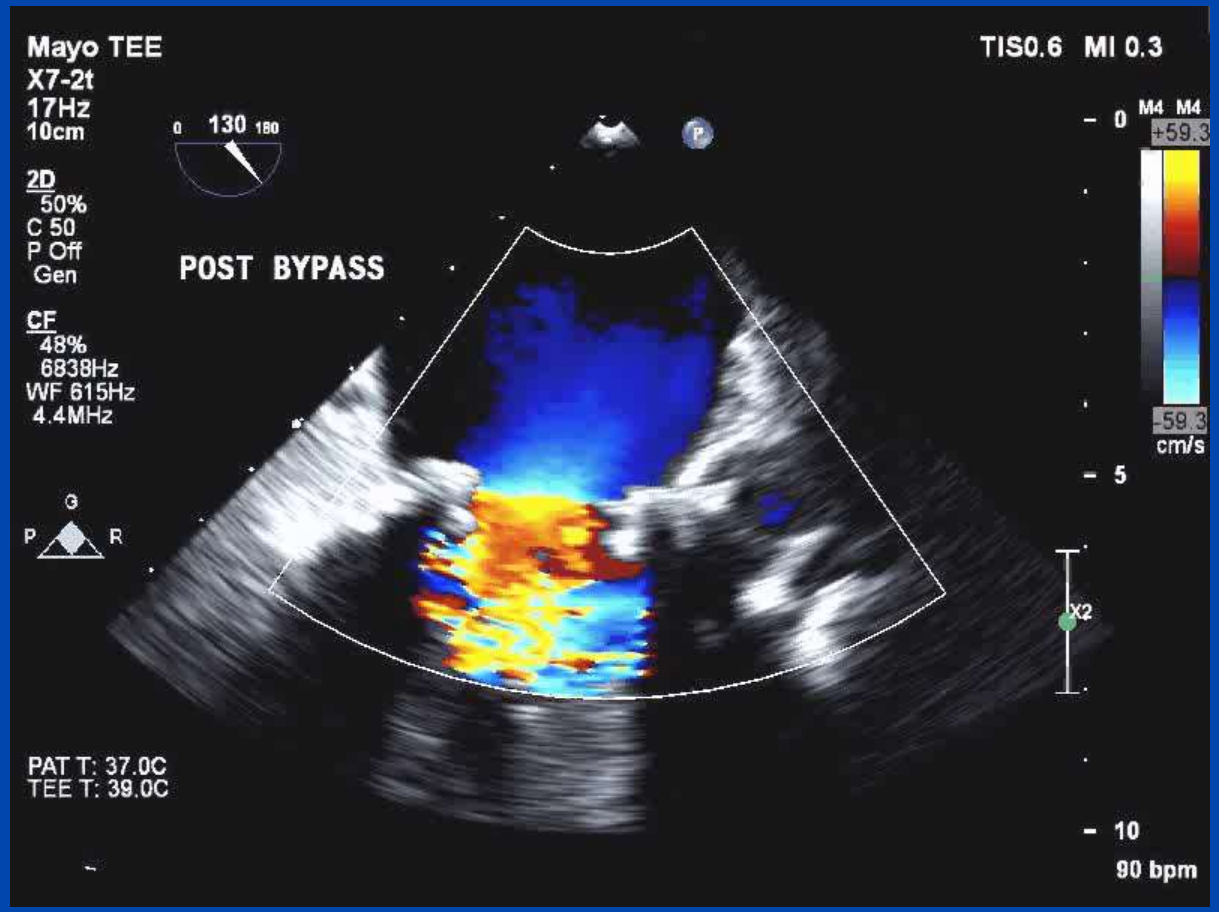


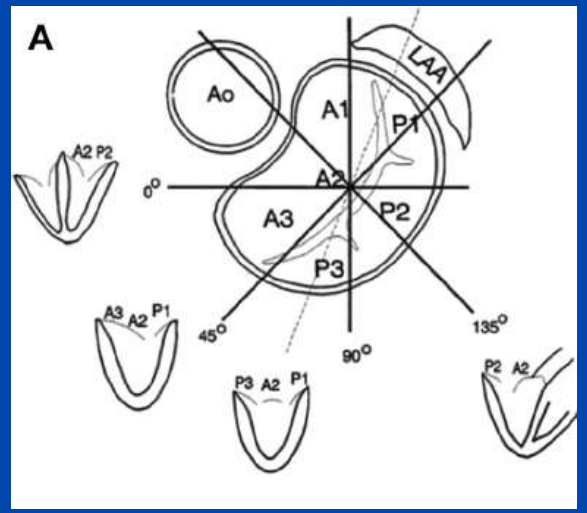
2 chamber

MAYO CLINIC

Mitral Replacement

Paravalvular regurgitation



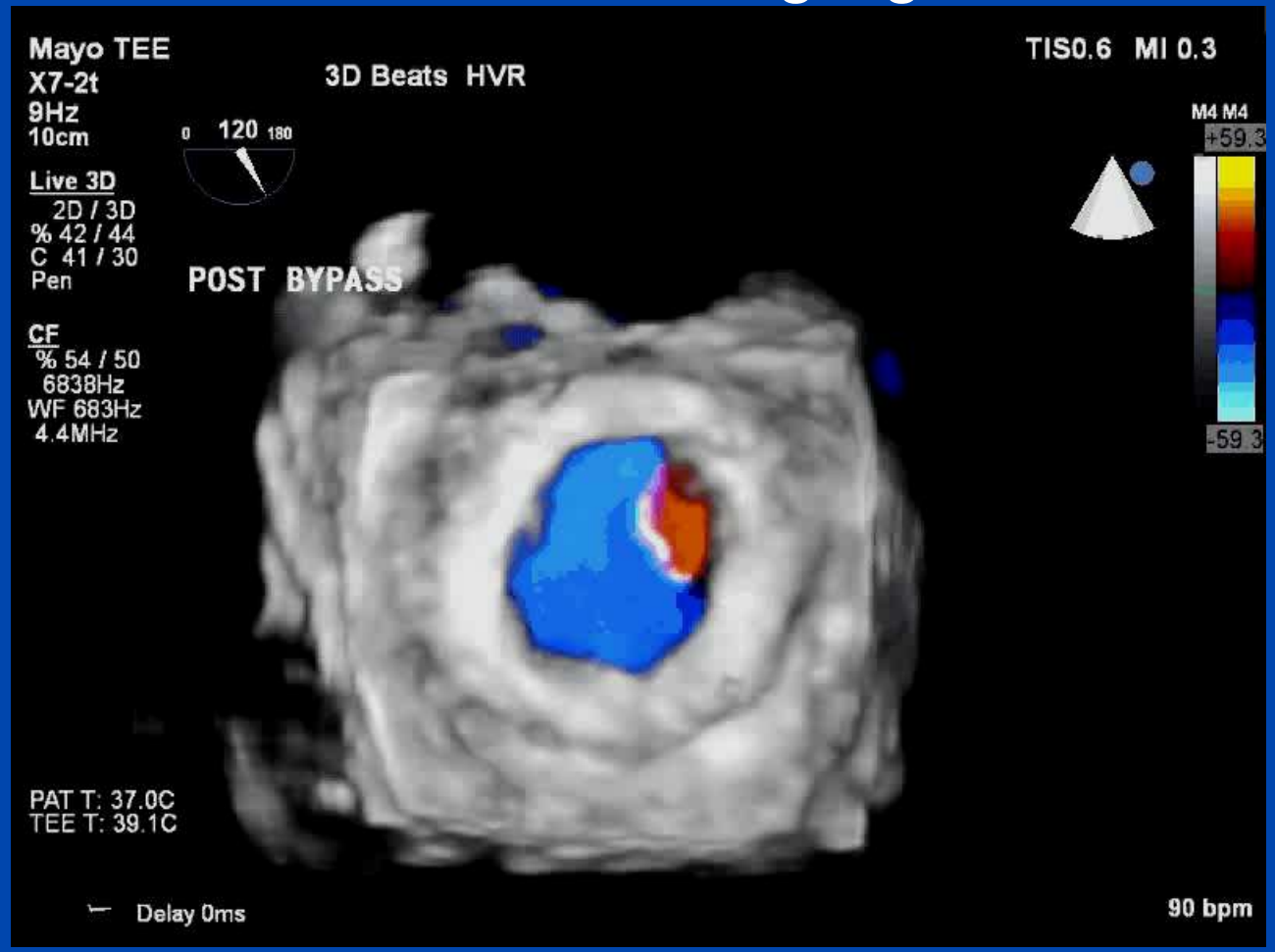


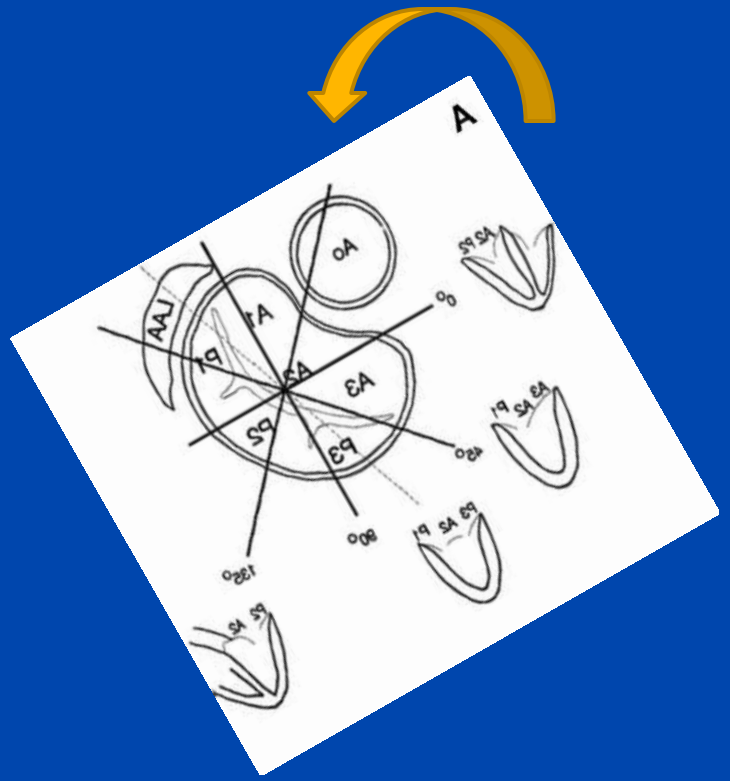
Long axis

Mitral Replacement

Paravalvular regurgitation

- Spatial
- Temporal
- Encompass valve





Single beat mode immediately after bypass

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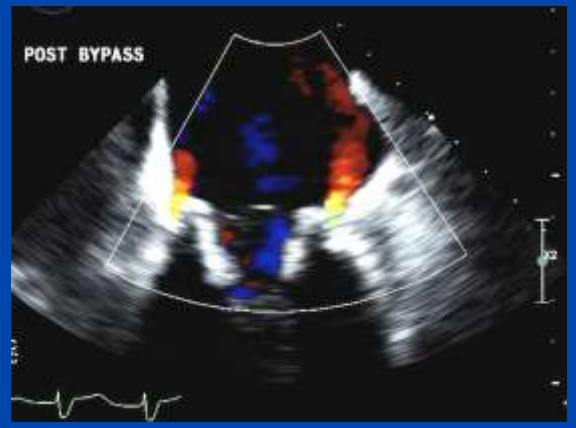
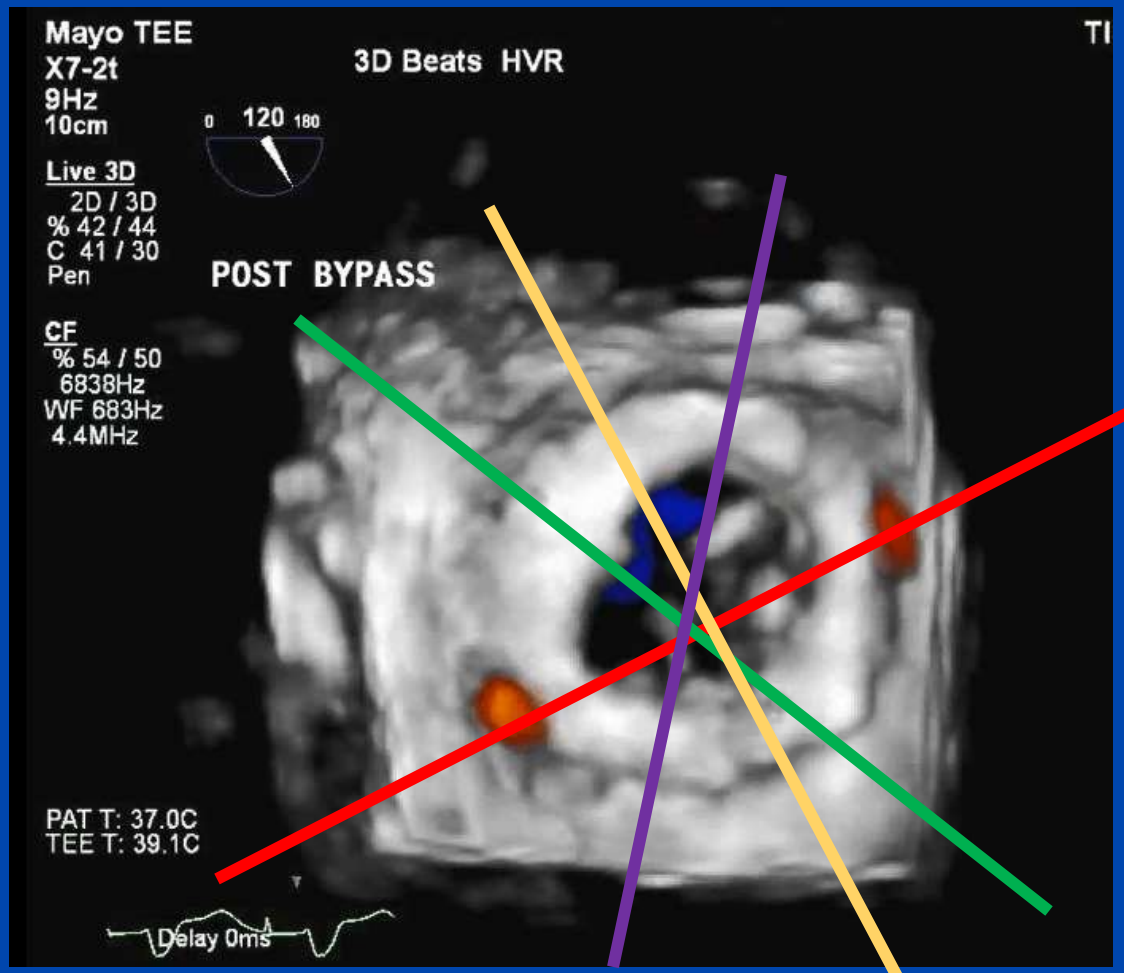
Mitral Replacement

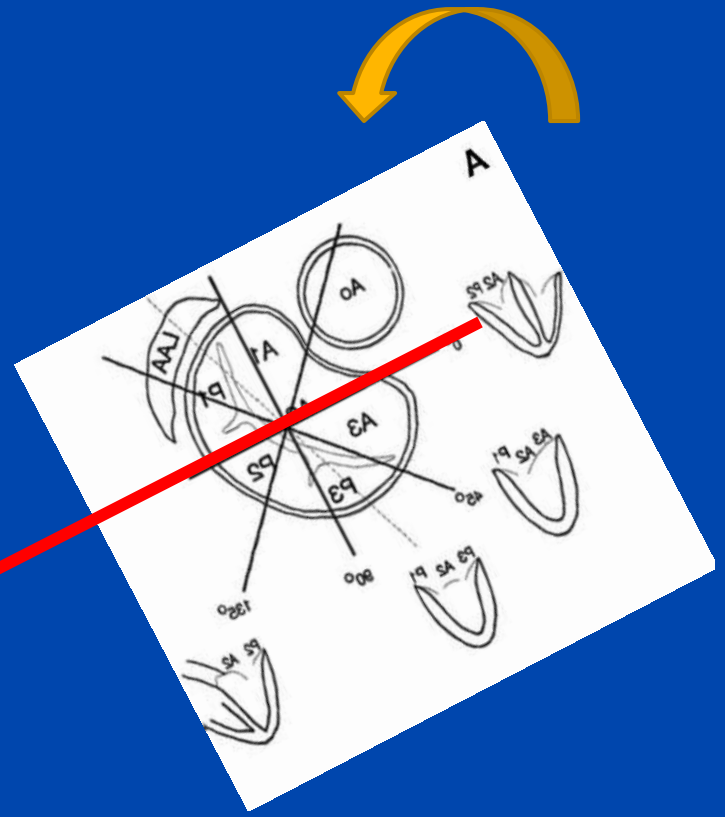


4 chamber

Facilitates communication. May be quicker.

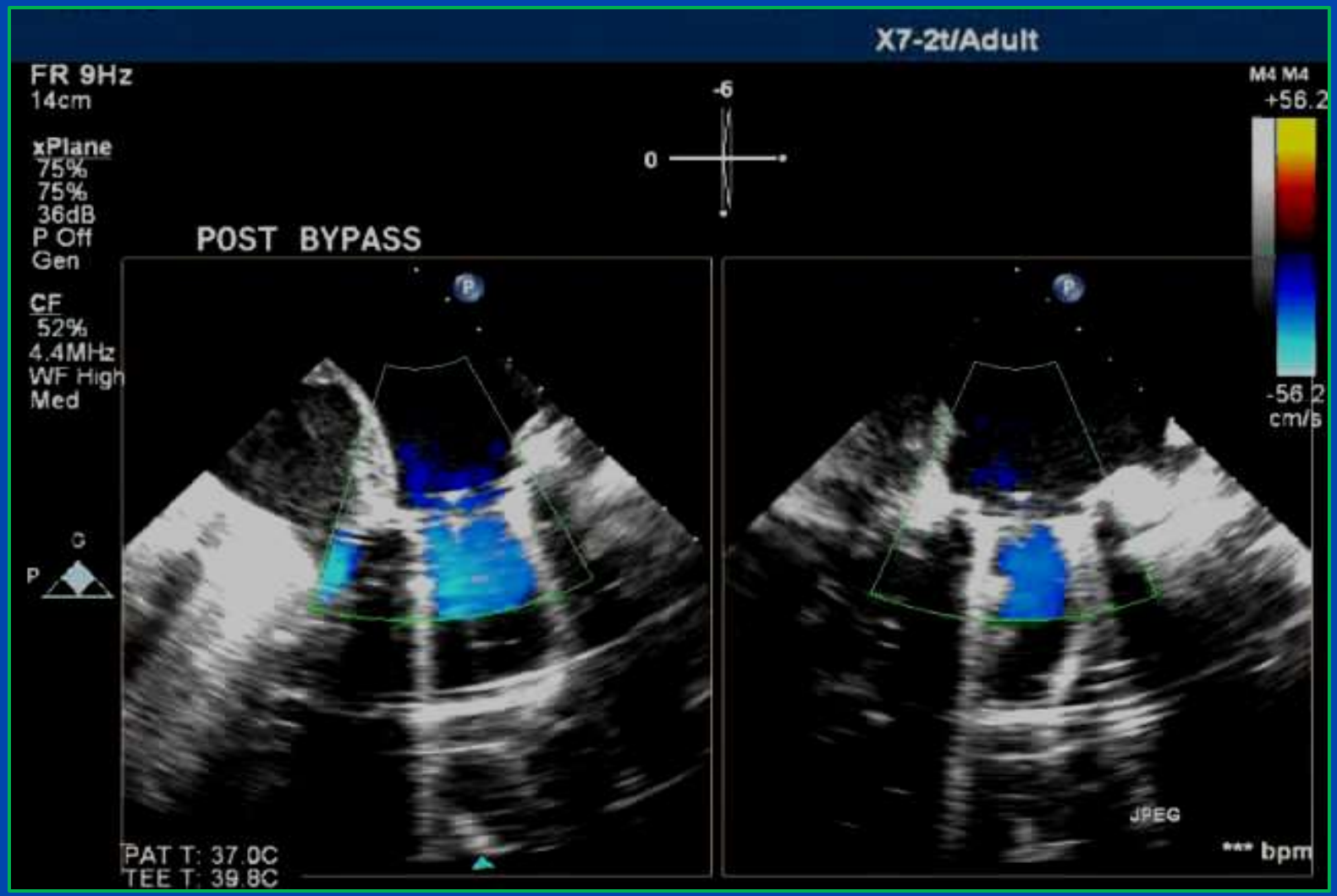
Paravalvular regurgitation





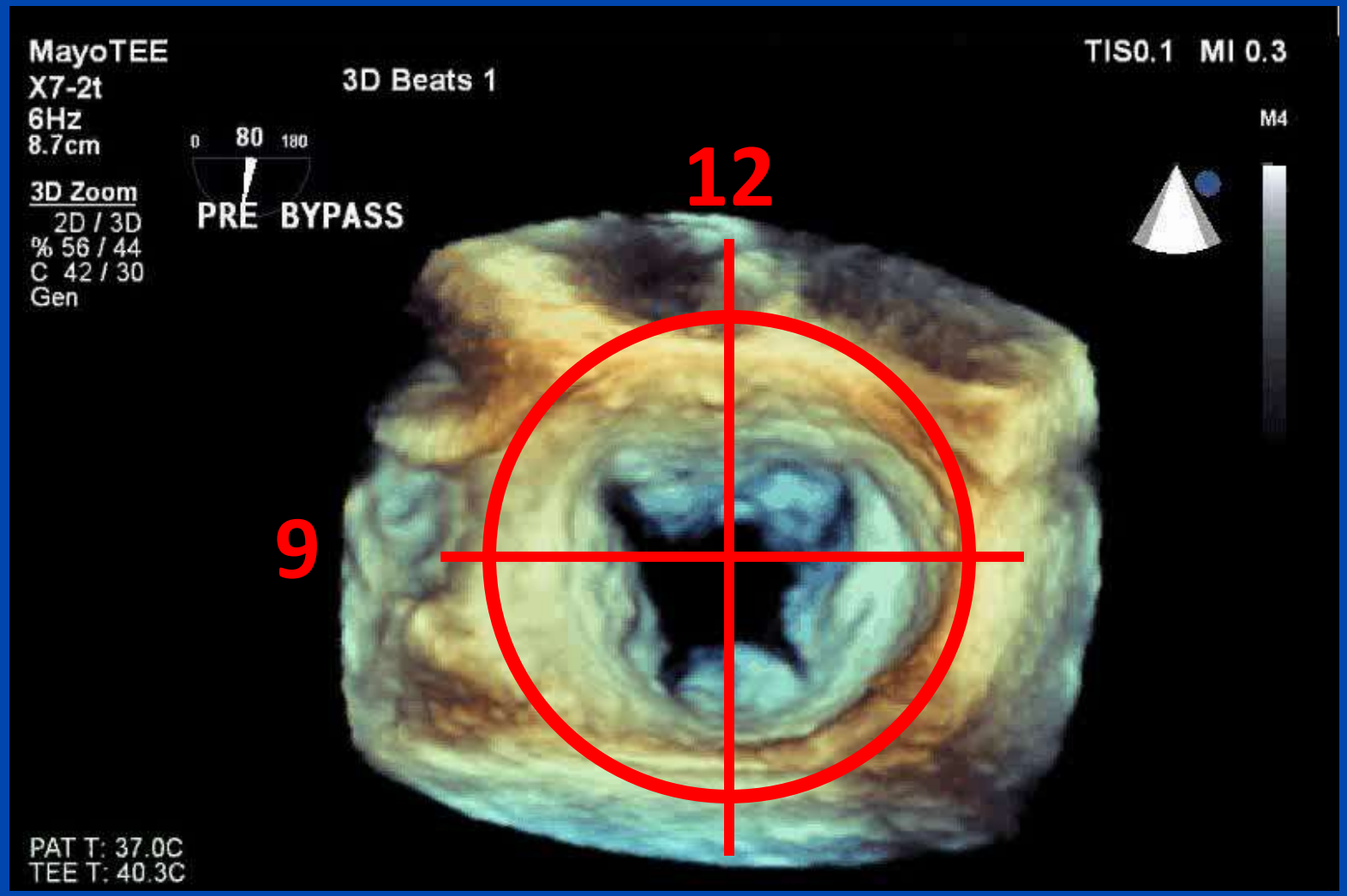
Another 3D option for prosthesis assessment

Simultaneous orthogonal



3D facilitates communication

Standard display



Left Ventricular Function

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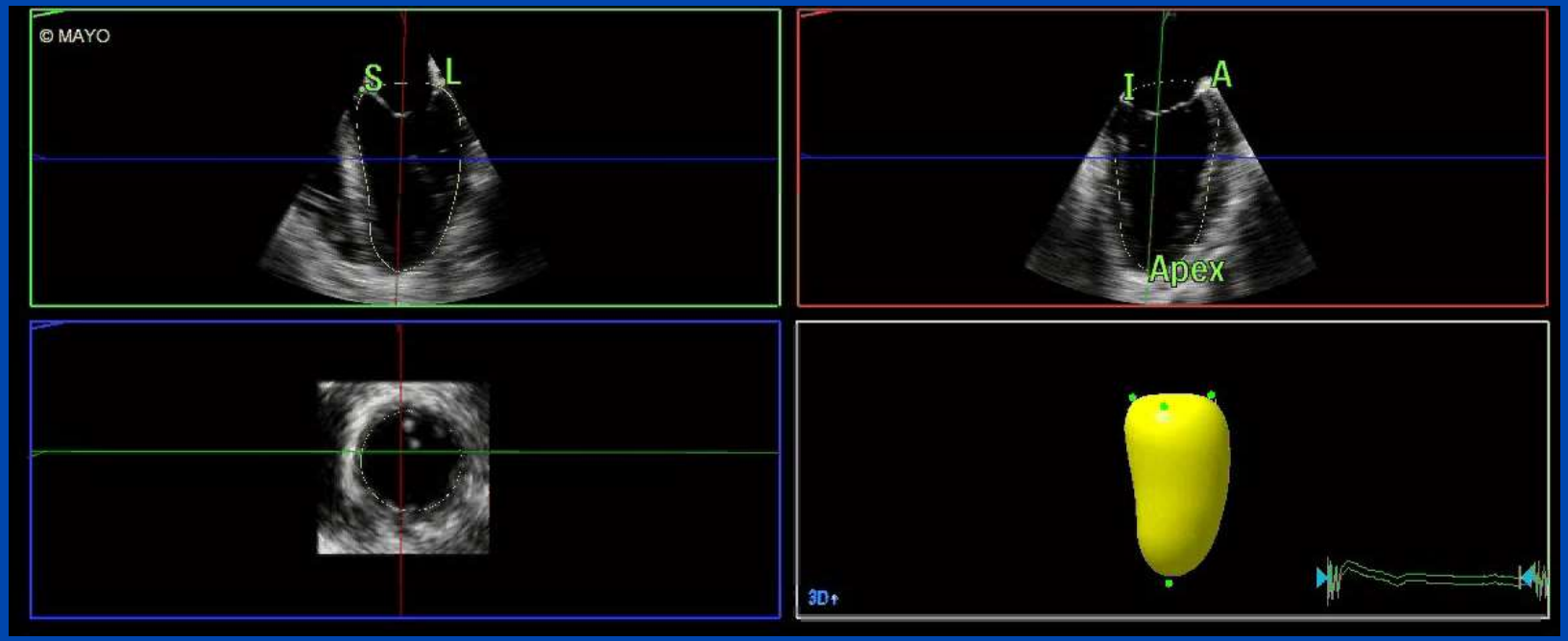
Left ventricle

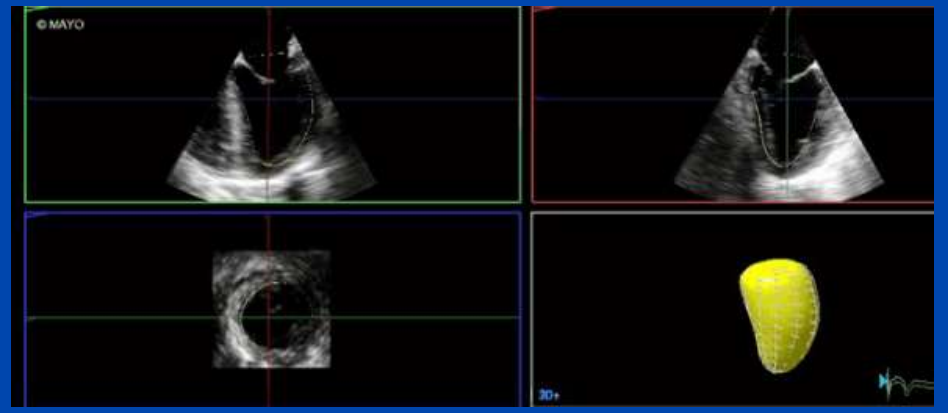
- 3D interrogation consistently recommended
- Strongly consider 3D volume, EF:
  - *Global or regional function abnormal at baseline*
  - *Global or regional function at risk for decline*

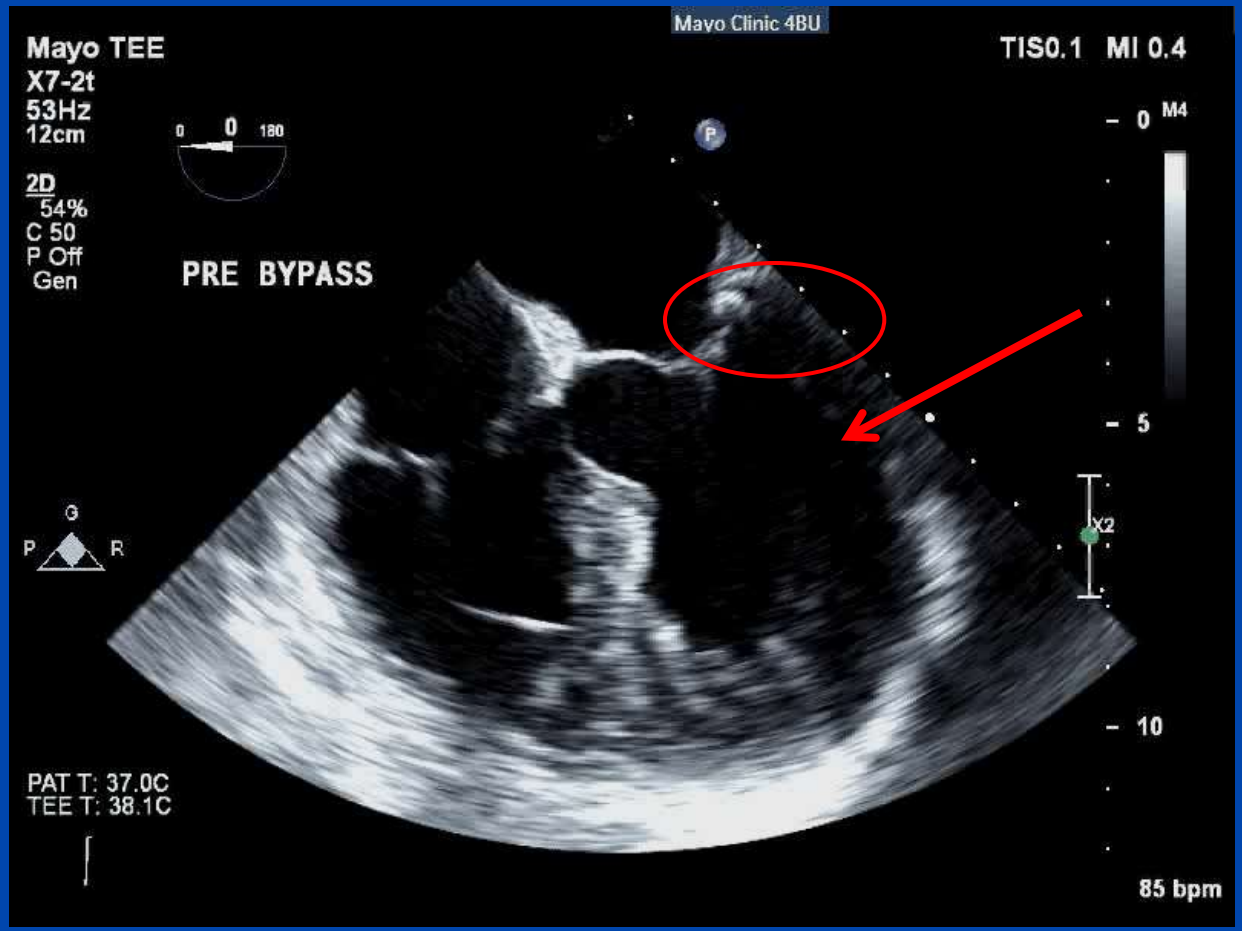


- No geometrical assumption
- Unaffected by foreshortening
- More accurate and reproducible compared to other imaging modalities

Left ventricle

- Not feasible in all

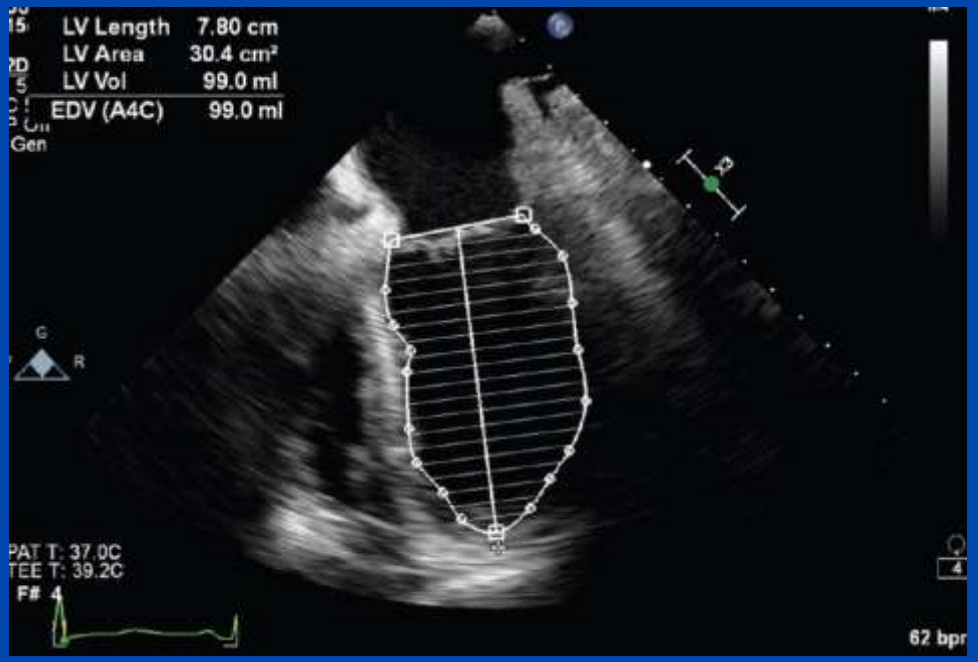


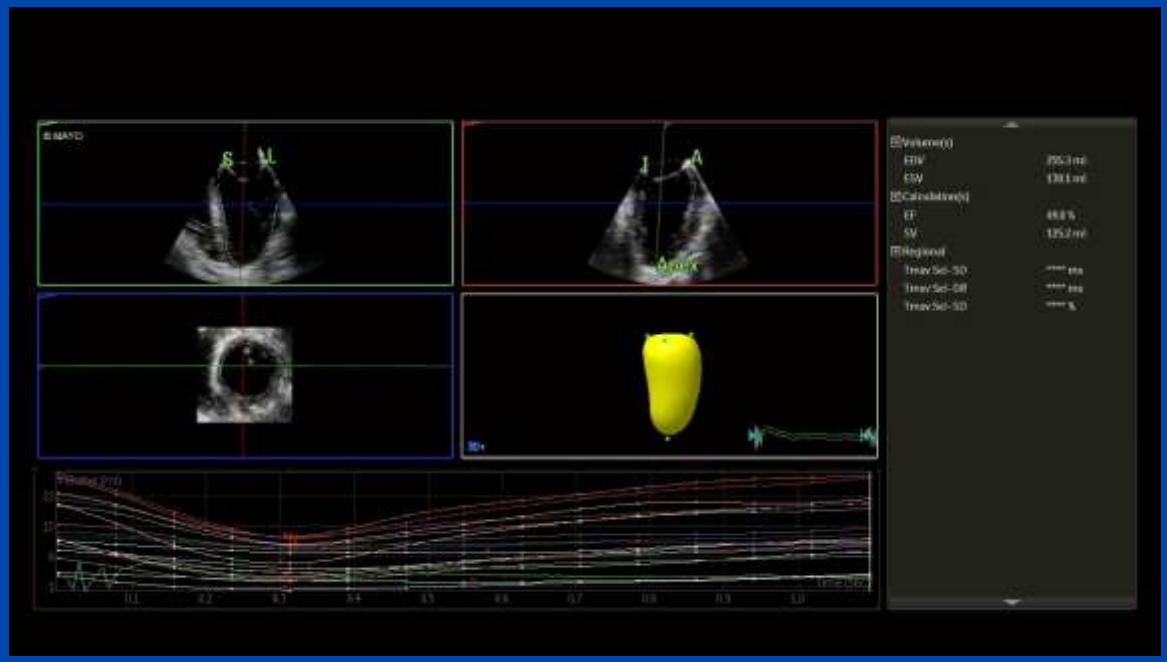


- Lower temporal resolution
- Less published data on normal values
- Image quality dependent

Left ventricle

Measurement of ejection fraction





"3DE is the only echocardiographic technique that measures myocardial volume directly, without geometric assumptions regarding LV shape and distribution of wall thickening."
ASE Chamber Quantification 2015

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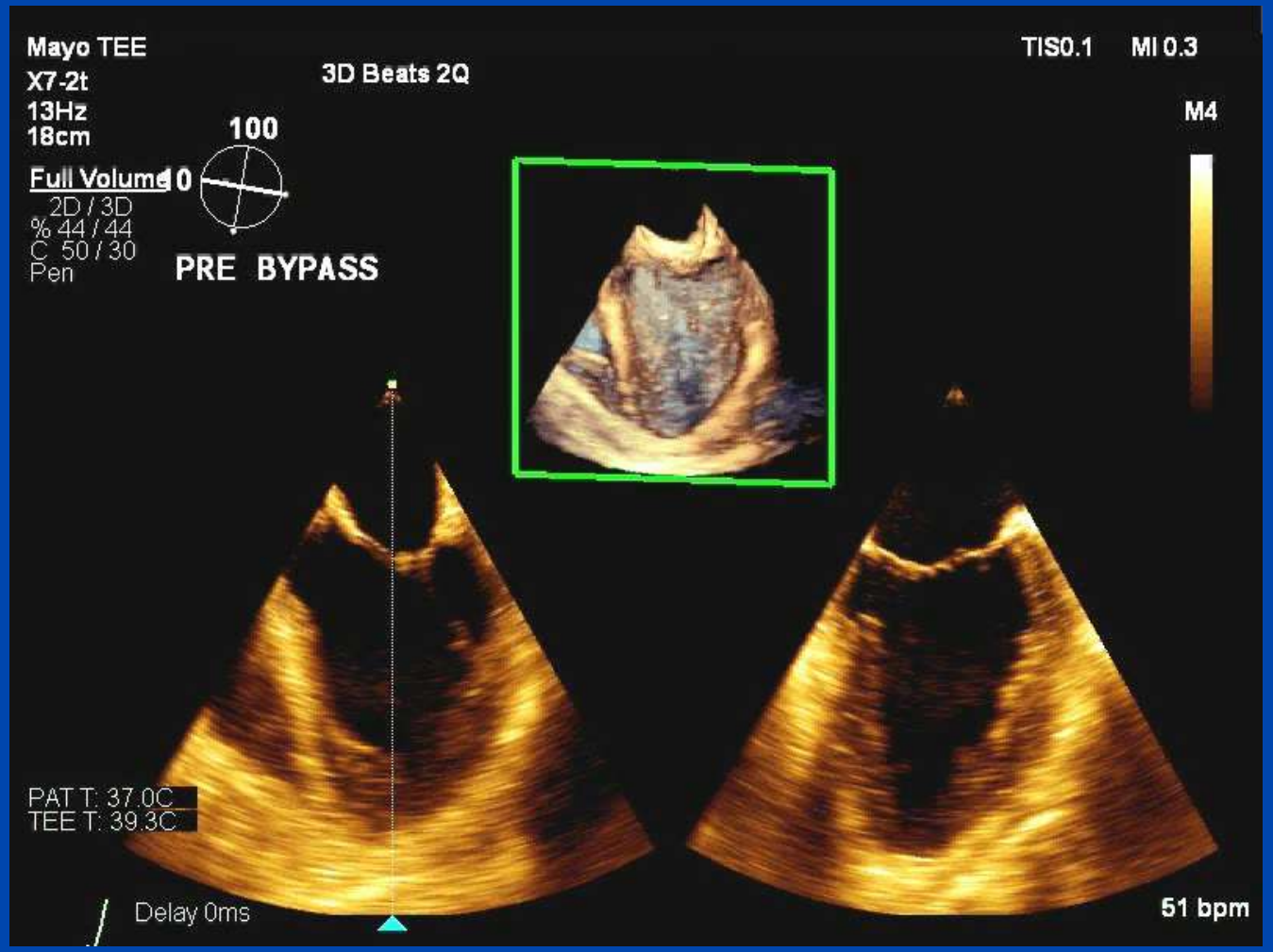
Left ventricle

Left Ventricle	
	1. Obtain a view of the left ventricle from the 0°, 60°, or 120° mid-esophageal positions
	2. Use the biplane mode to check that the left ventricle is centered in a second view 90° to the original.
	3. Acquire using wide-angle, multi-beat mode



"3D echocardiographic measurements are accurate and reproducible and should therefore be used when available and feasible."
ASE Chamber Quantification 2015

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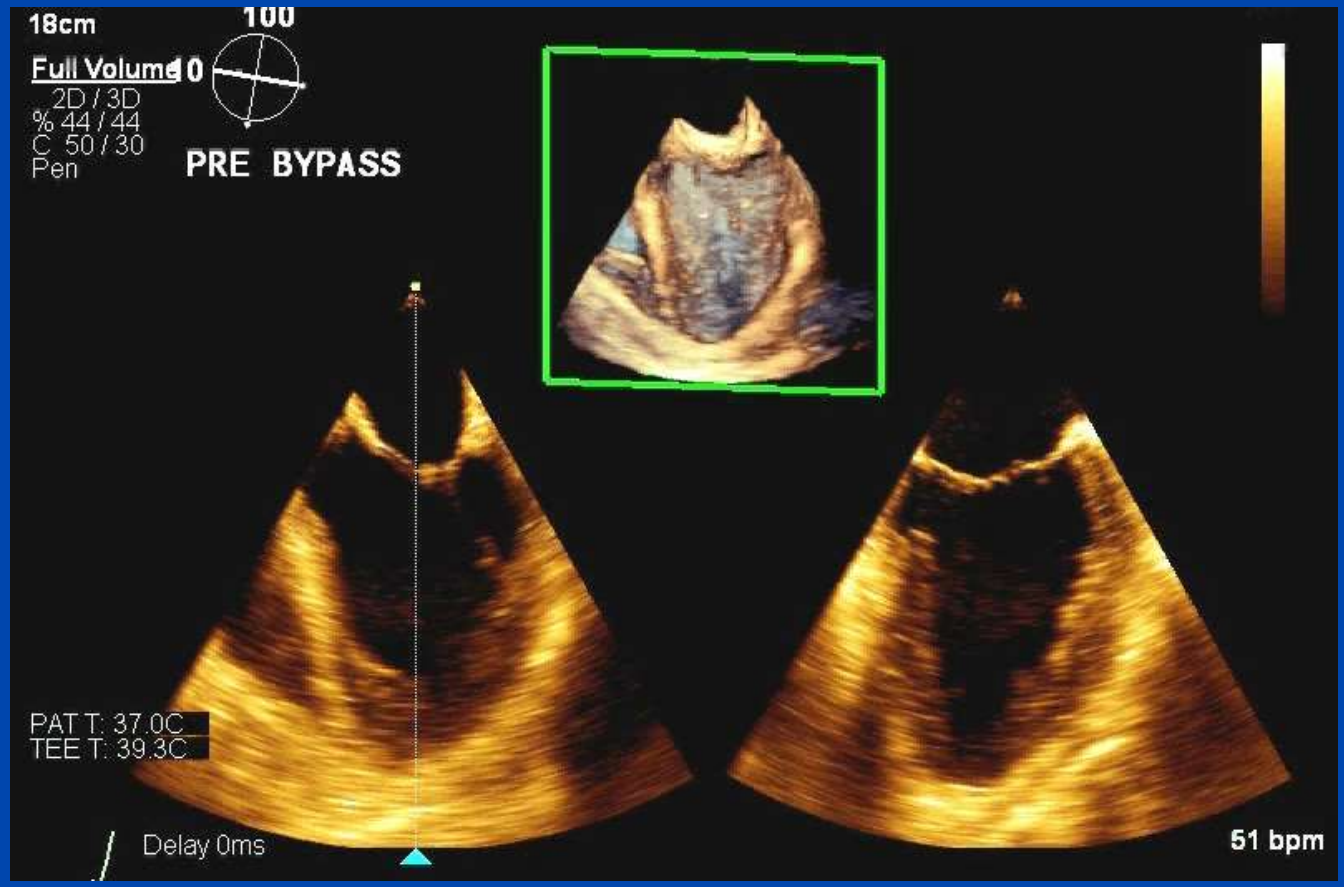
Left ventricle

- LV requires wide angle /full volume
- Multi beat, gated capture
  - *Acquire early*



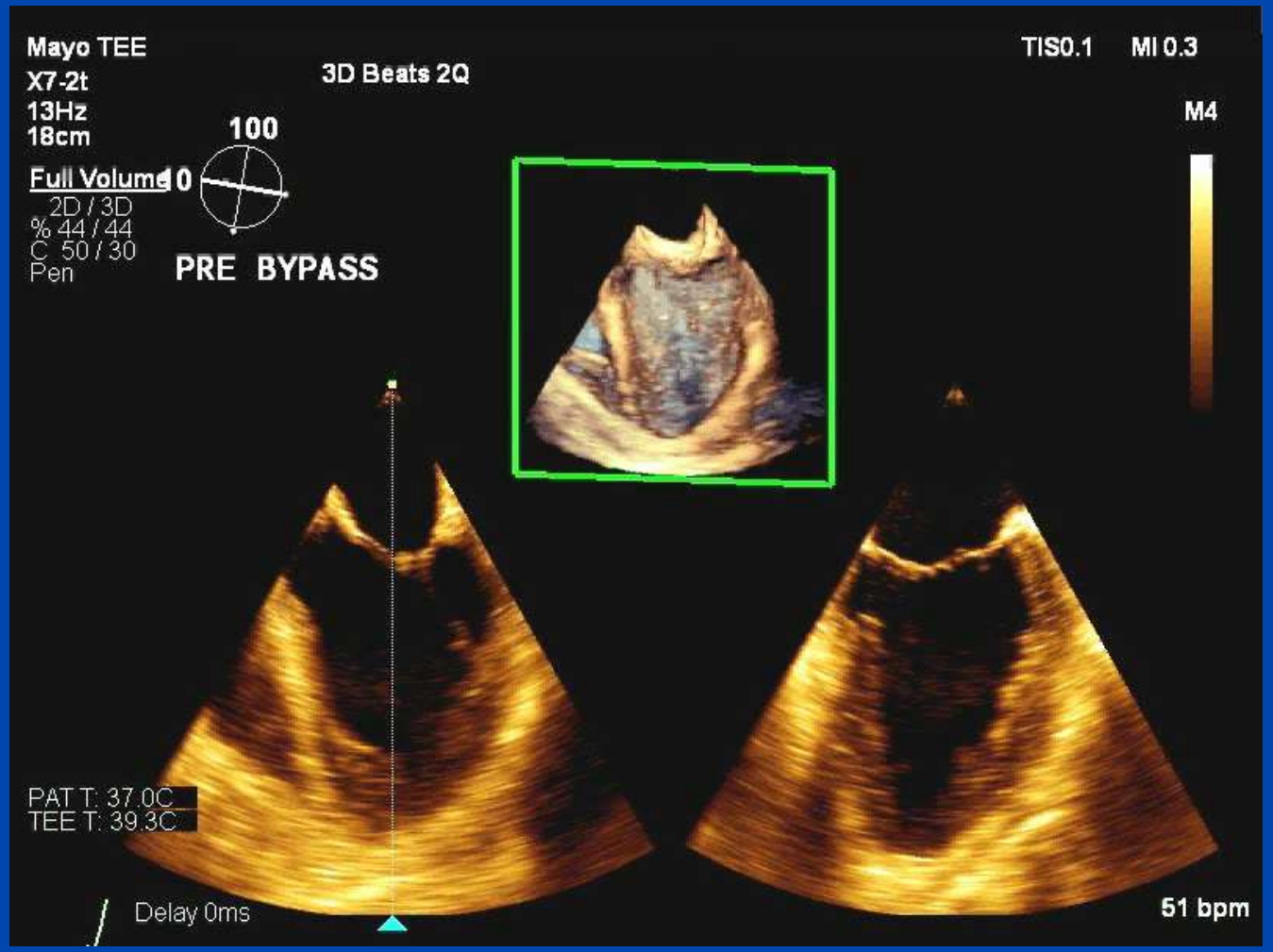
"To ensure reasonably accurate identification of end-systole, the temporal resolution of 3D imaging should be maximized without compromising spatial resolution." *ASE Chamber Quantification 2015*

MAYO CLINIC

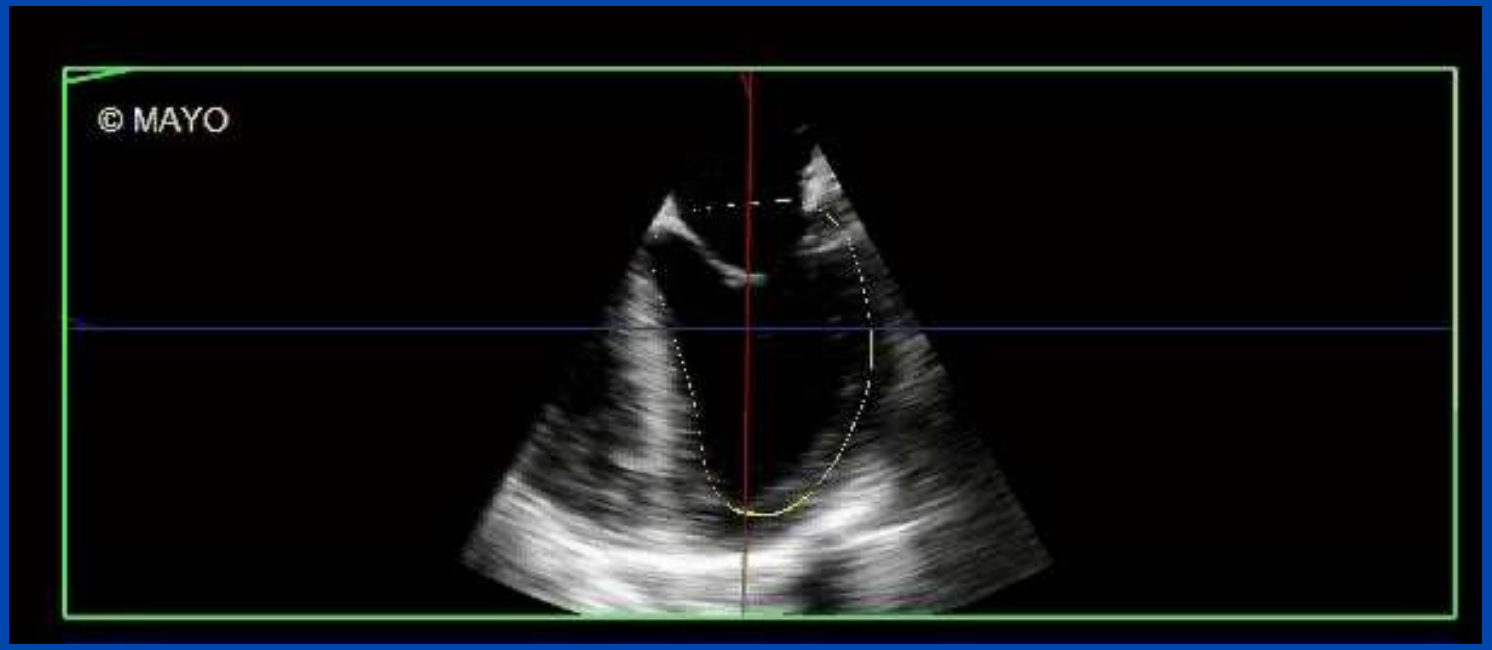
Left ventricle

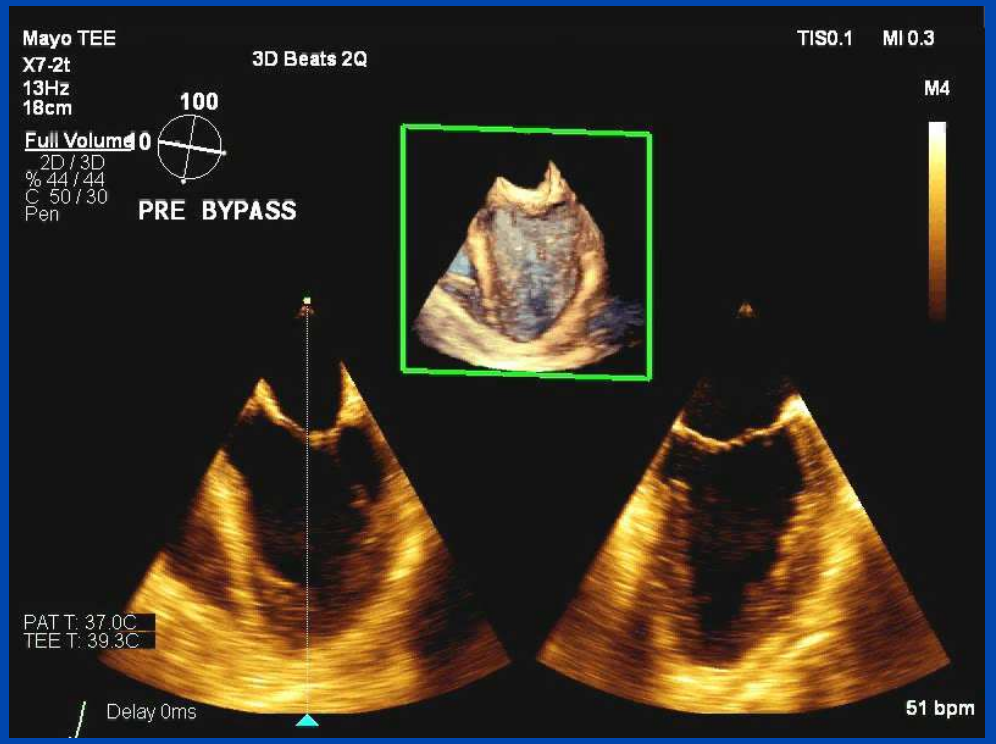
Left Ventricle	
	1. Obtain a view of the left ventricle from the 0°, 60°, or 120° mid-esophageal positions
	2. Use the biplane mode to check that the left ventricle is centered in a second view 90° to the original.
	3. Acquire using wide-angle, multi-beat mode

Need spatial and temporal resolution



Left ventricle



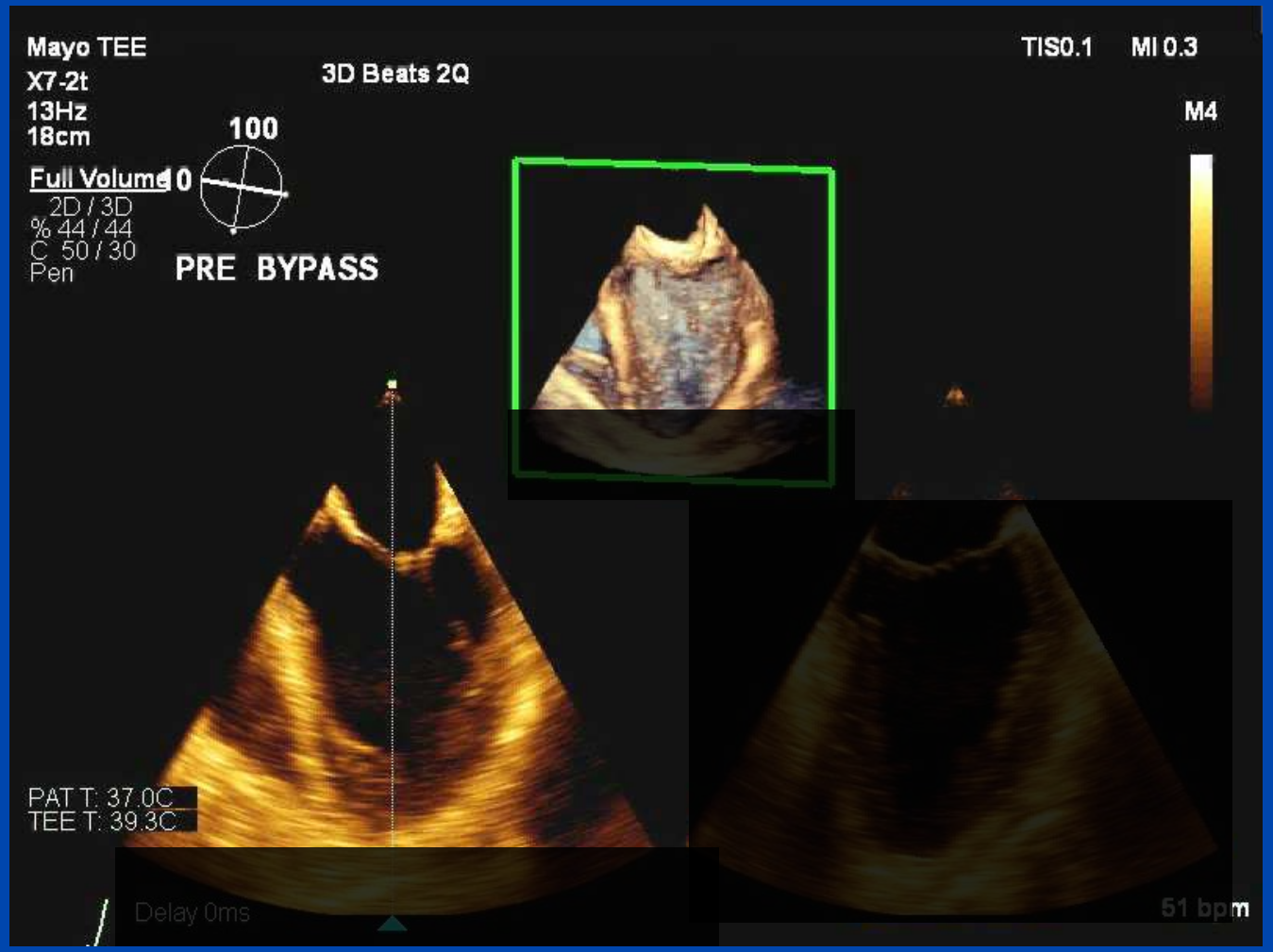


- Spatial res: edit, update border tracking
- Temp res: identify end-systole, end-diastole

Left ventricle

Benefit of 3D:

- *Detects foreshortening*



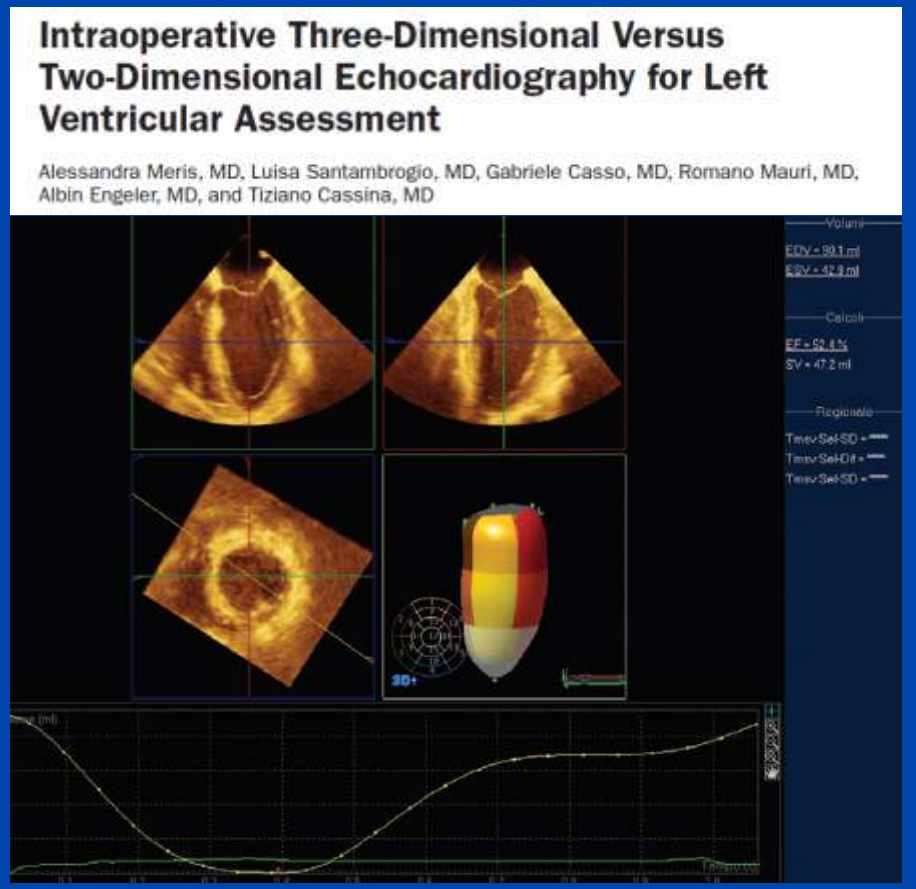
Intraoperative Three-Dimensional Versus Two-Dimensional Echocardiography for Left Ventricular Assessment

Anesth Analg 2014;118:711–20

3D TEE LV volumes greater than 2D TEE, though EF similar

3D TEE Advantage for EF determination?

VS



No significant differences in LV EF determination by 2D versus 3D intraoperative TEE

Anesth Analg 2014;118:711–20

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3D Assessment of LV EF

- Value in setting of wall motion abnormalities

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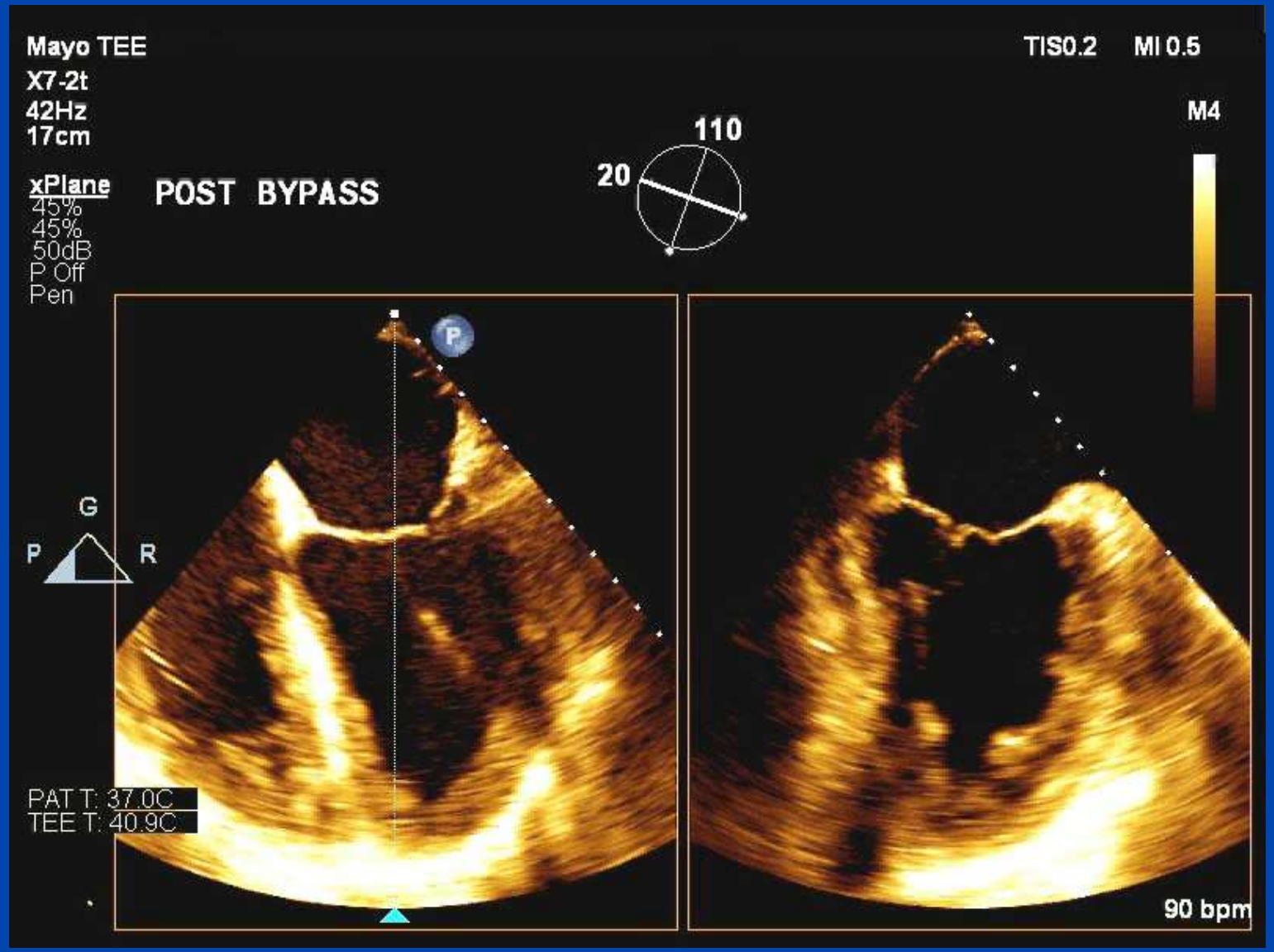
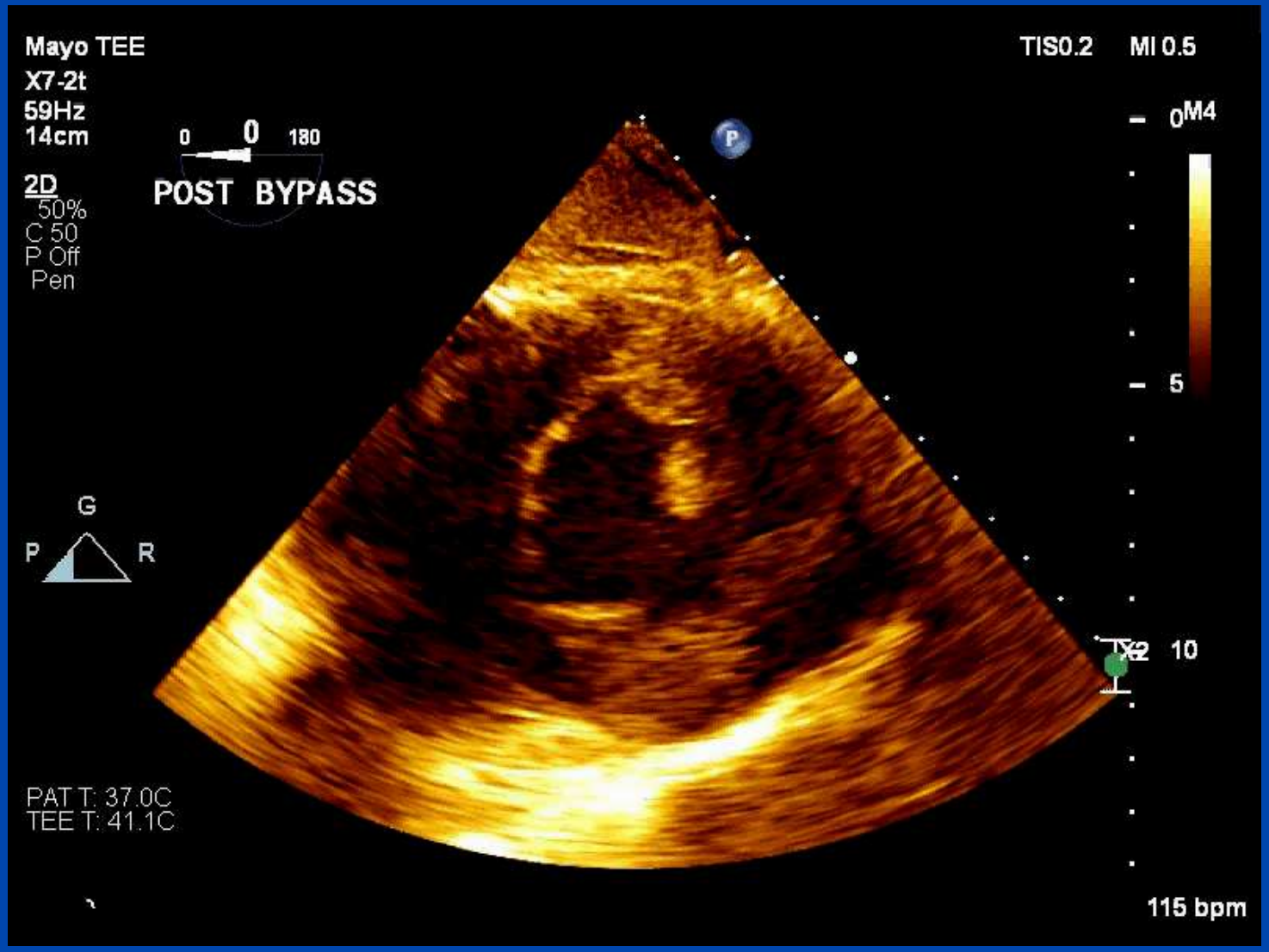
Left ventricle

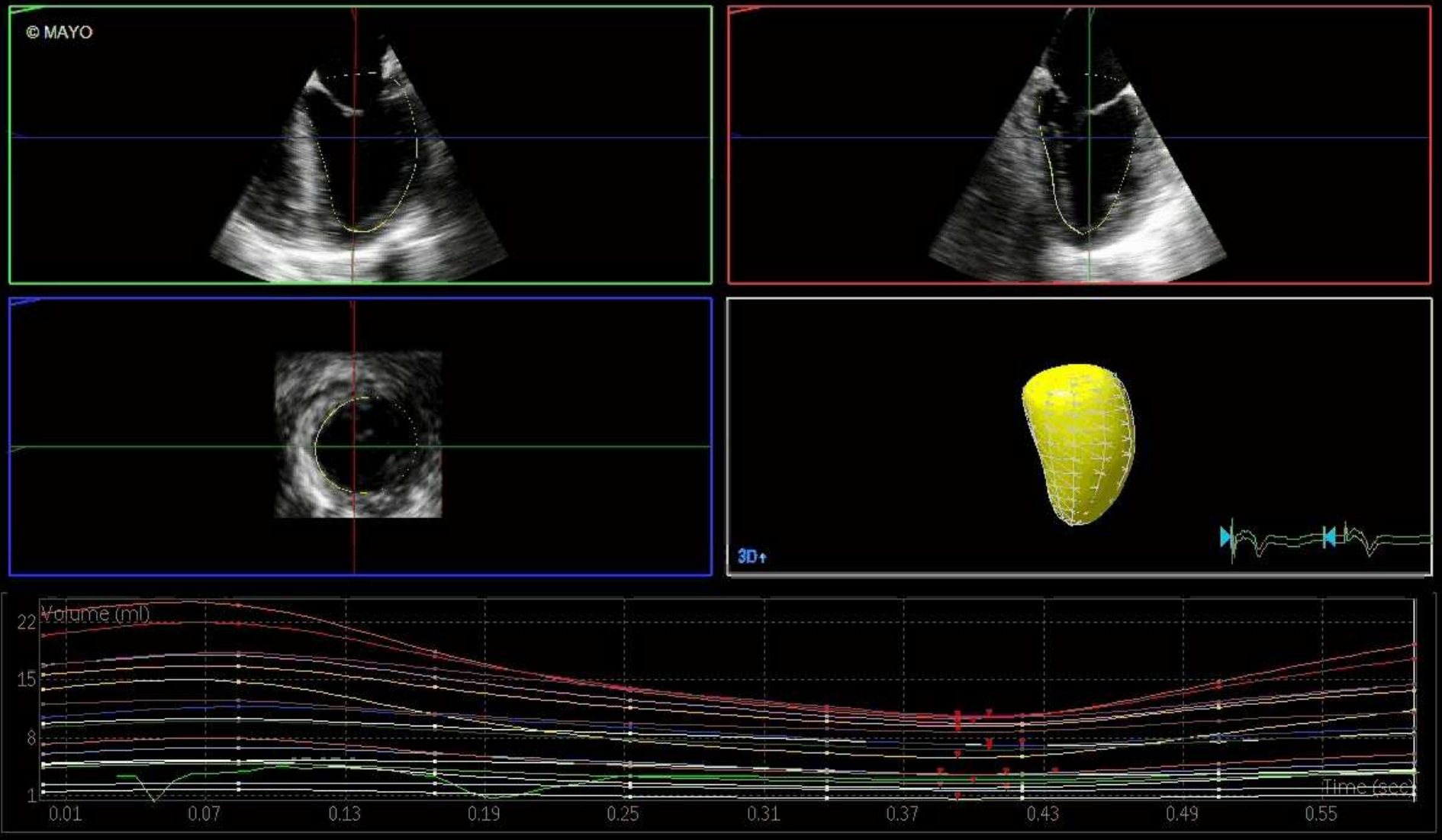
Measurement of ejection fraction post-bypass: CABG



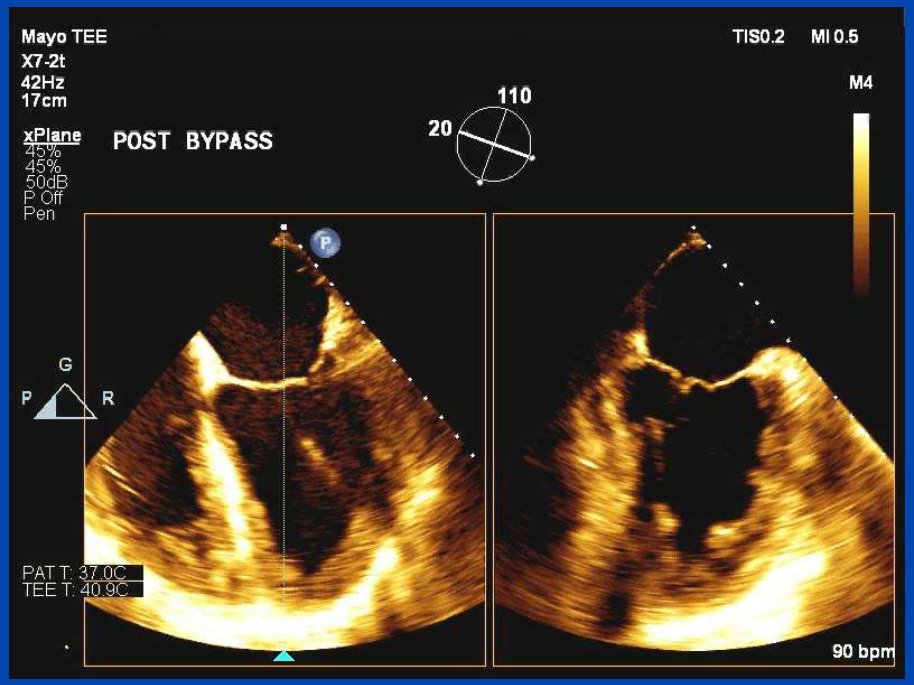
Left ventricle

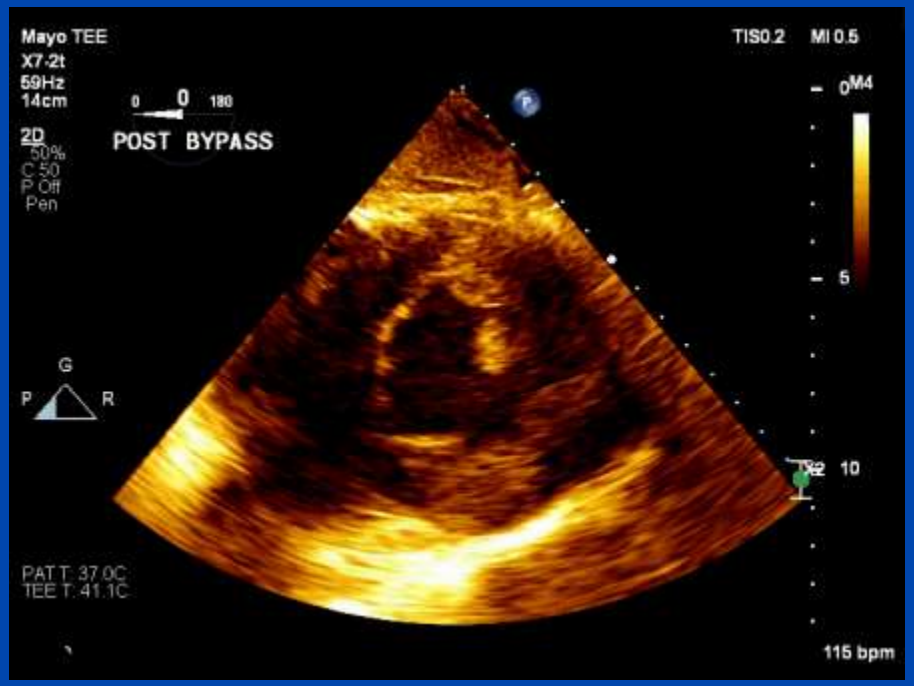
Measurement of ejection fraction

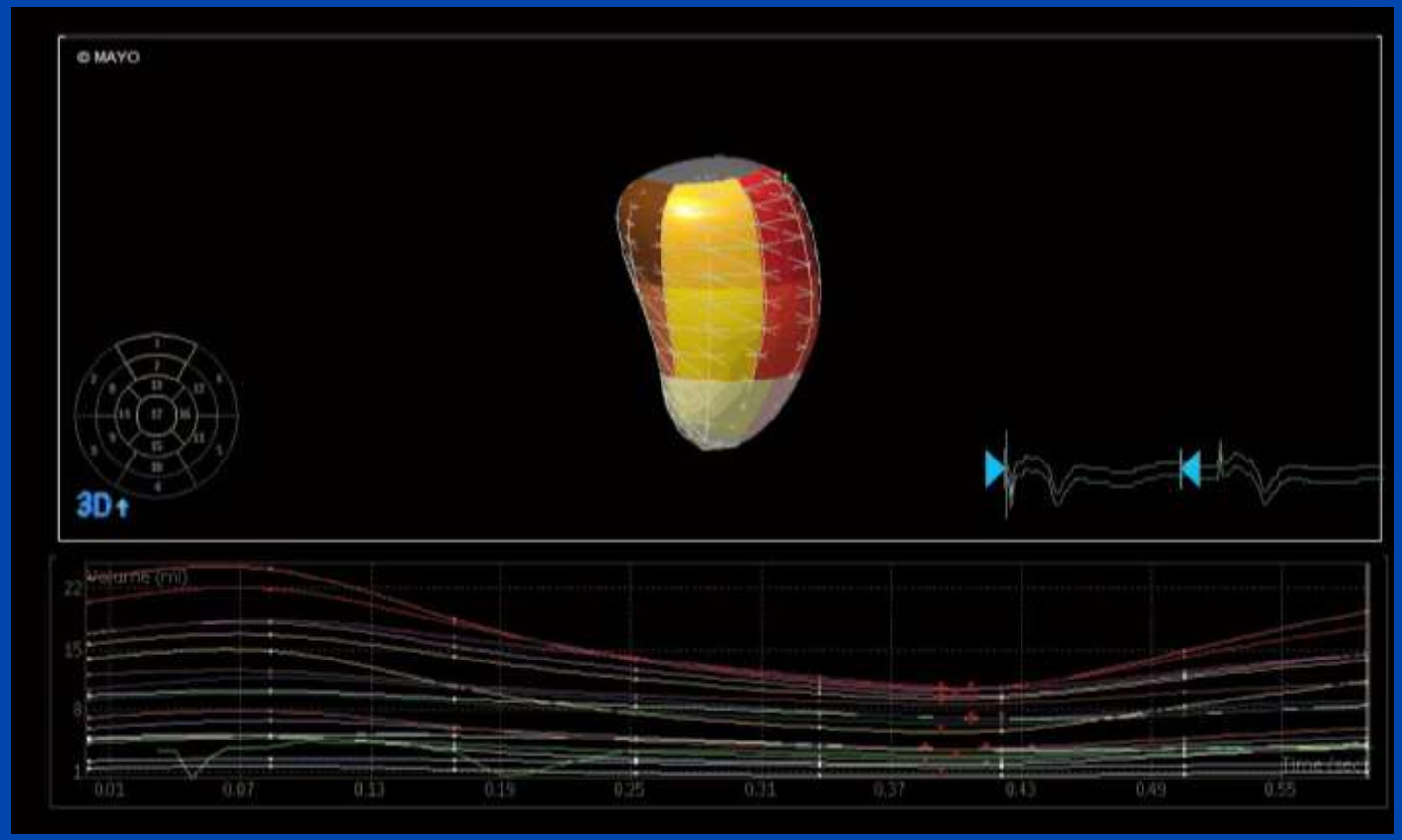




Volume(s)	
EDV	194.2 ml
ESV	107.3 ml
Calculation(s)	
EF	44.8 %
SV	86.9 ml
Regional	
Tmsv Sel-SD	**** ms
Tmsv Sel-Dif	**** ms
Tmsv Sel-SD	**** %







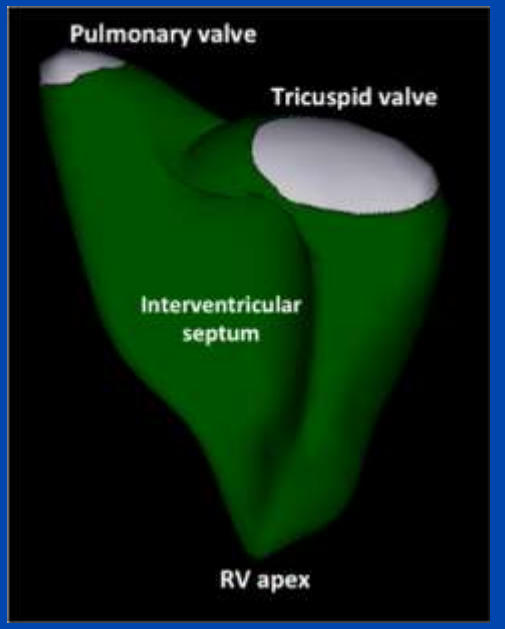
Volume(s)	
EDV	194.2 ml
ESV	107.3 ml
Calculation(s)	
EF	44.8 %
SV	86.9 ml

MAYO CLINIC

Right Ventricle

MAYO CLINIC

Right Ventricle



- Difficult to assess
- Only assess limited portions (FAC, TAPSE, S')
- After cardiac surgery, longitudinal measures reduced, not representative

"…with appropriate 3D platforms and experience, 3DE-derived RV EF should be considered." ASE Chamber Quantification 2015

Multi-beat, gated acquisition, 20-25 volumes/sec

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Congenital

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EACVI/ASE EXPERT CONSENSUS DOCUMENT

Three-dimensional Echocardiography in Congenital Heart Disease: An Expert Consensus Document from the European Association of Cardiovascular Imaging and the American Society of Echocardiography

J Am Soc Echocardiogr 2017;30:1-27

"There have been no randomized trials relating to procedural success, morbidity or mortality related to the application of 3DE."

"…our consensus view of the added value of 3DE to assess some major groups of lesions."

"3DE should be regarded as a technique that complements rather than replaces 2DE for assessment of CHD."

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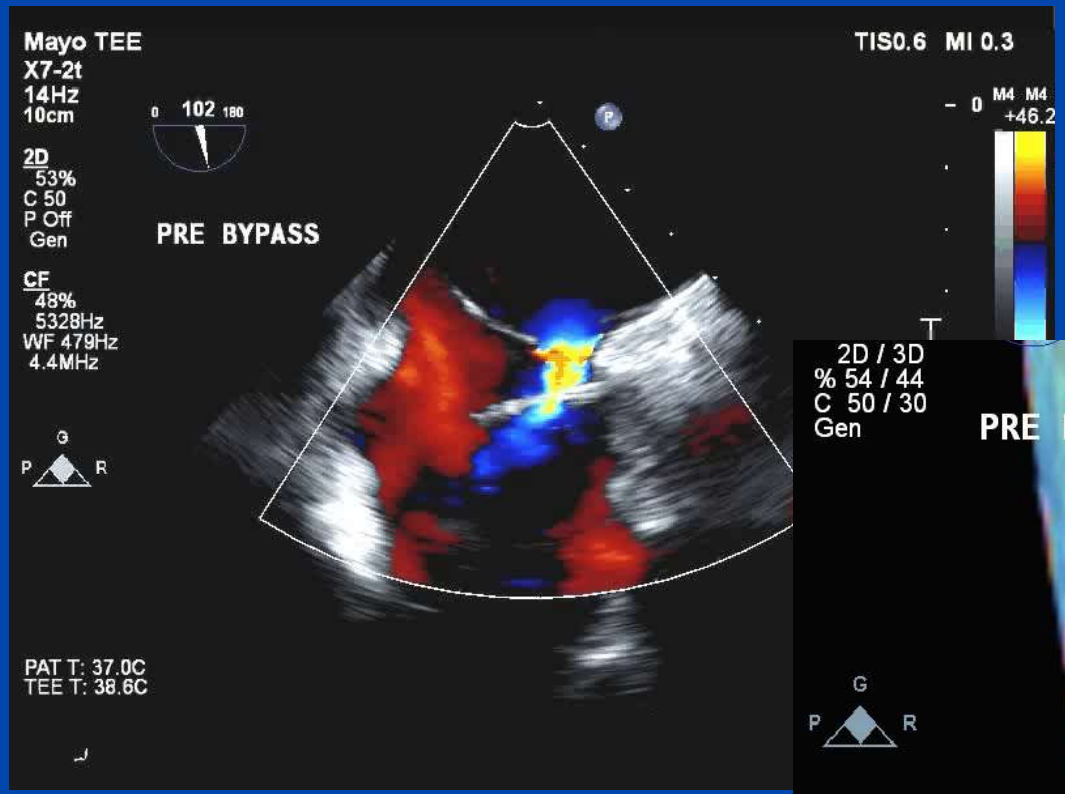
	3D-TEE
Atrial septum	
ASD	+++
SV ASD	+++
AV junction	
AVSD	+++
Ebstein's/TV dysplasia	+
MV chordal structure	+++
Double orifice MV	++
MVP	+++
Parachute MV	++
Supra mitral membrane	+++
Ventricular septum	
mVSD (except anterior defects)	++
Membranous VSD	++
Doubly committed subarterial VSD	++
Outlets	
Aortic valve	+++
Pulmonary valve	++
Double outlet right ventricle	+

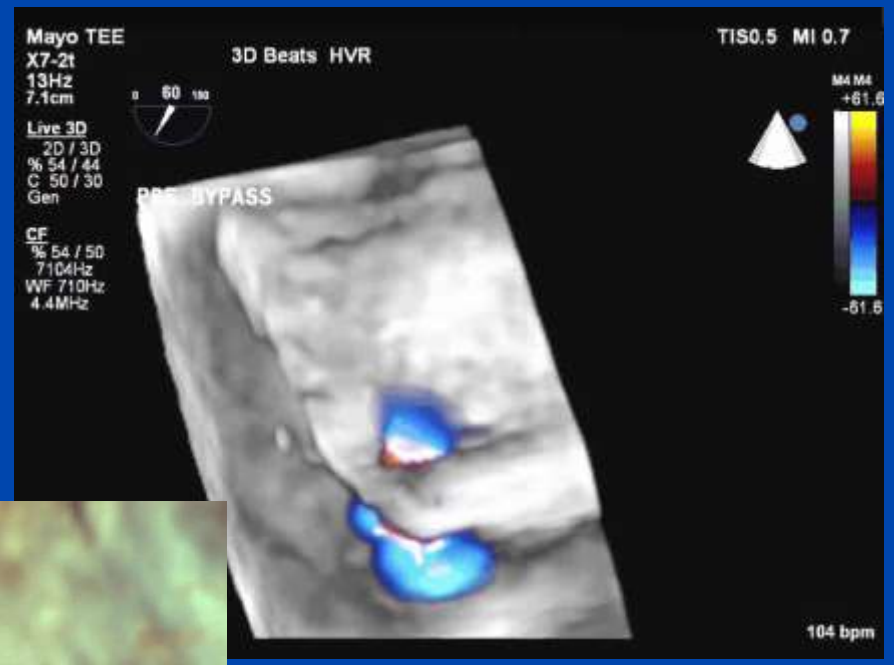
Utility of 3D TEE:

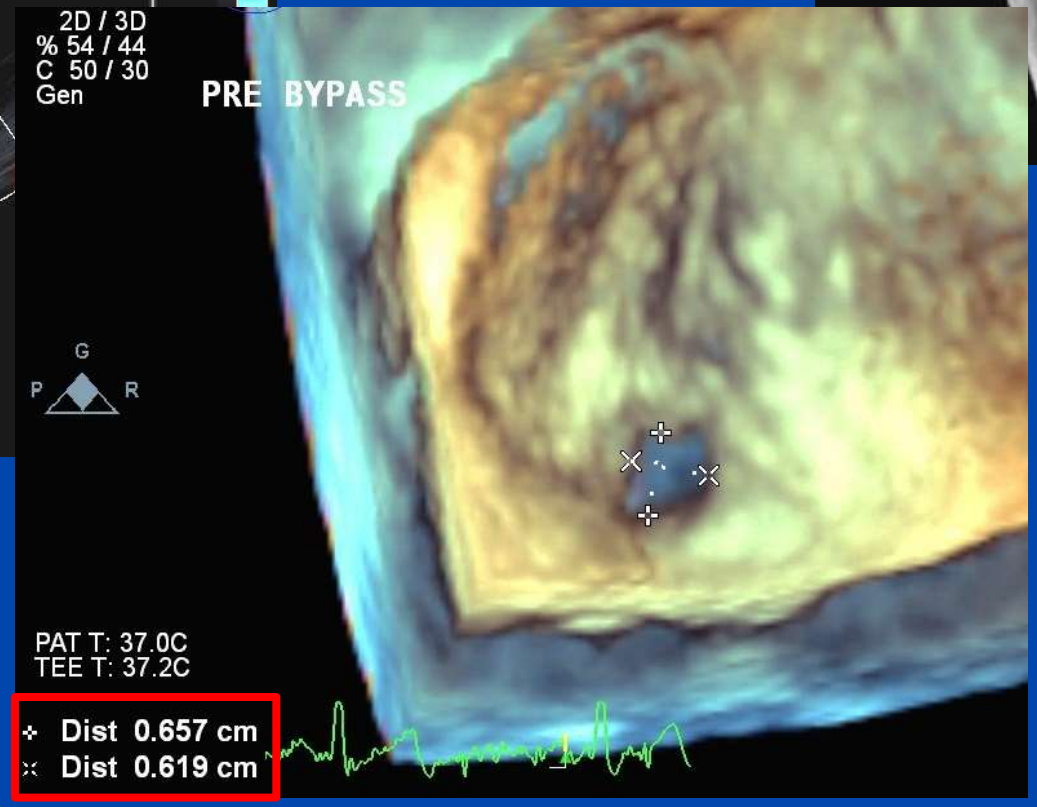
ASD, MV, AV > VSD

Region of interest	3D modalities	Information acquired (I) Comment (C)	Strength of recommendation
Atrial septum	GS/CFM TTE/TEE	I: Size/number/shape/location of defects C: High value for multiple defects, multiple device deployment, residual leaks, spiral defects	HIGH for complex or residual defects MODERATE for single central defects LOW for PFO[11,11,28,30-33]
Tricuspid valve abnormality	GS/CFM TTE/TEE	I: Leaflet morphology Chordal support Delineation of regurgitant jets C: Mechanism/severity of regurgitation refined	HIGH[34-39]
Mitral valve	GS/CFM TTE/TEE	I: Leaflet morphology Chordal support Delineation of regurgitant jets C: Mechanism/severity of regurgitation refined	HIGH[8,12,40-42]
Ventricular septum	GS/CFM TTE/TEE	I: Size/number/shape/location of defects C: High value for multiple defects, unusually located defects or consideration of interventional closure	HIGH for more complex defects LOW for other defects[43-48]
Left ventricular outflow tract	GS/CFM TTE/TEE	I: Morphology of subaortic obstruction and aortic valve C: Clarify mechanism of obstruction and/or regurgitation	HIGH[19,49,50]
Aortic valve	GS/CFM TTE/TEE	I: Measurement of aortic valve Morphology of aortic valve leaflets Mechanism of aortic regurgitation C: Imaging of aortic valve leaflets more difficult by 3D TTE, 3D TEE preferred	HIGH Especially by TOE[21,51,52]
Aortic arch	GS/CFM TTE	I: Morphology and sizing of aortic arch C: Imaging may be difficult due to probe size, acoustic access	LOW/MOD[53]
Right Ventricular Outflow tract	GS/CFM TTE/TEE	I: RVOT morphology Visualization of site of RVOT obstruction C: Questionable benefit over 2DE	LOW/MODERATE[54,55]
Pulmonary valve	–	I: PV morphology and function C: May be able to visualize PV morphology better than 2DE	Low[54,55]
Branch pulmonary arteries	–	Not routinely used	None

Secundum ASD



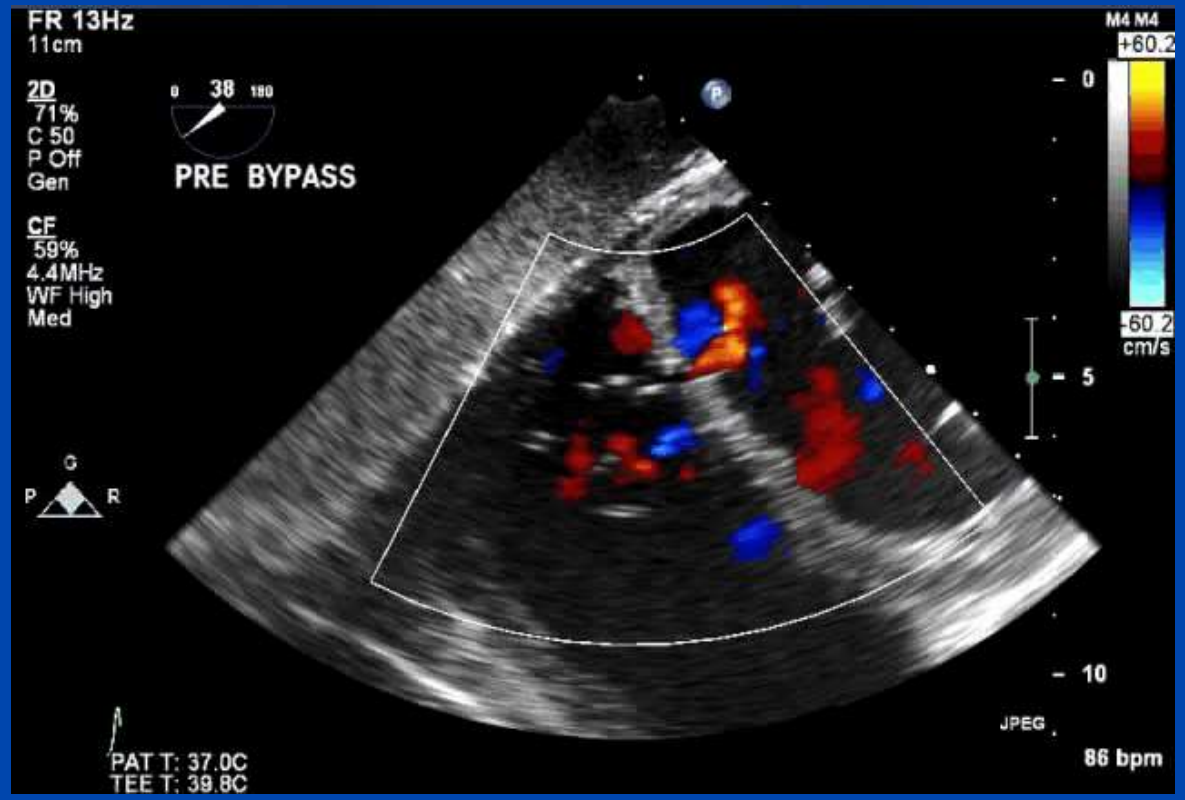


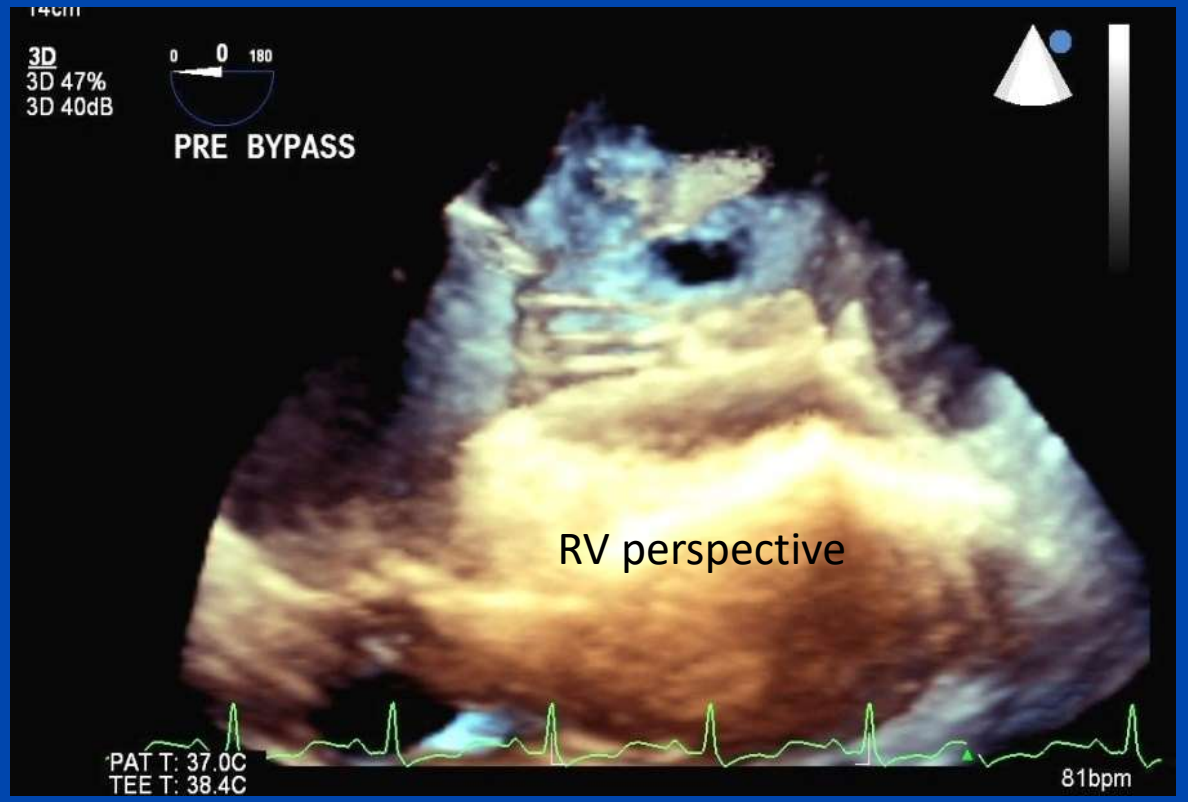


Improved understanding:

- Size
- Geometry
- Rims

Simple muscular VSD





- Size
- Geometry
- Surrounding structures

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 |

Suggested Intra-op TEE Exam Sequence: 3D Era

1. Comprehensive 2D, Doppler exam
2. Identify structures of interest for 3D exam
3. Acquire specific 3D images / datasets
4. Post-acquisition analysis of 3D images / data

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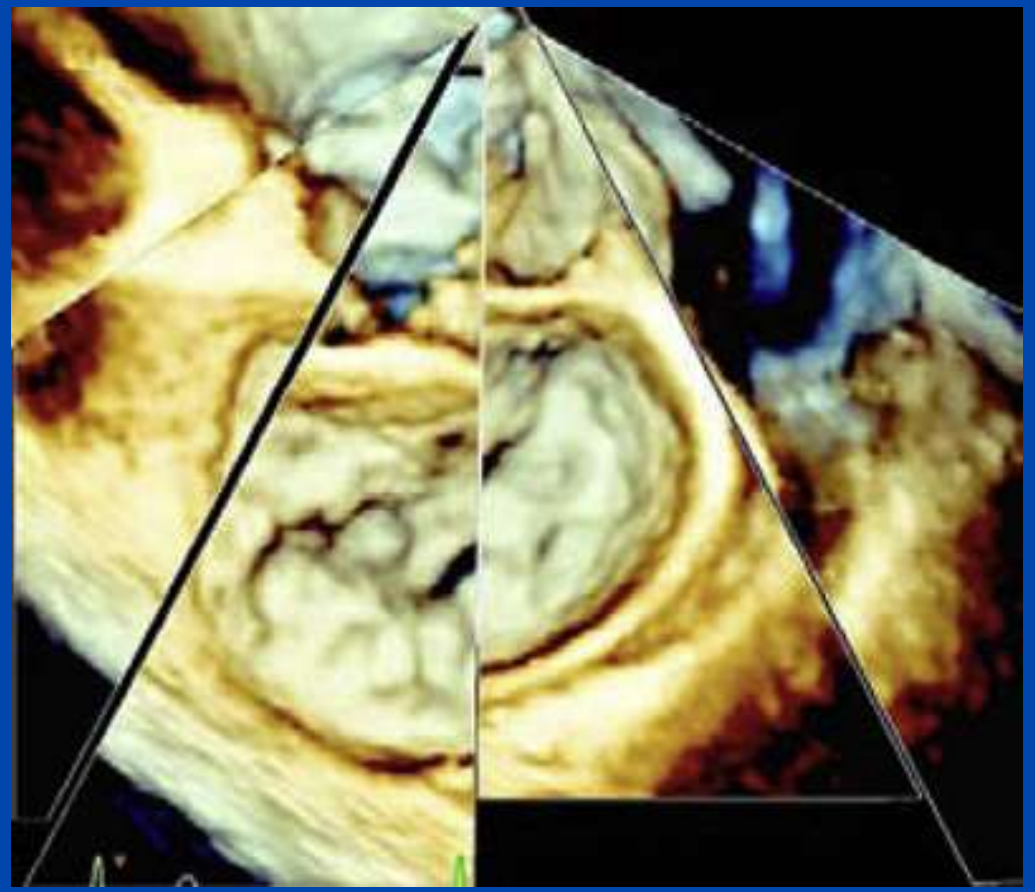
Time-sensitive nature of 3D acquisition

Race against time



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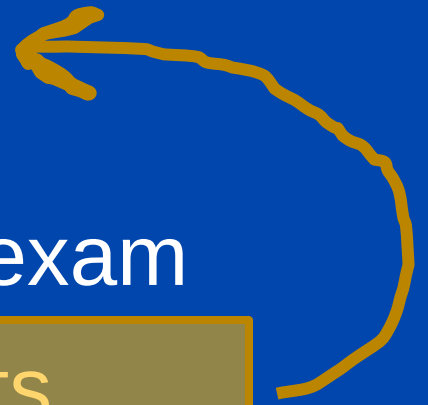
Suggested Intra-op TEE Exam Sequence: 3D Era



1. Comprehensive 2D, Doppler exam
2. Identify structures of interest for 3D exam
3. Acquire specific 3D images / datasets
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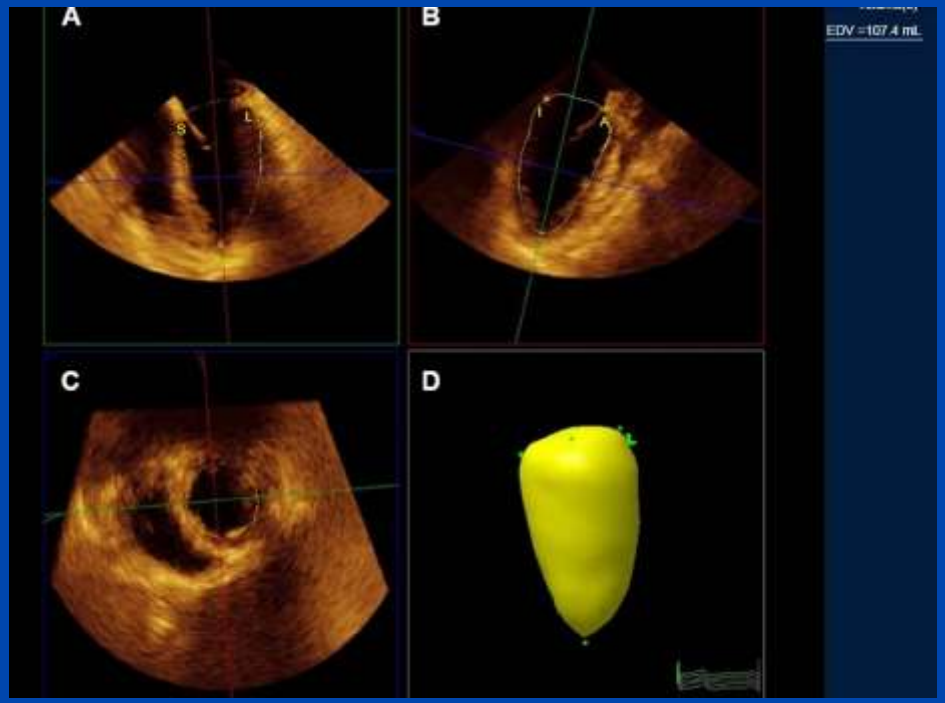
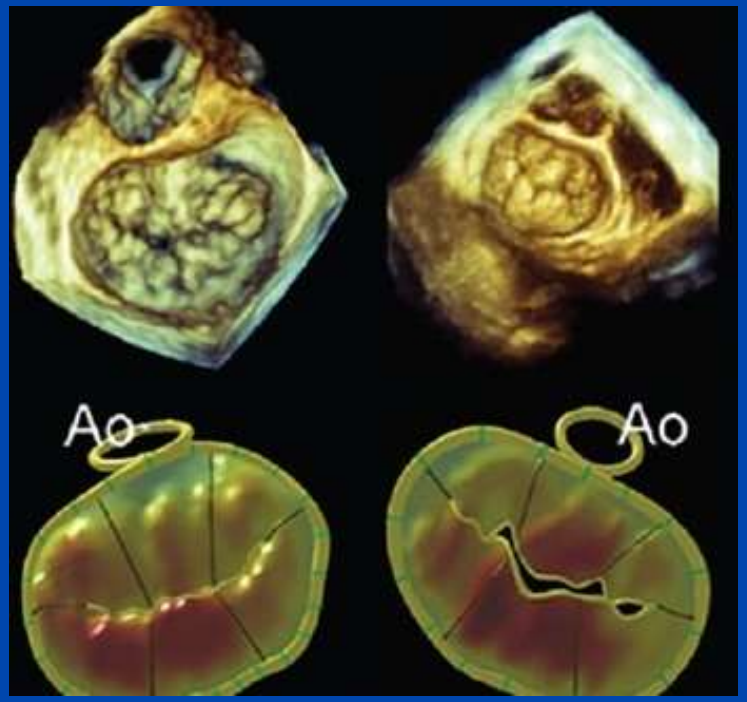
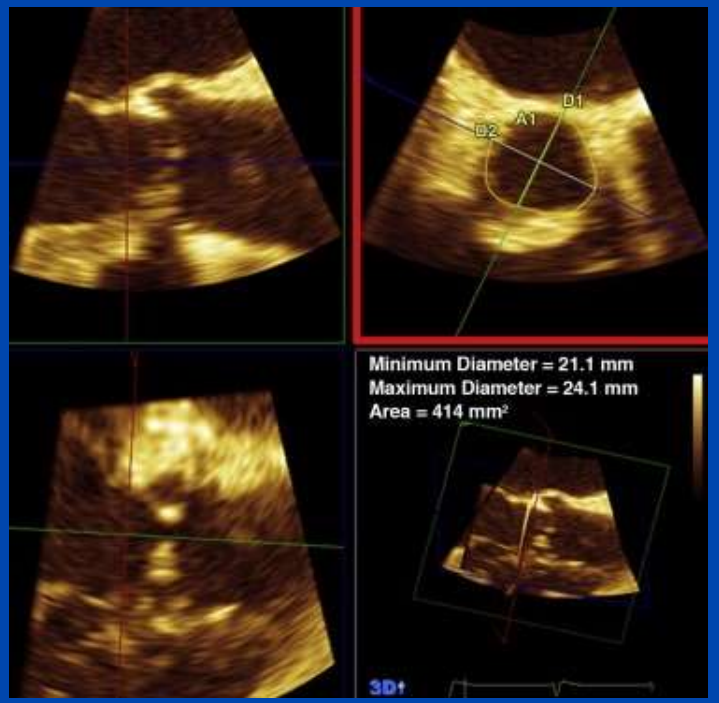
Procedural-driven 3D image acquisition







Obtain gated, multi-beat clips early

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Take Home Points

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The Standard 3D Exam

- 3D imaging is patient / procedure specific
  - No comprehensive, universal protocol for 3D exam
- 3D complementary to 2D exam
- Mode of 3D exam dictated by:
  - Structures of interest
  - Patient factors
  - Procedural factors

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The Standard 3D Exam

- Cases with high 3D yield
  - Catheter-based
  - Valve repair / replacement
    - *Pre-operative diagnostic*
    - *Post-intervention assessment*
  - Congenital
  - Ventricular function

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Thank You !

rehfeldt.kent@mayo.edu

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