

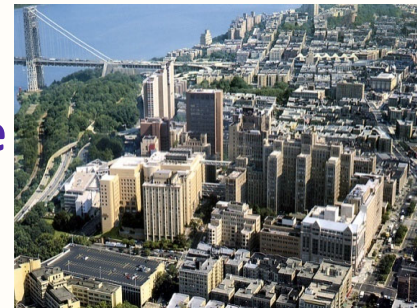


Advances in Imaging for Tricuspid Valve Interventions: Lessons Learned, Future Direction

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Director of Interventional Echocardiography, The
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Chief Scientific Officer, Echo Core Lab/CRF
New York, NY



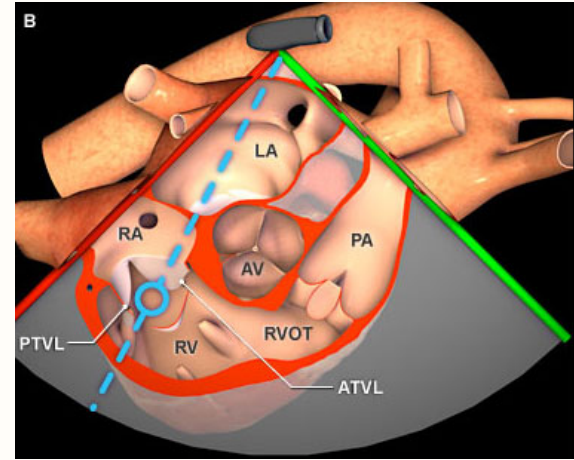
Disclosures: Rebecca Hahn

- **Speaker/Consultant:**
 - Abbott Vascular
 - Baylis Medical
 - Edwards Lifescience
 - Philips Healthcare
- **Institutional Consulting Contracts (no direct compensation)**
 - Abbott Vascular
 - Boston Scientific
 - Edwards Lifescience
 - Medtronic
 - Philips Healthcare

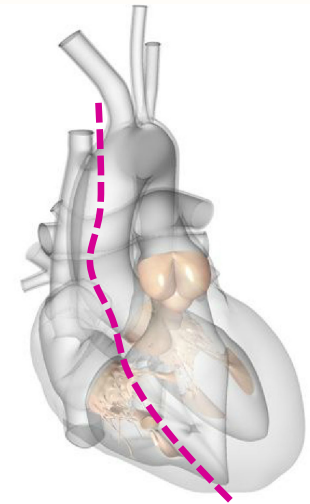
Procedural Imaging for Transcatheter Tricuspid Valve Interventions

Imaging Requirements for TTVI

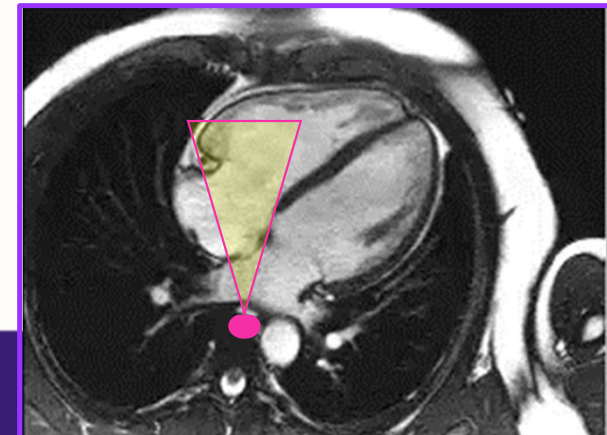
- Tricuspid valve more difficult to image than Mitral
 - Further away from probe
 - Thin leaflets
- Ideally, need two good views for leaflet grasp and verification of capture
- Understand tricks to overcome anatomic challenges (left sided valves, horizontal heart, etc)



Virtual Transesophageal echocardiography; Toronto General Hospital Department of Anesthesia-perioperative interactive education



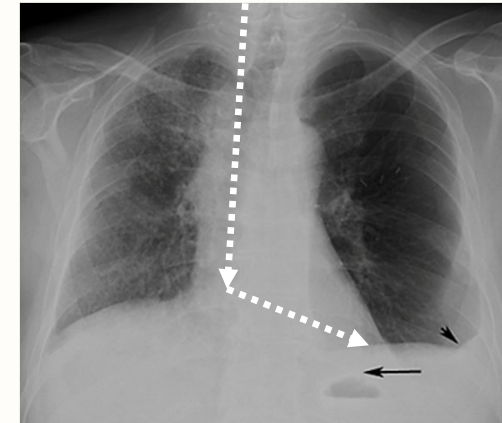
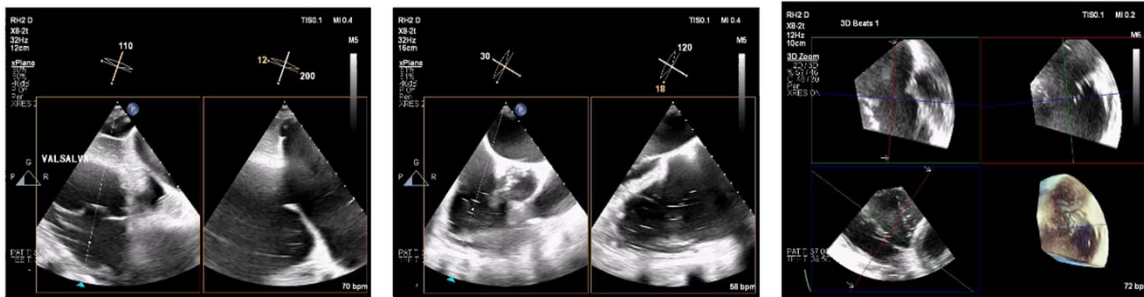
Esophagus



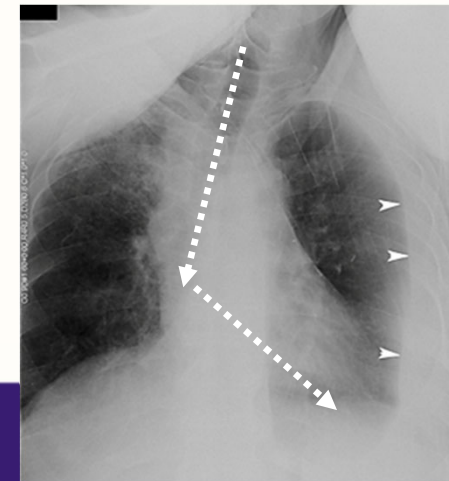
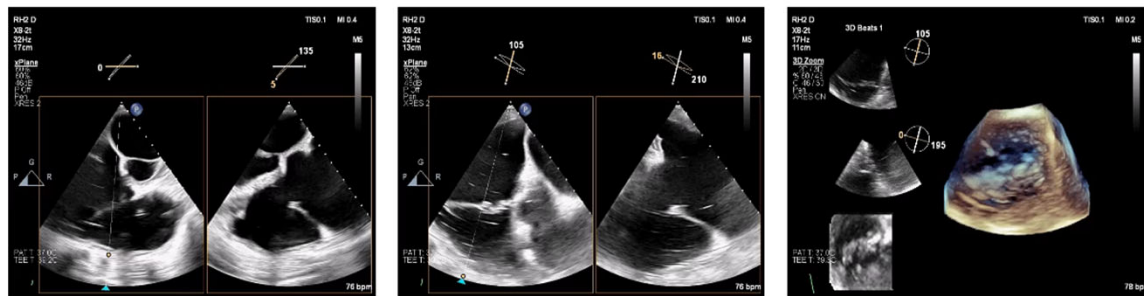
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Lesson #1: Position Patient to Mimic Left Lateral Decubitus Position and Optimize Probe Position

Initial Imaging

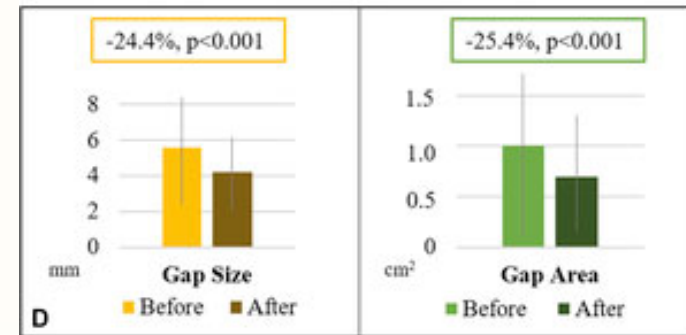
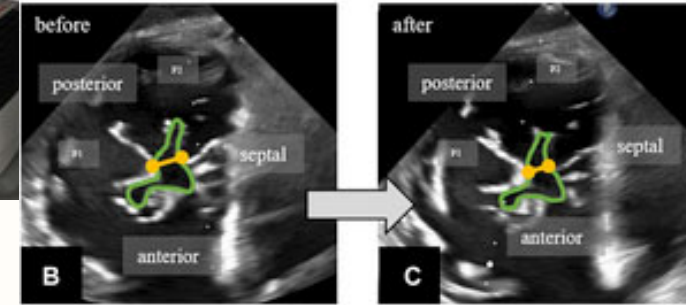
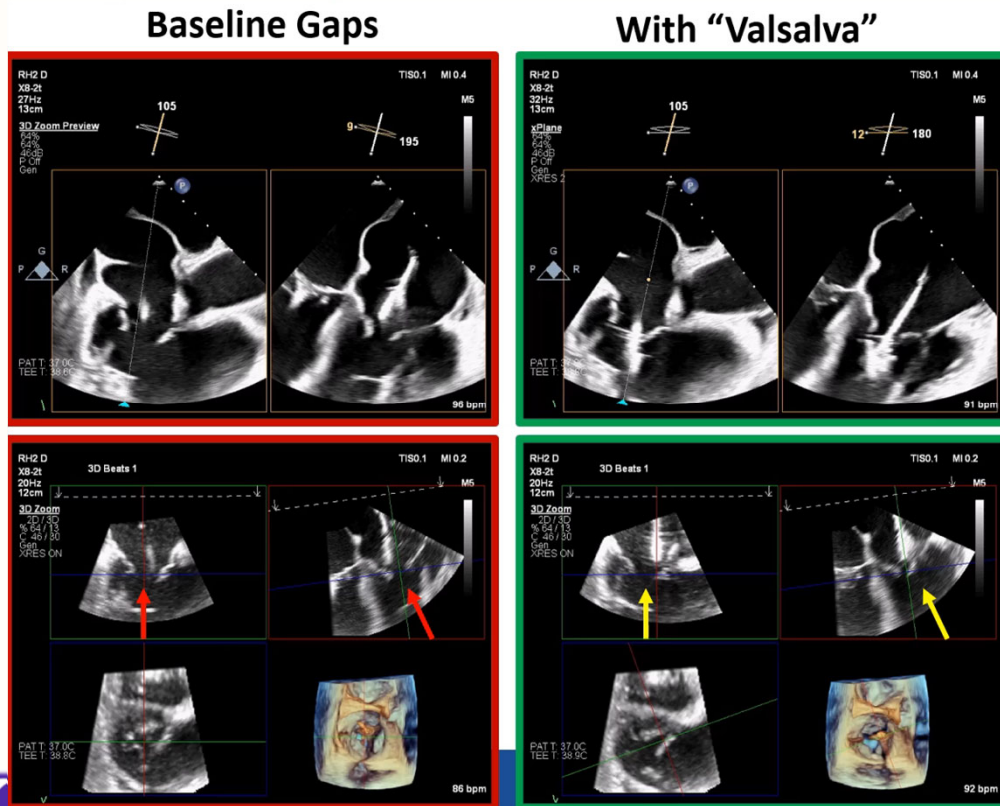


Right Shoulder Roll



Left Lateral Decubitus Position

Different from Manuevers to Reduce Gaps

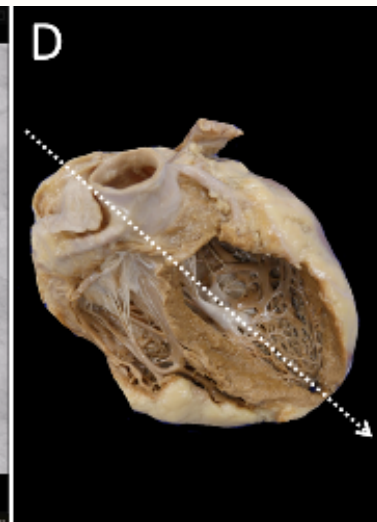
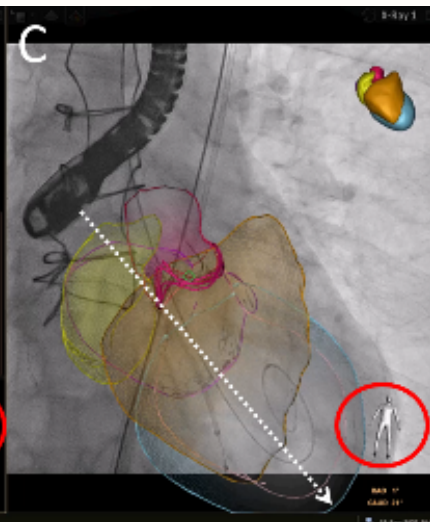
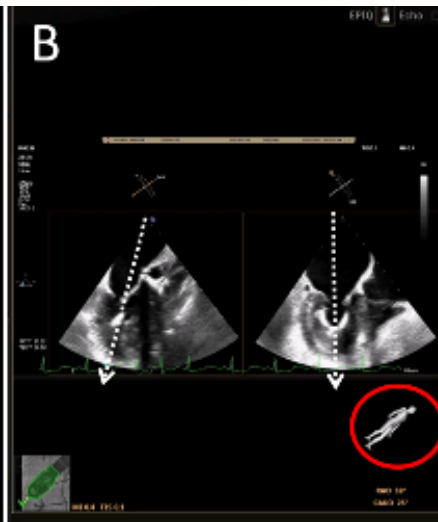
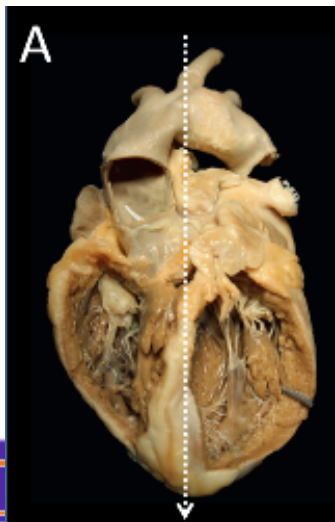
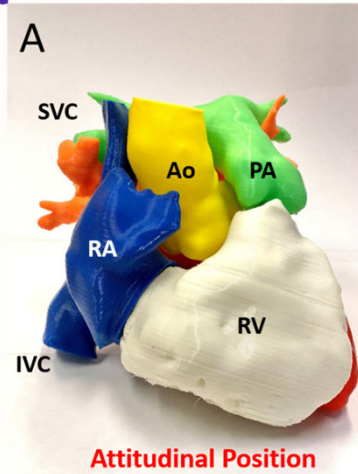
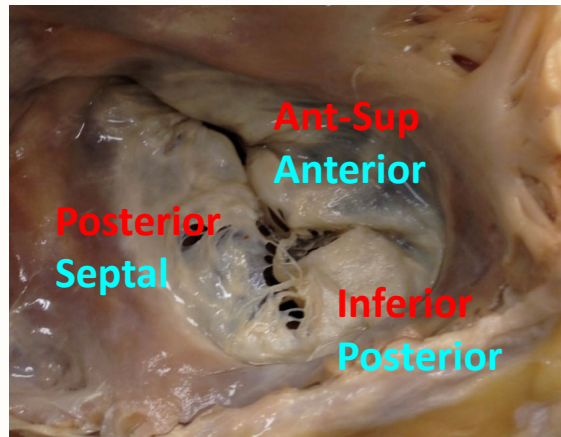
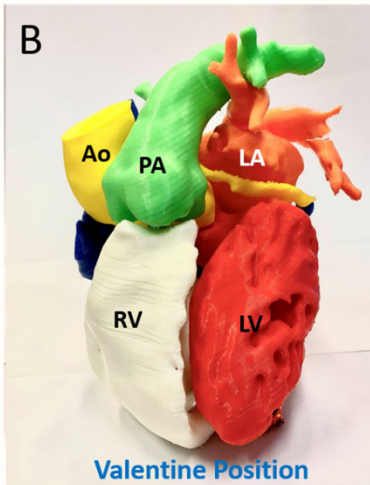


Godoy Rivas C, et al. JACC Case Rep. 2023 Apr 28;15:101850

Wild MG et al. J Am Coll Cardiol Intv. 2022 May, 15 (9) 1004–1006

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Echo-Fluoro Relationship

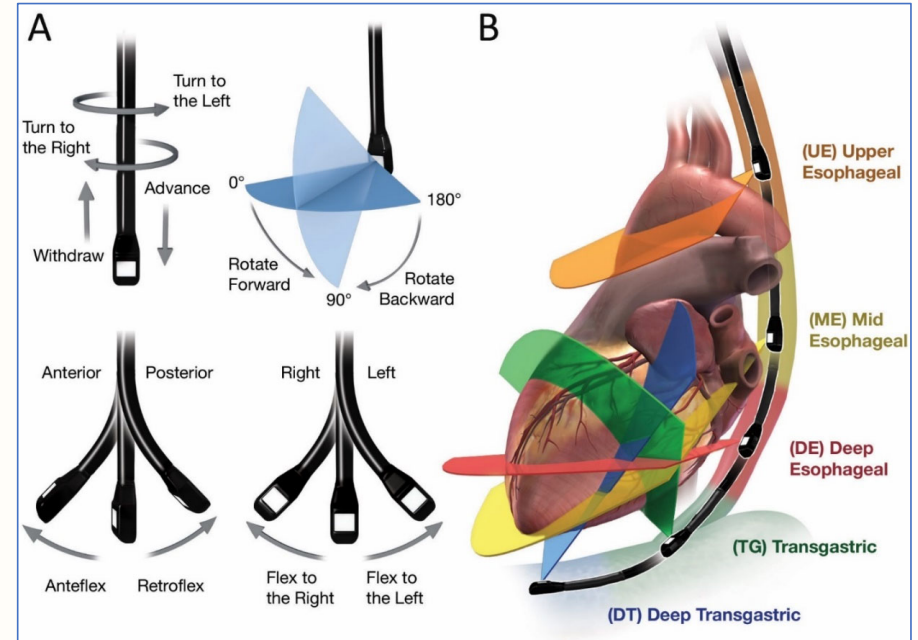


GUIDELINES AND STANDARDS

Recommended Standards for the Performance of Transesophageal Echocardiographic Screening for Structural Heart Intervention: From the American Society of Echocardiography

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Keywords: Transesophageal echocardiography, Structural heart disease



FIVE Probe Manipulations:

1. Advance/Withdraw
2. Rotate (CW/CCW)
3. Ante- & Retro-Flexion
4. Right & Left Flexion
5. Mechanical Rotation

FIVE Advanced 2D and 3D Modalities:

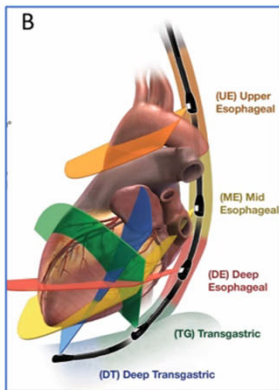
1. Simultaneous Multiplane
2. Real Time 3D, 3D MPR
3. Full Volume 3D
4. Zoom 3D
5. Color 3D

FIVE Levels of Imaging:

1. Upper Esophageal
2. Mid Esophageal
3. Deep Esophageal
4. Shallow Transgastric
5. Deep Transgastric



Lesson #2: Use all 4 Main Imaging Levels for the TV



Imaging Level: DE Inflow-Outflow View 60°

Acquisition Protocol:

- Imaging the TV in the center of the inflow sector. Inflow-outflow calculation is 180° made in the DE inflow-outflow view, also known as the TV centerline view.

| Planar Imaging | Volume Imaging | Functional Imaging |
|----------------|----------------|--------------------|
| | | |

Inflow-Outflow = Commissural

SWEEP of Septal Coaptation Line

Acquisition Protocol:

1. DE Inflow imaging (inflow view) may be particularly useful to assess and describe the commissural region.
2. Sweep DE Inflow view allows imaging of the valve area in DE inflow and a proximal aortic view (able to approach commissure).
3. DE Inflow imaging (inflow view) may be particularly useful to assess and describe the commissural region.
4. Sweep DE Inflow view allows imaging of the valve area in DE inflow and a proximal aortic view (able to approach commissure).
5. DE Inflow imaging (inflow view) may be particularly useful to assess and describe the commissural region.
6. Sweep DE Inflow view allows imaging of the valve area in DE inflow and a proximal aortic view (able to approach commissure).

Imaging Level: Deep Esophageal Views

Acquisition Protocol:

- Careful insertion of the TEE probe into the distal esophagus brings the probe closer to the tricuspid annulus. Frequently there is no left atrium seen, and only the RA and coronary sinus with the orthogonal view imaging the RV outflow tract.

| Planar Imaging | Volume Imaging | Functional Imaging |
|----------------|----------------|--------------------|
| | | |

Acquisition Protocol:

1. From deep esophageal imaging planes (over the diaphragm), left heart structures may be avoided, because imaging in these diaphragm often the anterior and posterior leaflets are seen.
2. Inflow imaging shows the deep esophageal inflow-outflow view in the orthogonal plane.
3. Real time multiplanar reconstruction (MPR) allows for rapid re-orientation of the 2 orthogonal long-axis views using the short-axis and 3D surface view for orientation.
4. Off-line MPR can be used to measure the tricuspid annulus (area, perimeter and dimension) at any point in the cardiac cycle.
5. Right ventricular (RV) function should be assessed by the guideline-recommended methods (e.g., Teich, fractional area change) or newer methods (strain imaging).
6. Quantitative Doppler and 3D vena contracta area should be performed.

Imaging Level: Transgastric

Acquisition Protocol:

- With both left and right flexion and rotating the probe clockwise to center the TV in the imaging plane, a two-chamber inflow-outflow view of the right heart is obtained.

| Planar Imaging | Volume Imaging | Functional Imaging |
|----------------|----------------|--------------------|
| | | |

Transgastric 20-60°

Acquisition Protocol:

1. From the TG level of anatomical orientation, with right and left flexion, the inflow-outflow view of the right heart can be imaged. Rotate imaging the orthogonal plane of the TV of the heart can be performed.
2. DE Inflow-Outflow imaging (inflow view) may be particularly useful to assess and describe the commissural region.
3. Sweep DE Inflow view allows imaging of the valve area in DE inflow and a proximal aortic view (able to approach commissure).
4. DE Inflow imaging (inflow view) may be particularly useful to assess and describe the commissural region.
5. Sweep DE Inflow view allows imaging of the valve area in DE inflow and a proximal aortic view (able to approach commissure).

3D Vena Contracta Area

Acquisition Protocol:

1. Color Doppler imaging of the tricuspid valve (TV) can be used to identify the location and shape of the regurgitant jet.
2. The location of the TV can be used to identify the regurgitant jet.
3. The location of the TV can be used to identify the regurgitant jet.

Surgorin's View

Interventionalist's View

Transgastric View

Imaging Level: Deep Transgastric

Acquisition Protocol:

- Advancing the TEE probe further into the stomach along with rightward anterior flexion produces a deep transgastric (DT) view of the TV, which frequently can be used to assess TV function using Doppler parameters.

| Planar Imaging | Volume Imaging | Functional Imaging |
|----------------|----------------|--------------------|
| | | |

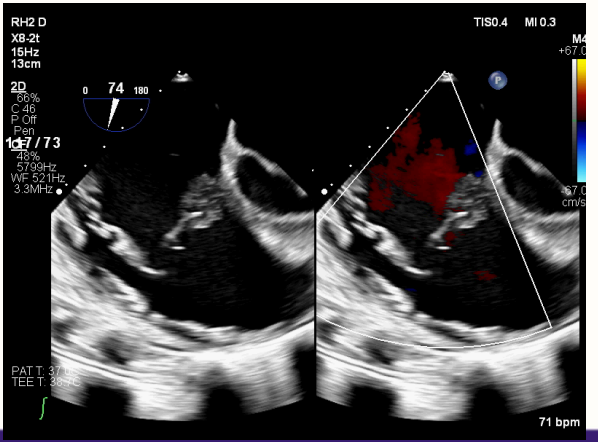
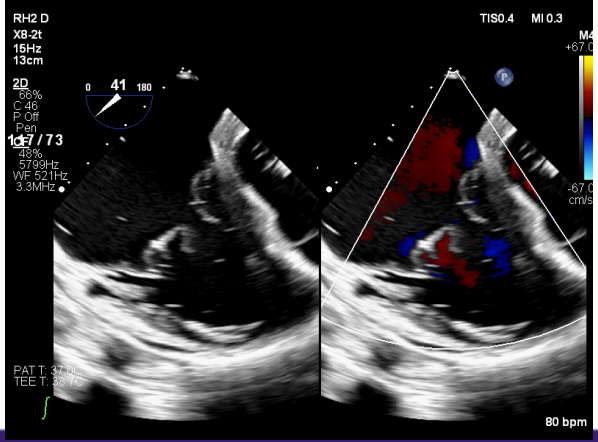
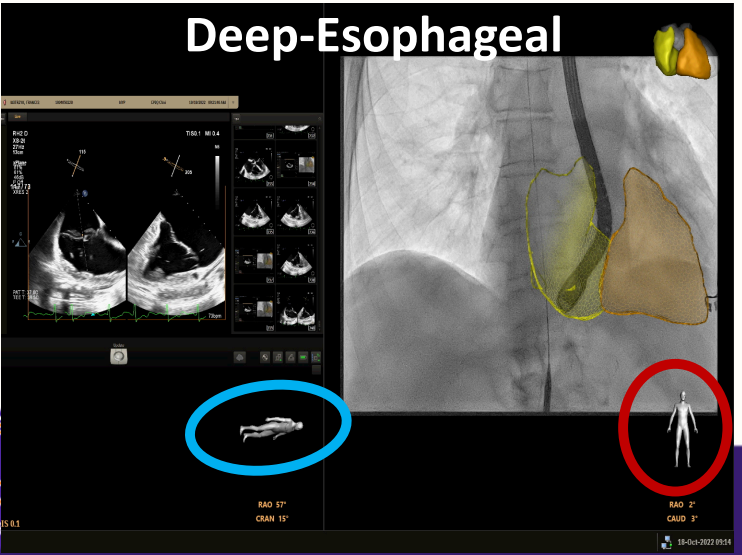
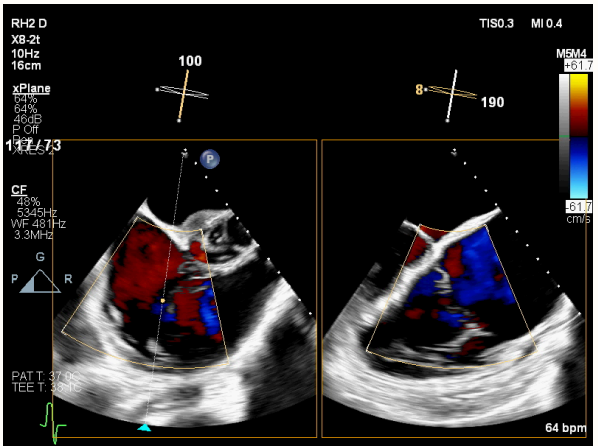
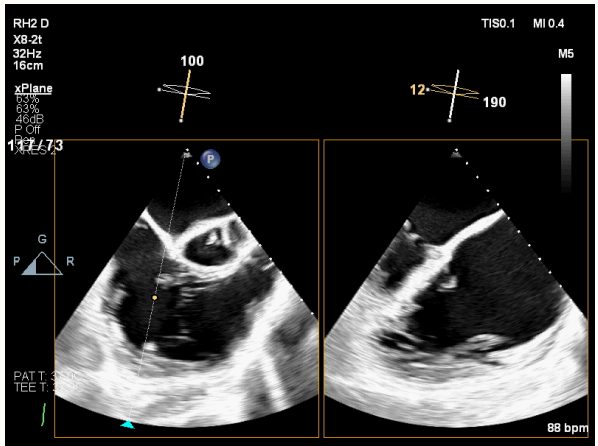
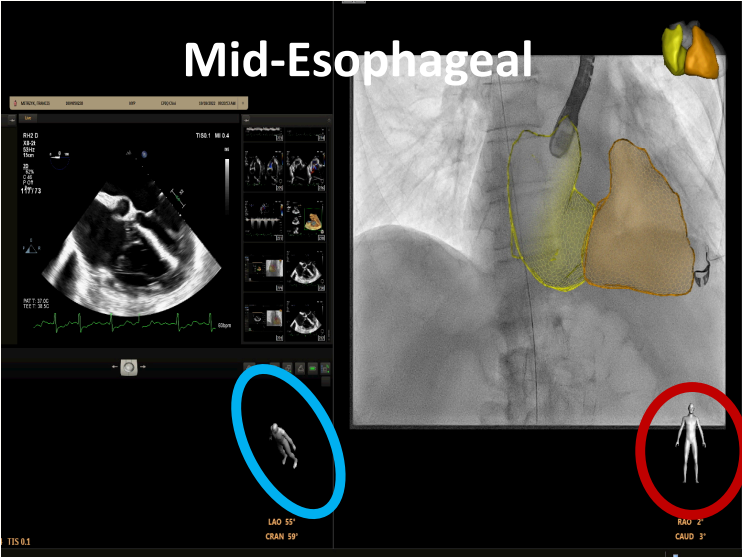
Sweep of Annulus

Acquisition Protocol:

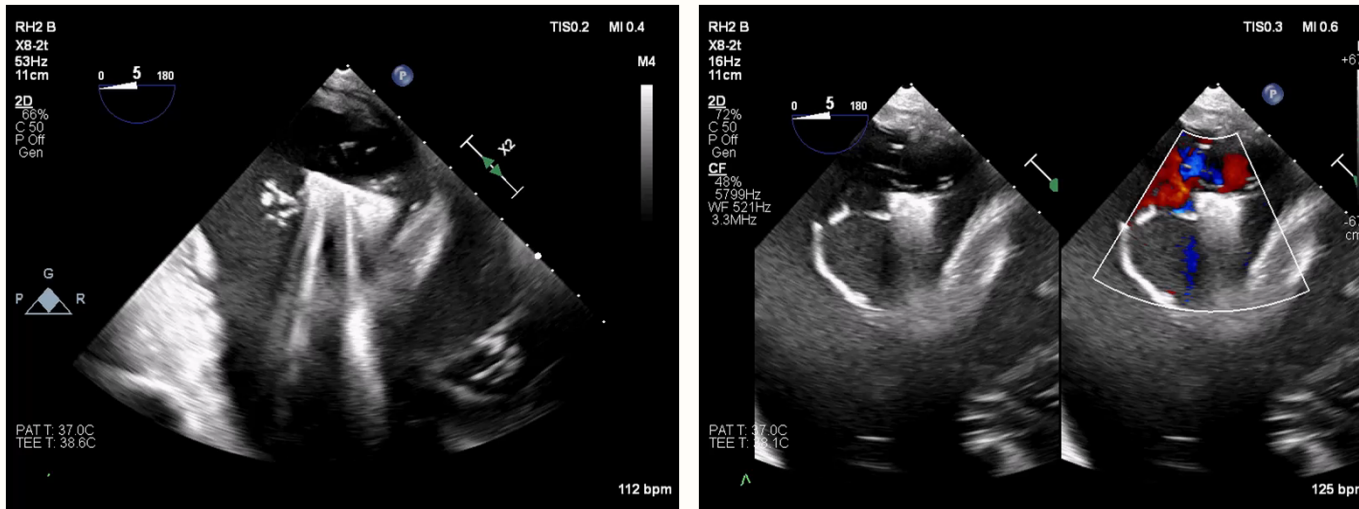
1. From the DT position, the probe is repositioned to the right ventricle with the tricuspid annulus more perpendicular to the ultrasound beam. In this example of a patient with rheumatic tricuspid stenosis, prominent doming of the leaflets is seen in diastole.
2. (DT) the ultrasound beam aligned with flow, a comprehensive Doppler assessment can be made.
3. The DT view can be used to acquire three-dimensional Doppler calculations of diastolic annular volume.
4. MPR is used to identify the tricuspid orifice area at the top of the leaflets (blue box).
5. PW Doppler at the annulus is used to perform quantitative Doppler calculations of diastolic annular volume.
6. The most complete and highest resolution Doppler velocities may be obtained from these views.
7. From any well-imaged 3D volume, quantitative assessments of annular or annular area can be made using on-line or off-line measurement tools. In this example of tricuspid stenosis, the area is significantly reduced.

Hahn, RT et al. J Am Soc Echocardiogr. 2022 Jan;35(1):1-76.

Mid & Deep Esophageal Views

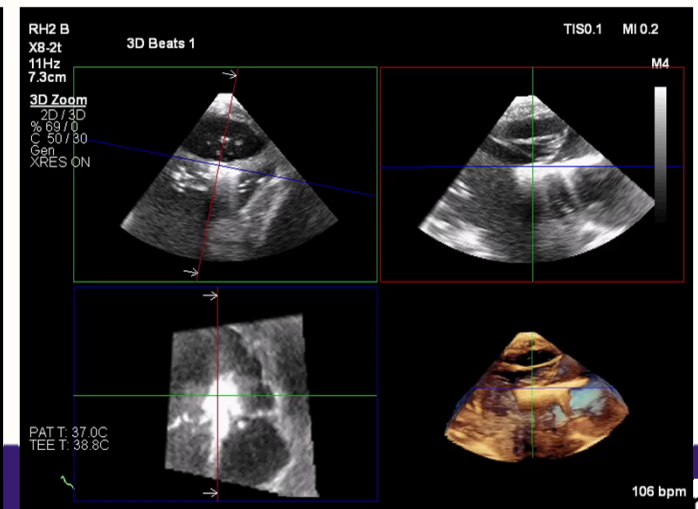
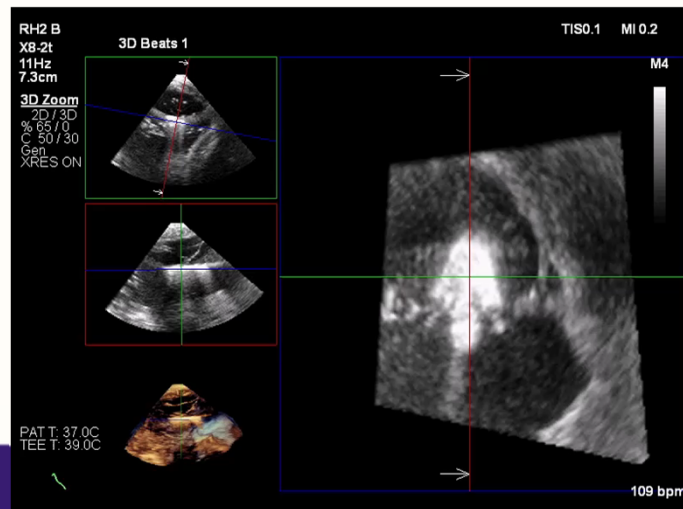


Transgastric Views

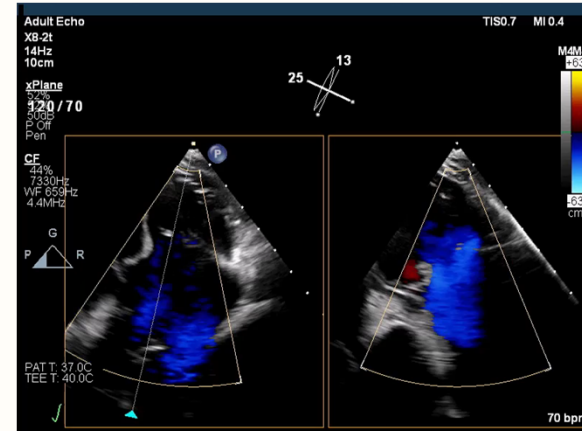
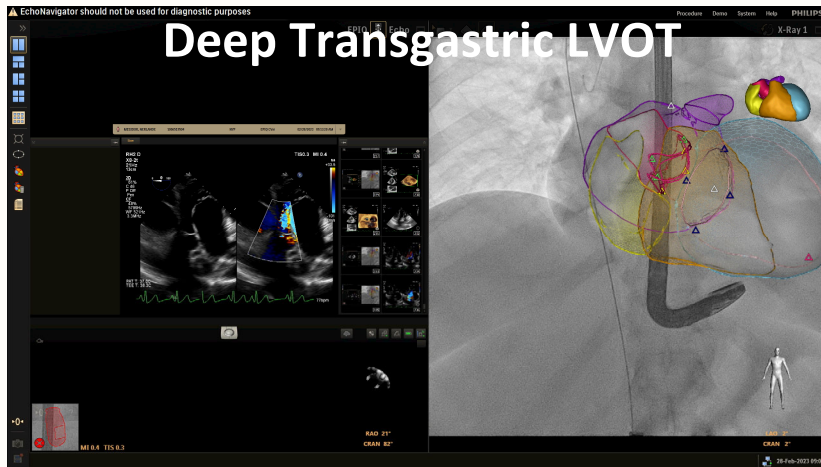


Grasping and closure from TG View:
Limitation is failure to document length of leaflet capture

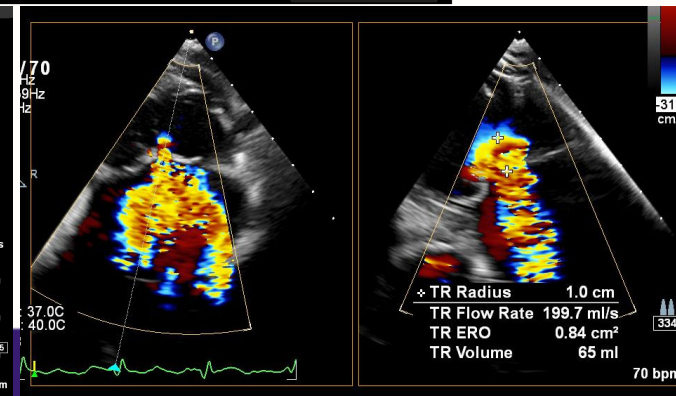
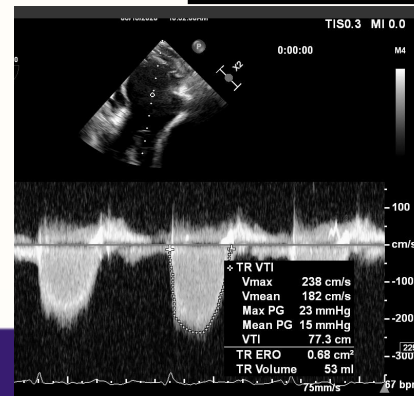
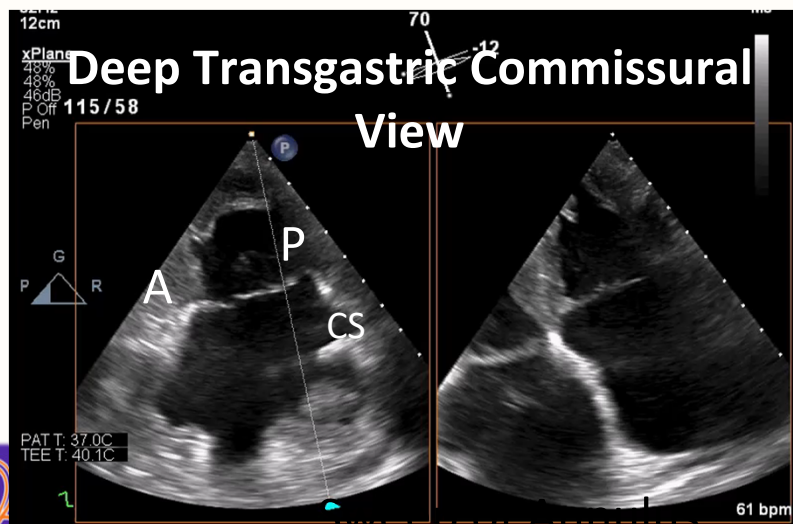
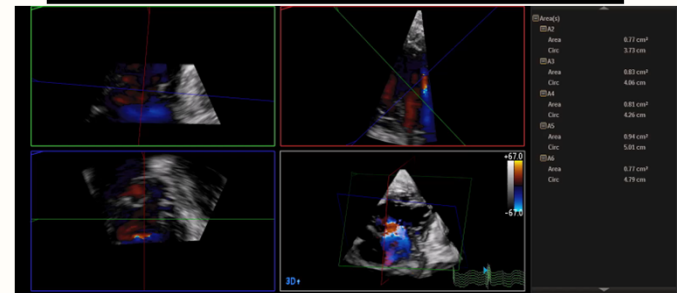
3D reconstruction of leaflets allows for measurement of residual leaflet lengths



Deep Transgastric

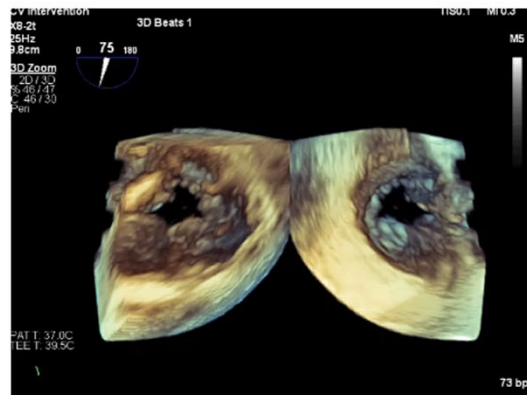


Doppler aligned with insonation beam

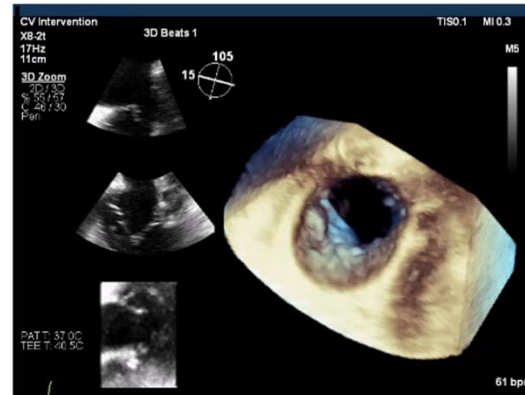


Lesson #3: Three-dimensional imaging is essential

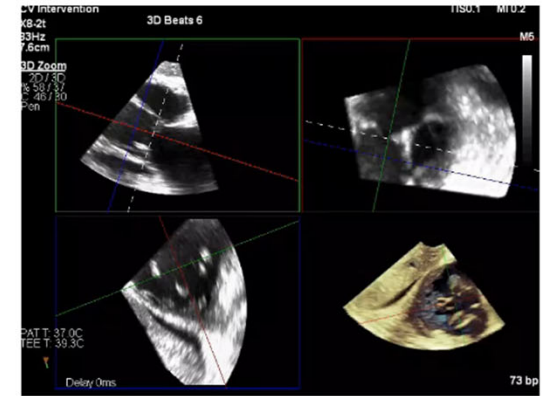
Mid-Esophageal



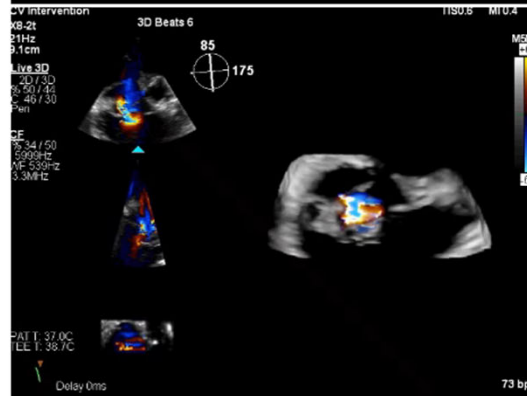
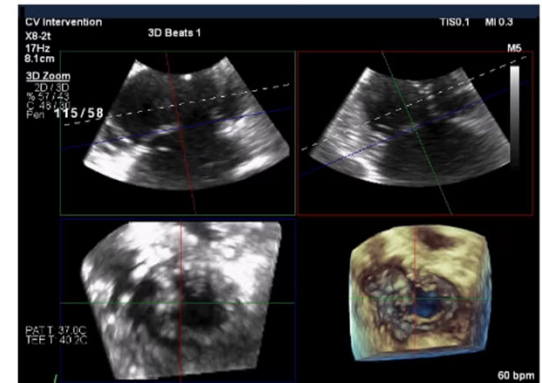
Distal Esophageal



Shallow Transgastric



Deep Transgastric



NEW 3D TOOLS FOR INTERVENTIONAL IMAGING

1. Biplane Imaging

- Tilt plane rotate
- Biplane Mechanical Rotate

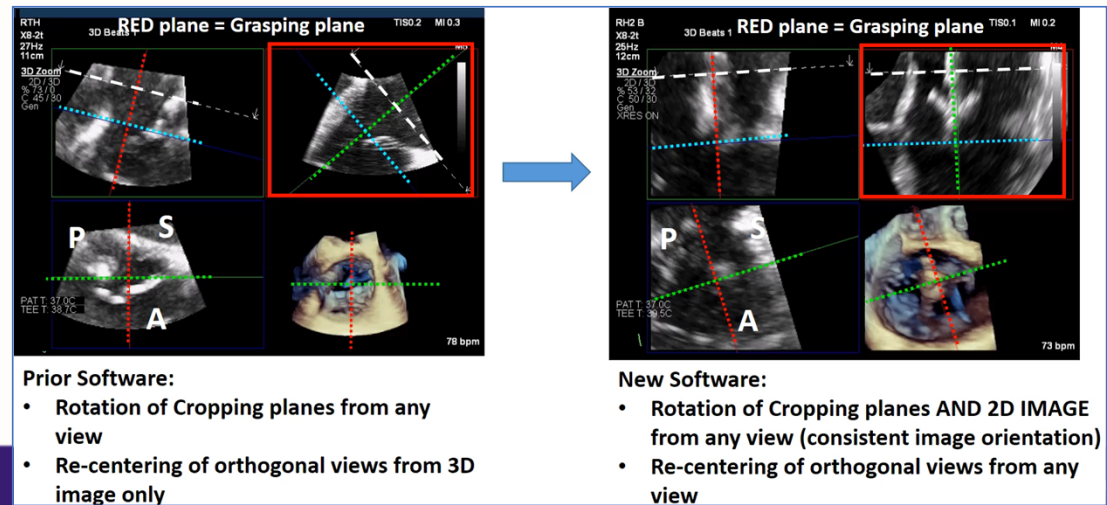
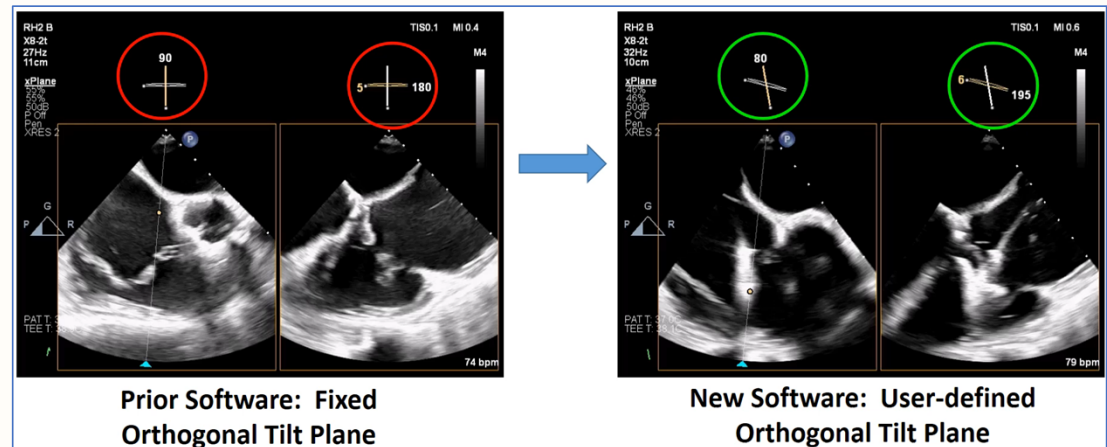
2. Live 3D Multiplanar Reconstruction

- 2D and 3D plane rotate

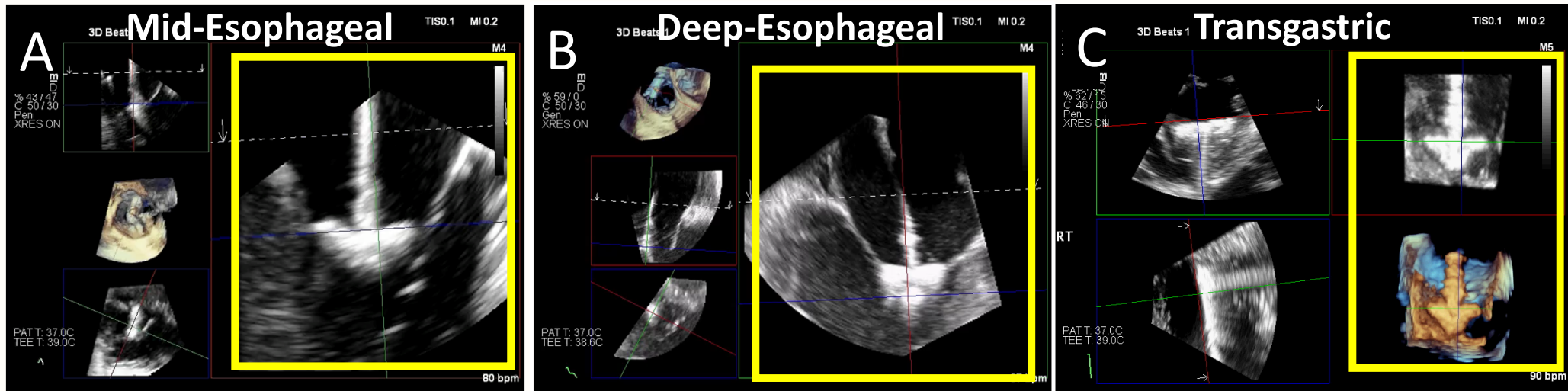
3. New Display Tools: tomographic imaging and others

4. New Rendering Tools

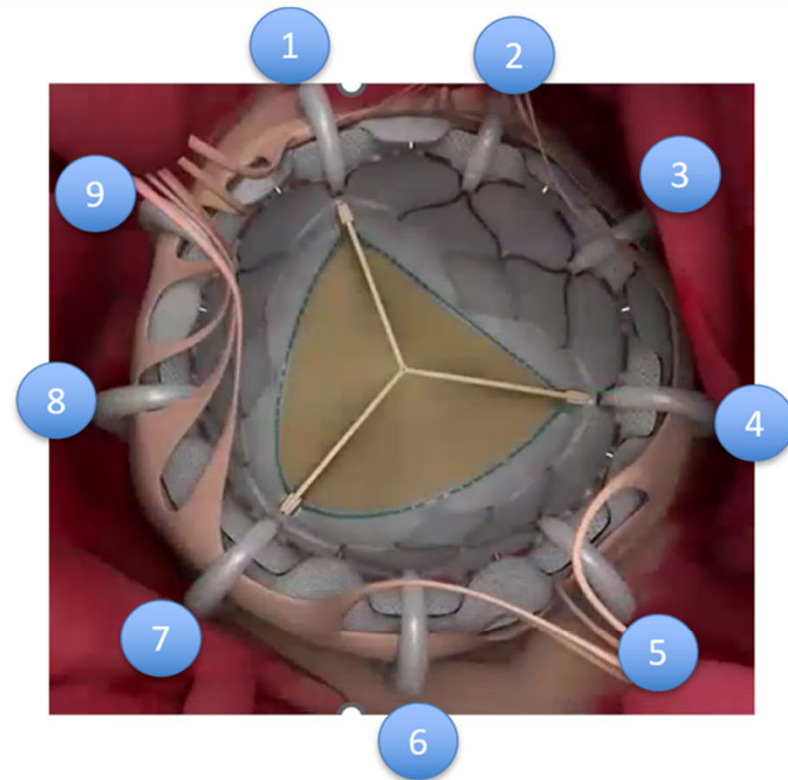
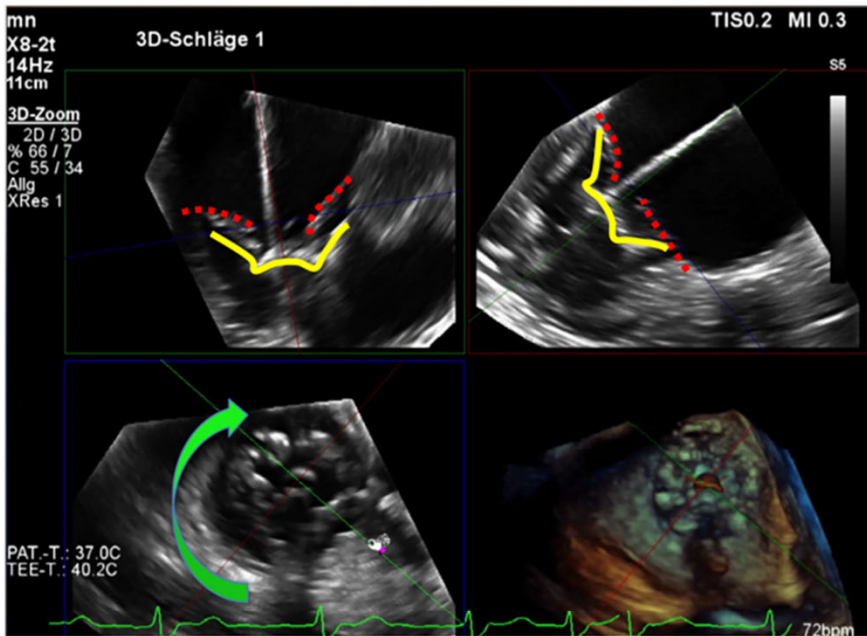
- TrueVue
- GlassVue



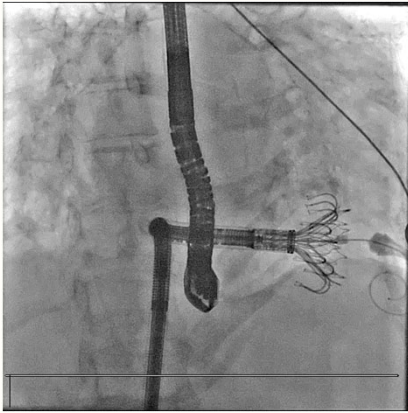
Three-dimensional Reconstruction from ANY Imaging Level



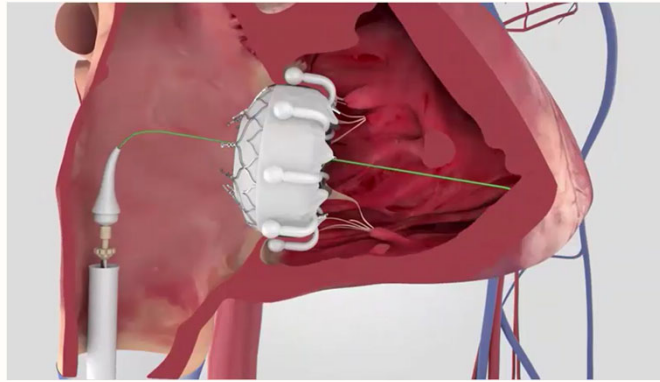
TTVR: Goals of Multi-planar Reconstruction



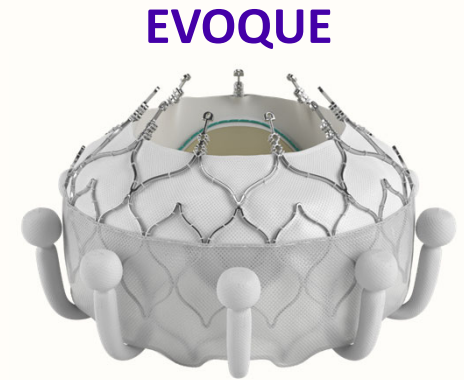
- **Multi-planar Reconstruction Used to:**
 - Identify all Nine Anchors
 - Confirm “coaxiality” with annulus with anchors below the annulus
 - Confirm all Leaflets captured (noting location of commissures)



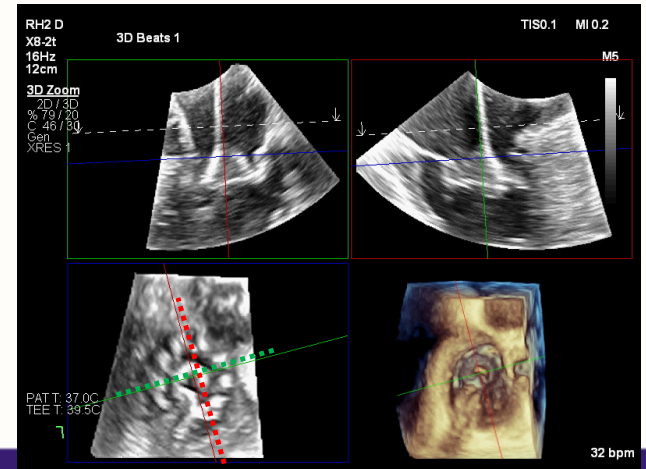
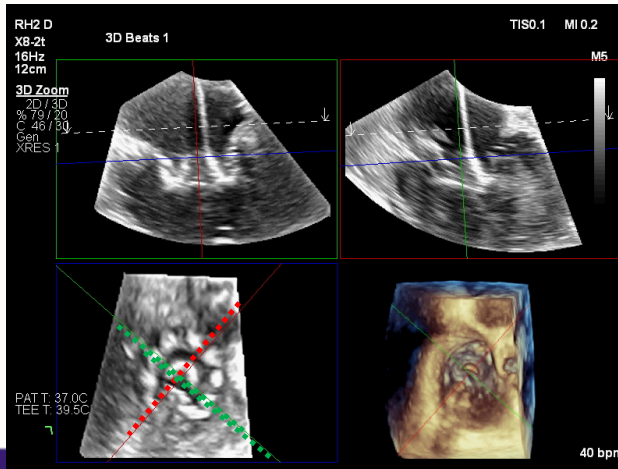
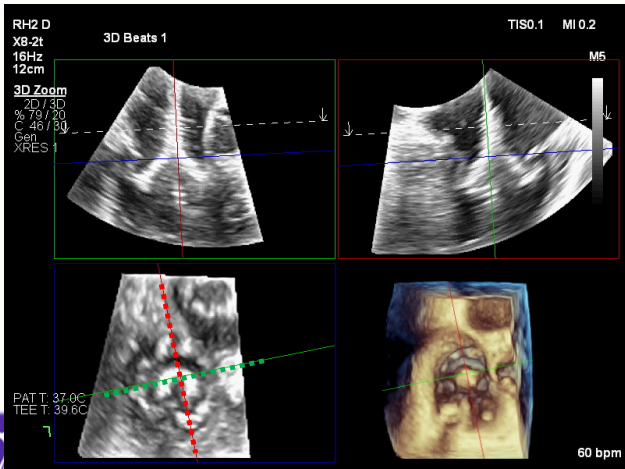
Ventricular Expansion of DEVICE—Inflection Point (MPR Spin)



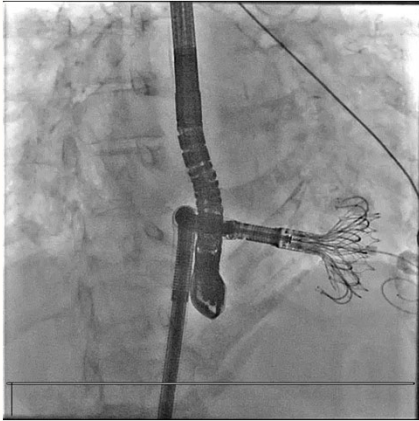
Rotation of MPR (visualize all 9 anchors)



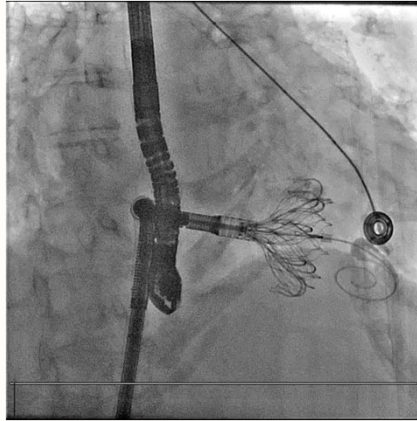
Rotation of MPR



MPR "Spin"



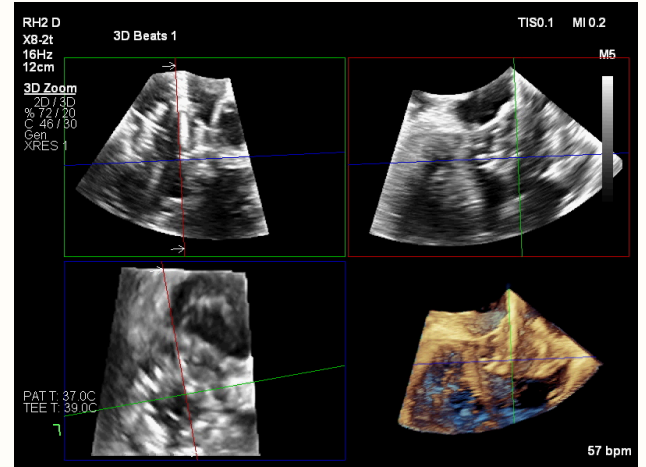
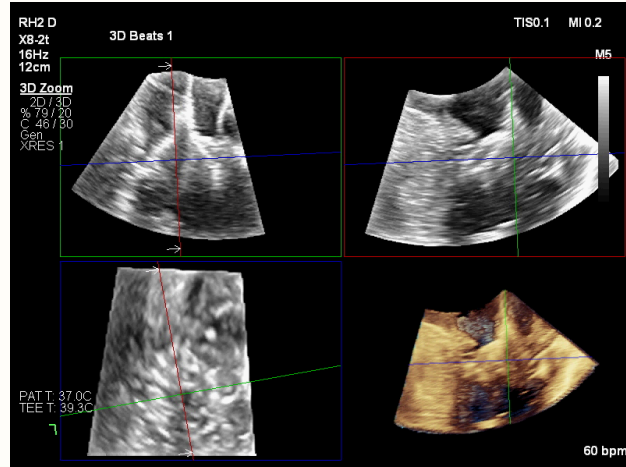
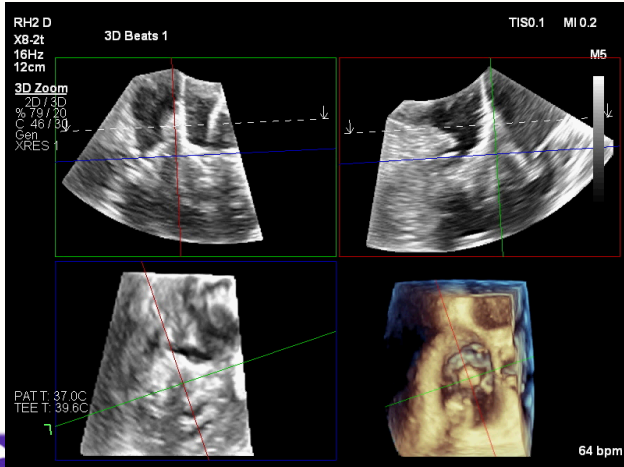
Full Ventricular Expansion of DEVICE



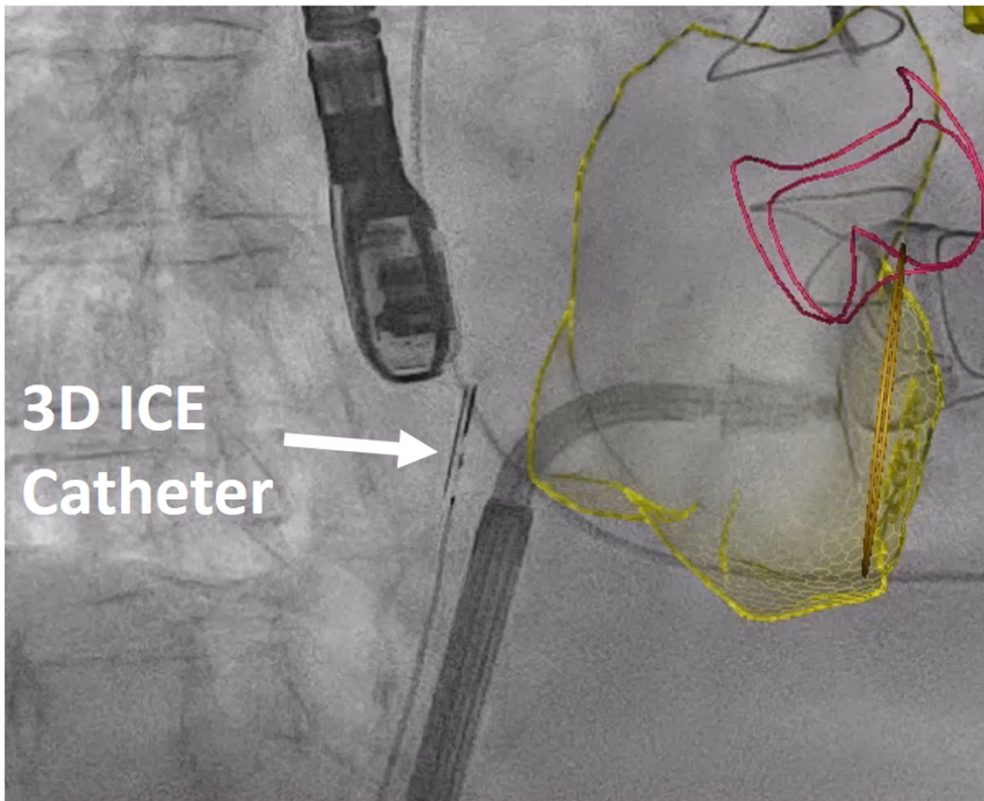
Atrial Expansion and Device Release



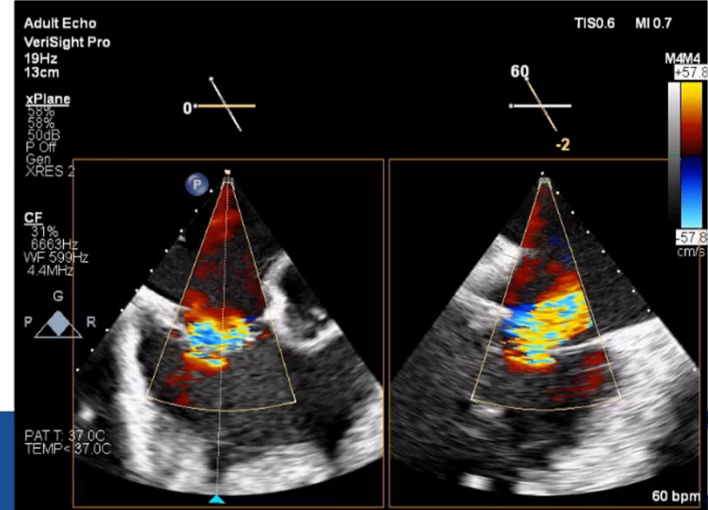
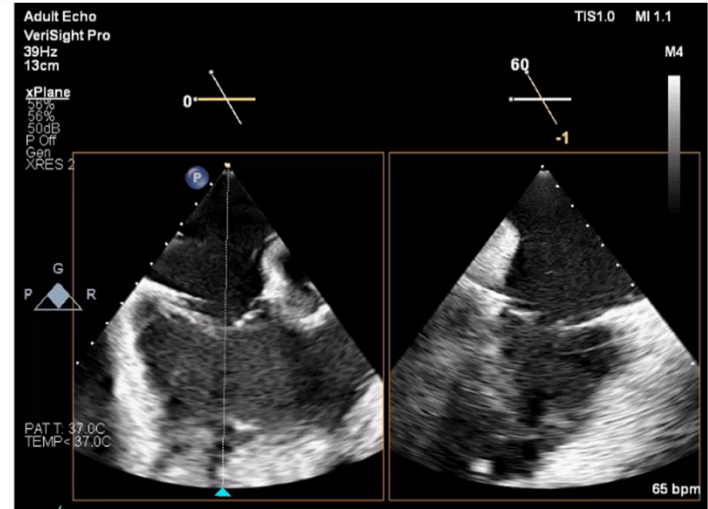
Final EVOQUE and Nosecone retraction



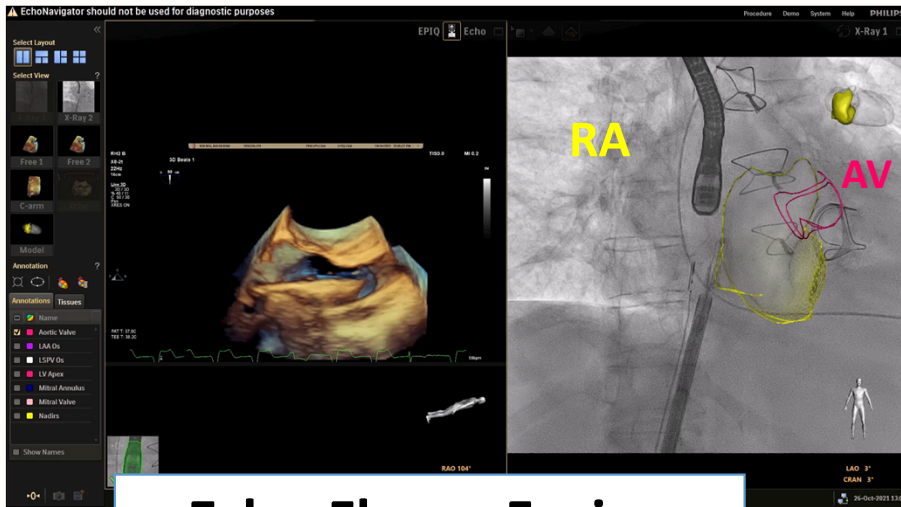
Lesson #4: New Imaging Modalities



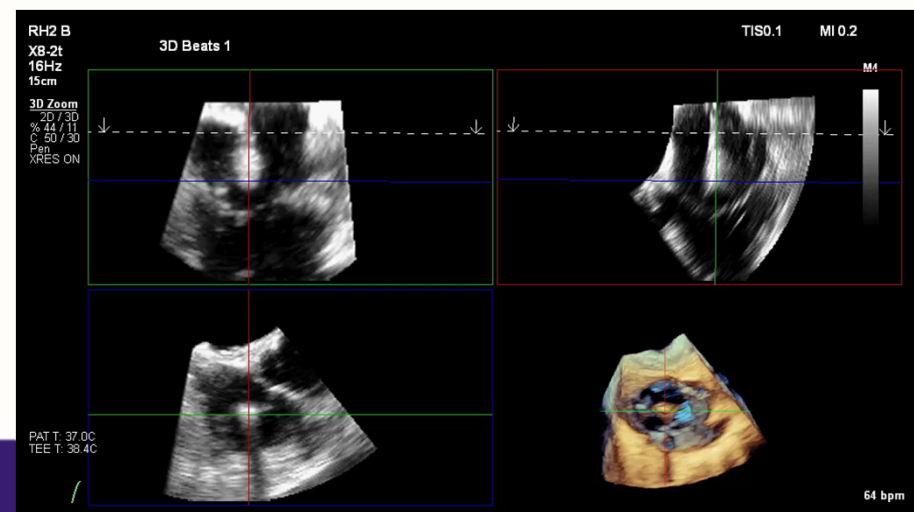
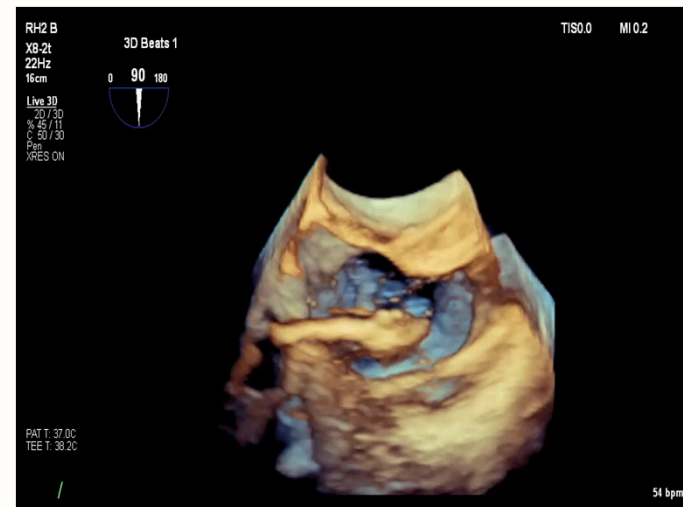
Three-dimensional Intracardiac Echocardiography



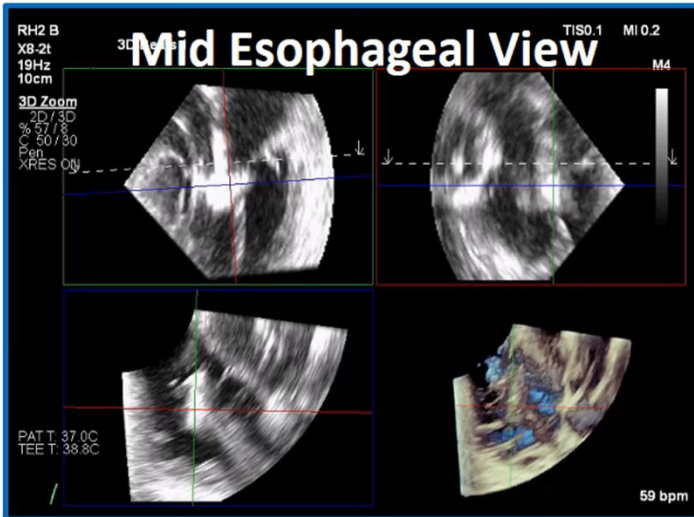
TEE: Introducing device and steering down to TA



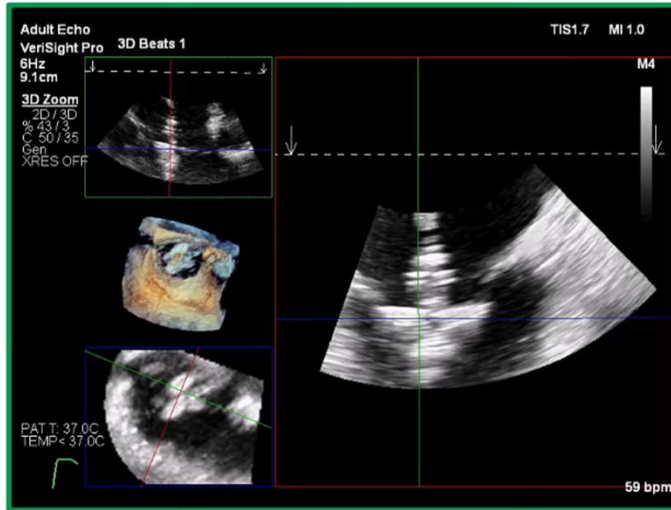
Echo-Fluoro Fusion



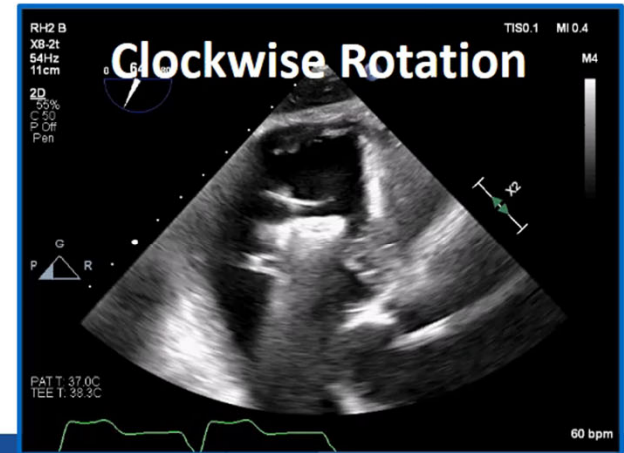
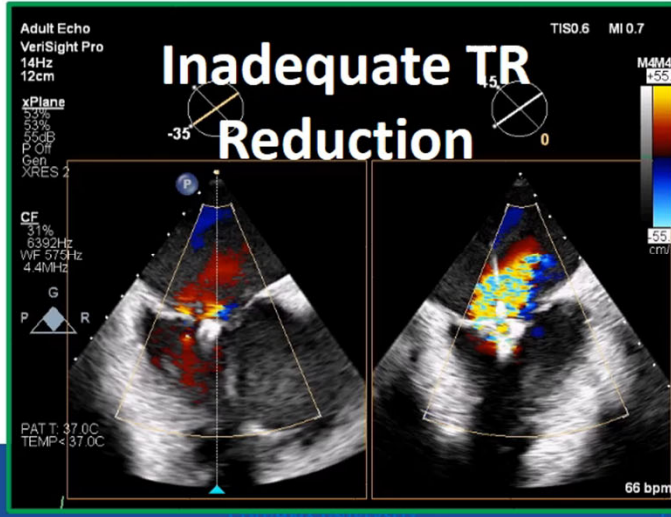
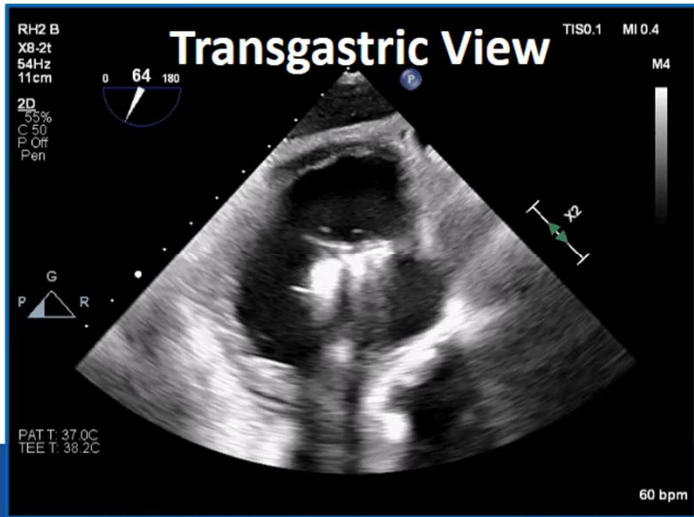
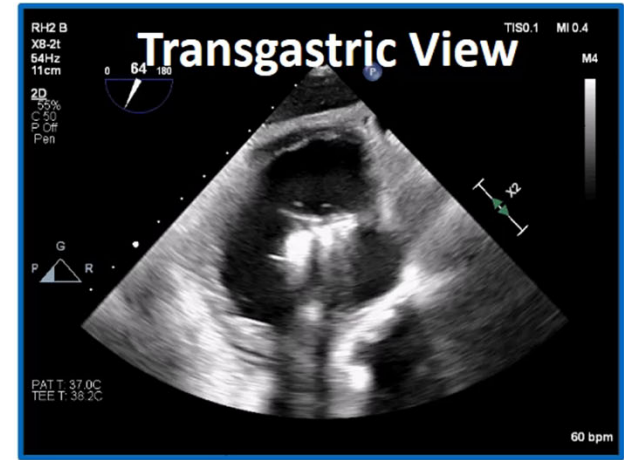
TEE: Orienting Device



ICE Leaflet Grasp

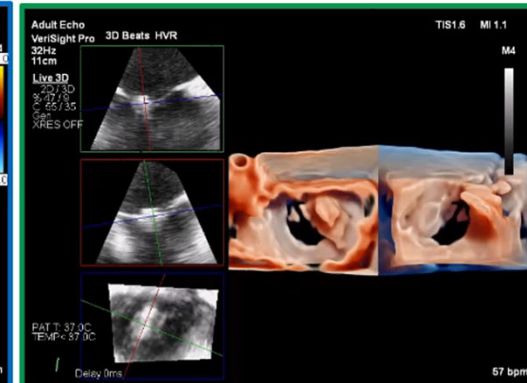
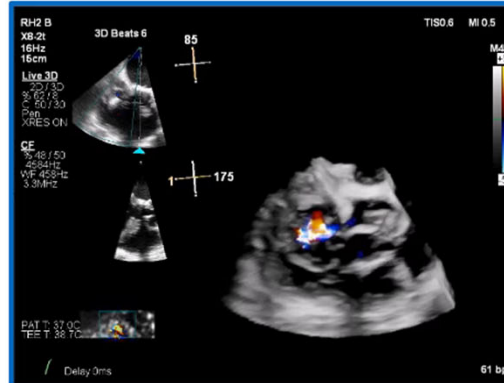
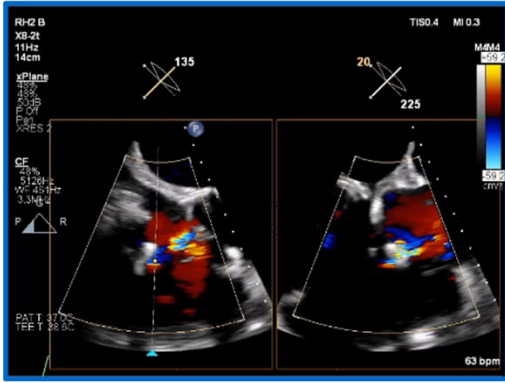
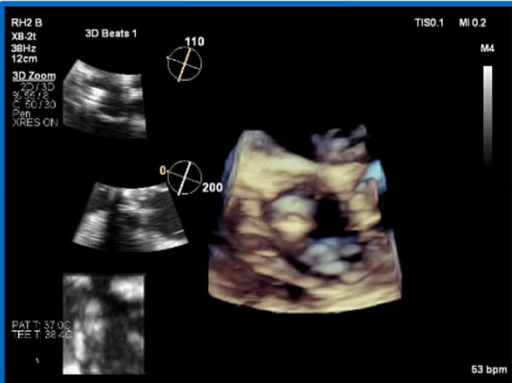
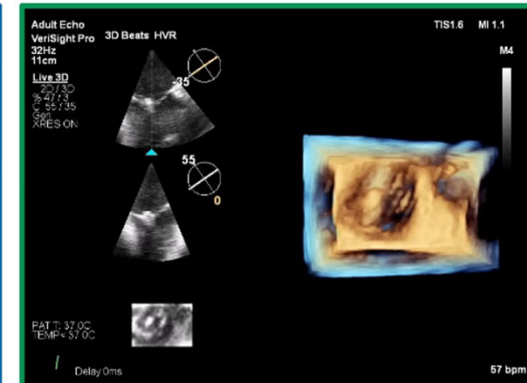
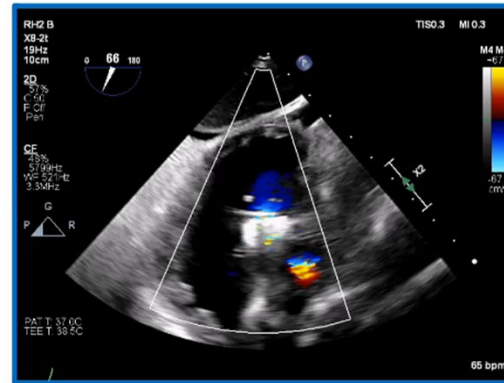
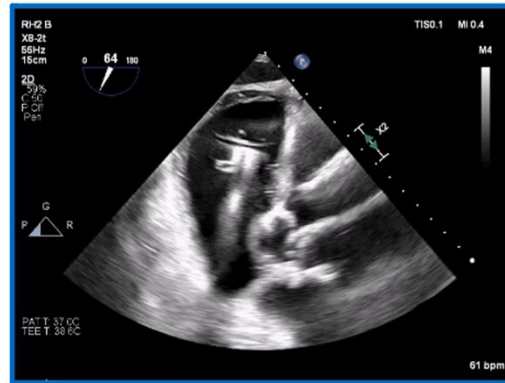
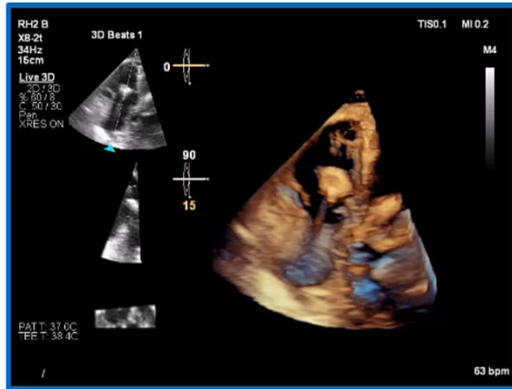


TEE: Re-Orienting Device



TEE FINAL T-TEER

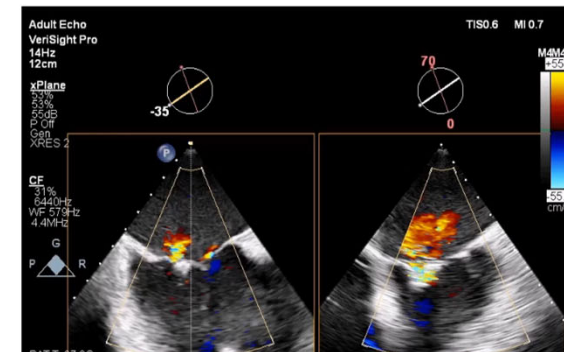
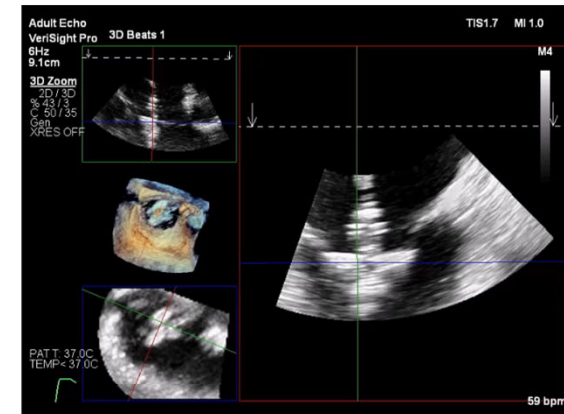
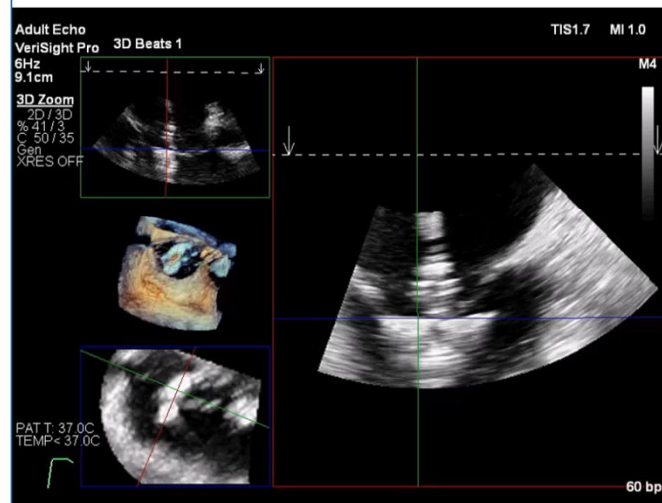
ICE FINAL T-TEER



Intracardiac Echo (ICE) for T-TEER

- In some patients, imaging will be poor despite various tricks
- Important to not deploy device without clear verification of capture
- 4D ICE will be a “game changer” and facilitate TEER

ICE Leaflet Grasp



The Future of Intraprocedural Imaging

Philips Next-Generation TEE / ICE Imaging

35% smaller
tip diameter vs.
X8-2t

| Transducer | X8-2t | X11-4t TEE* | S7-3t Mini | S8-3t Micro | VeriSight Pro ICE |
|--------------------|-----------------|-------------------|-------------|----------------------|-------------------|
| Main imaging modes | 2D, 3D, Biplane | 2D, 3D, Biplane | 2D | 2D | 2D, 3D, Biplane |
| Tech / elements | Matrix 2500 | Matrix 2500 | Standard 48 | Standard 32 | Matrix 840 |
| Frequency | 8-2 MHz | 11-4 MHz | 7-3 MHz | 8-3 MHz | 10-4 MHz |
| Indication | Adult | Adult & Pediatric | Pediatric | Pediatric (neonatal) | Adult |
| Weight range | > 30 kg | > 5 kg | > 3.5 kg | > 2.5 kg | NA |

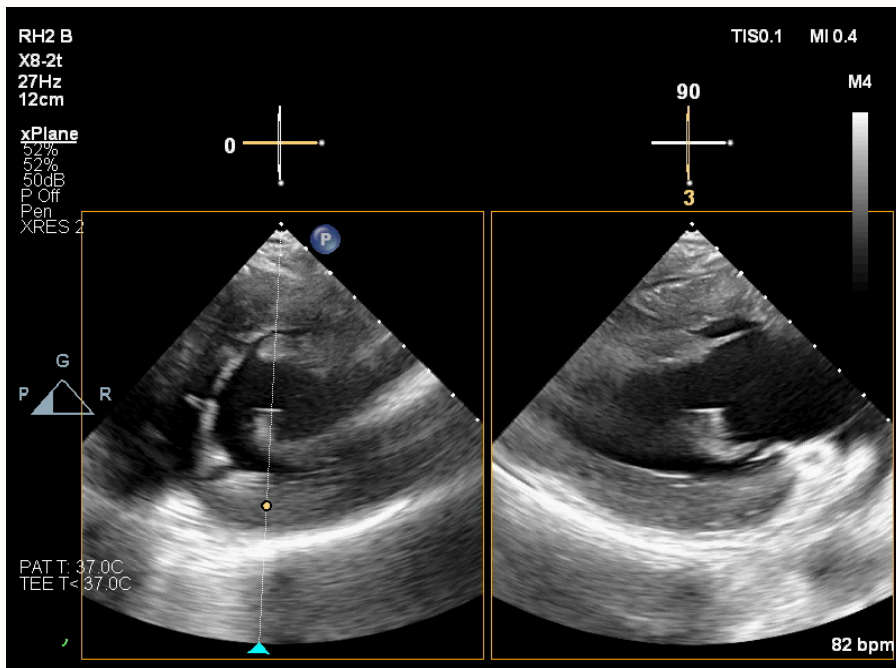


Dimensions not to scale

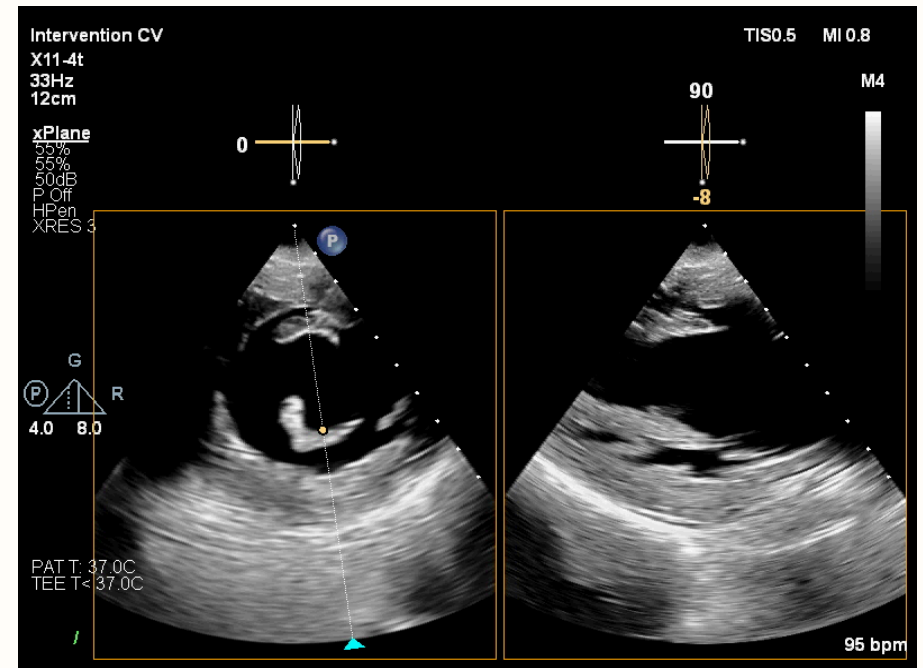
X11-4t TEE is FDA 510(k) pending and not available for sale.

Which image is generated by the Mini-TEE

X8-2t



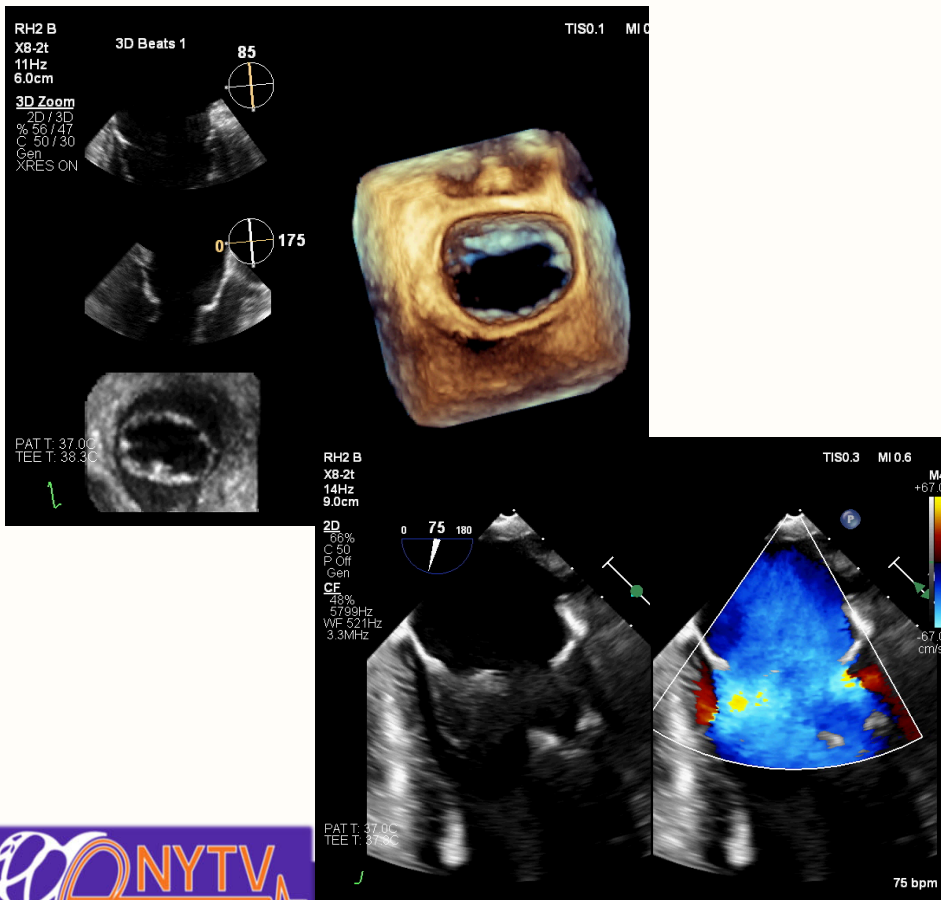
X11-4t



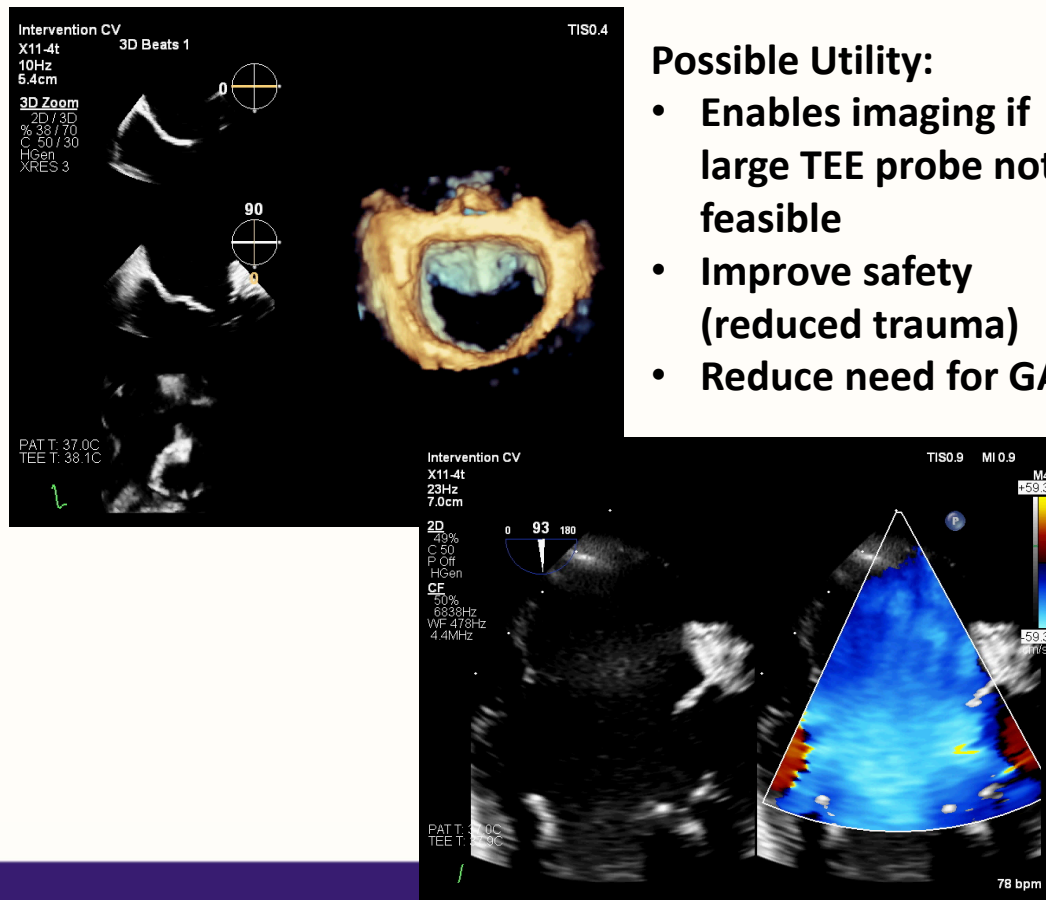
X11-4t TEE is FDA 510(k) submitted and not available for sale.

Next Generation TEE

X8-2t



X11-4t



- Possible Utility:**
- Enables imaging if large TEE probe not feasible
 - Improve safety (reduced trauma)
 - Reduce need for GA

X11-4t TEE is FDA 510(k) submitted and not available for sale.

HOLOSCOPE™ 

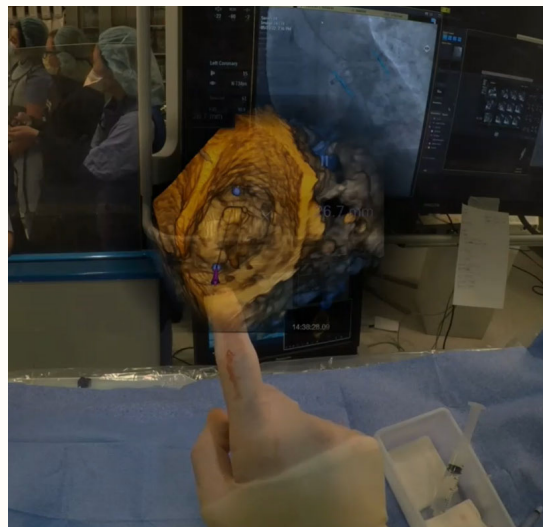
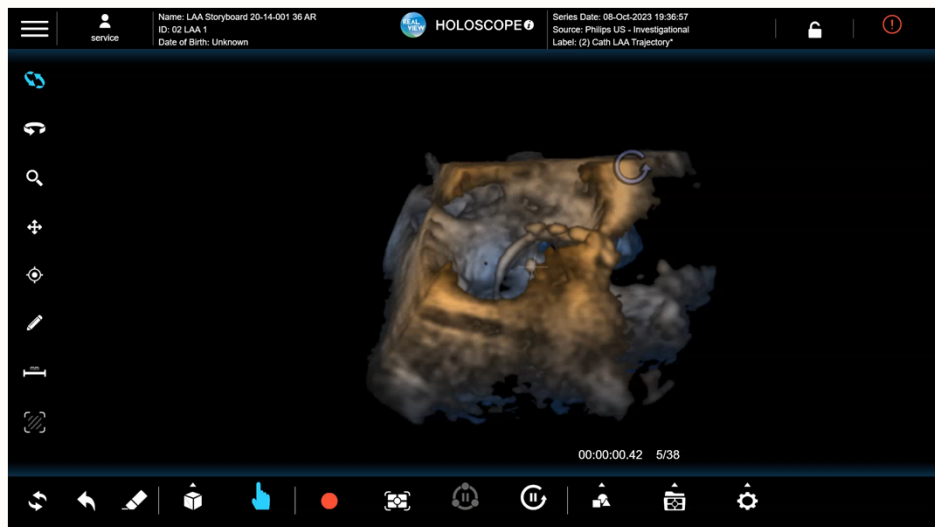
 **NewYork-Presbyterian**
The University Hospital of Columbia and Cornell

- First Clinical Use in the US



HOLOSCOPE™ - Clinical Use Case: LAAO

NewYork-Presbyterian
The University Hospital of Columbia and Cornell

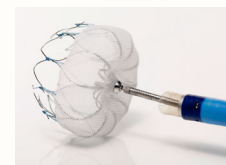


Procedure-specific added values:

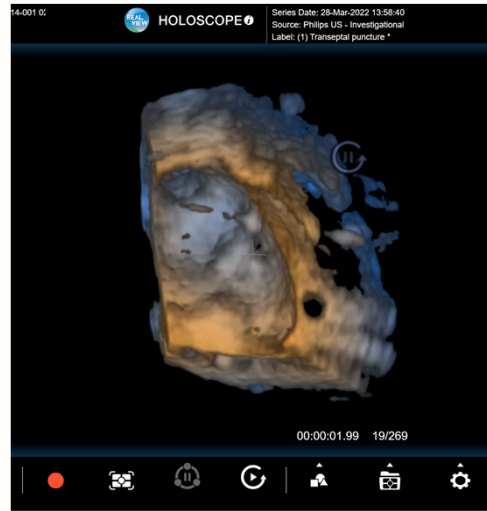
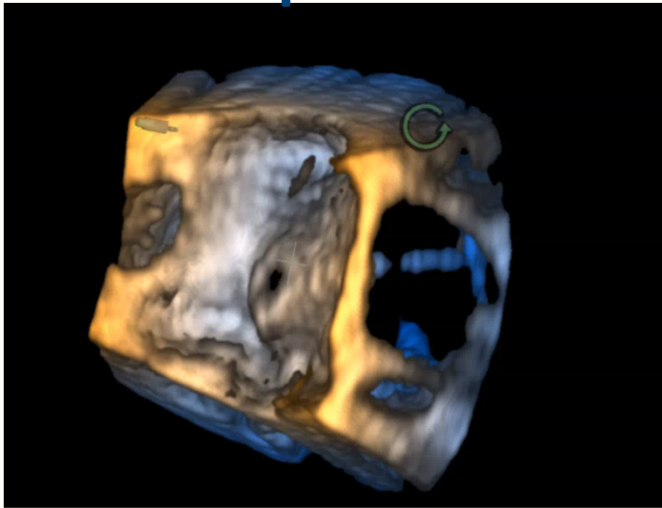
- Accurate intra-procedure 3D holographic assessment of LAA orifice diameter and shape (based on CT and 3D Echo)
- Optimal execution of transeptal puncture location and trajectory
- Holography guided sheath alignment to LAA
- Pre-release device evaluation (size, compression, location, angulation, tug test)

Impressions:

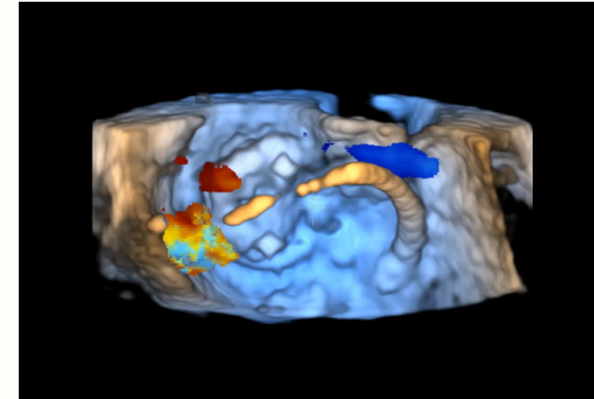
- *“Watchman is clearly sitting well, requiring less 360-degree ultrasound review that takes time”*
- *“There is no parallax error while using the hologram, allowing for the first time to easily make accurate measurement directly on the 3D data”*
- *“I see significant potential for fluoro reduction by using this system”*



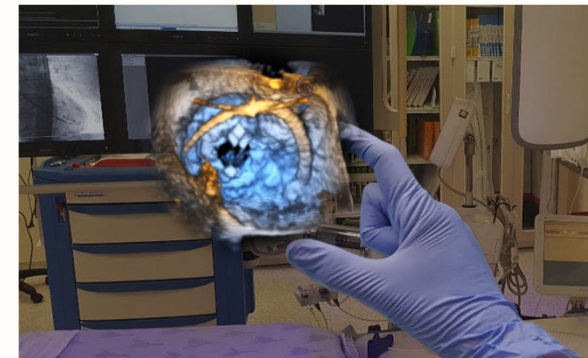
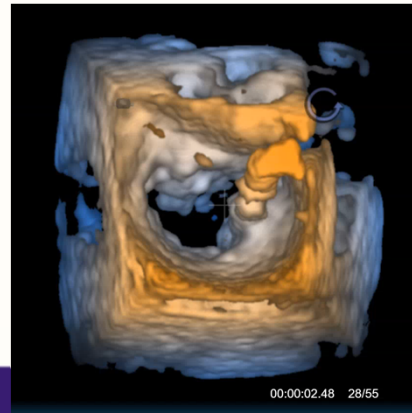
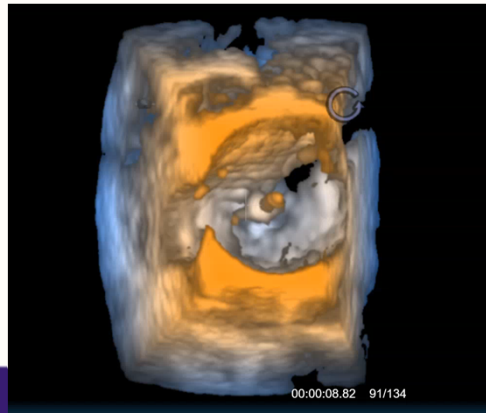
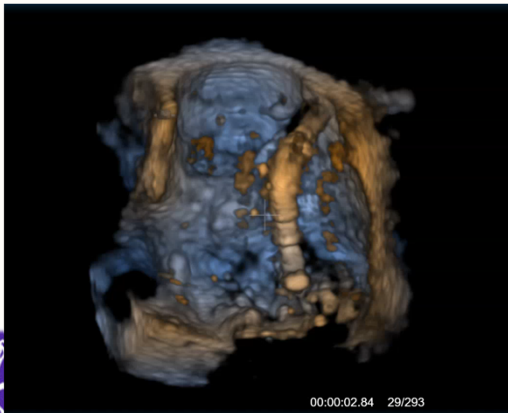
Transseptal Puncture



Paravalvular Leaks (PVL) Closure



Mitral TEER



Overcoming the challenges of intra-procedural imaging for TV interventions

- Use positioning (and other tools) to enhance imaging
 - Use all 4 Main Imaging Levels for the TV
 - Use ALL Three-dimensional TEE Tools
 - Use 3D ICE when TEE imaging is Limited
-
- EMBRACE THE FUTURE!!!

