



Applications of 3D Echo Imaging: A Case-Based Approach

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DISCLOSURE

Relevant Financial Relationship(s)

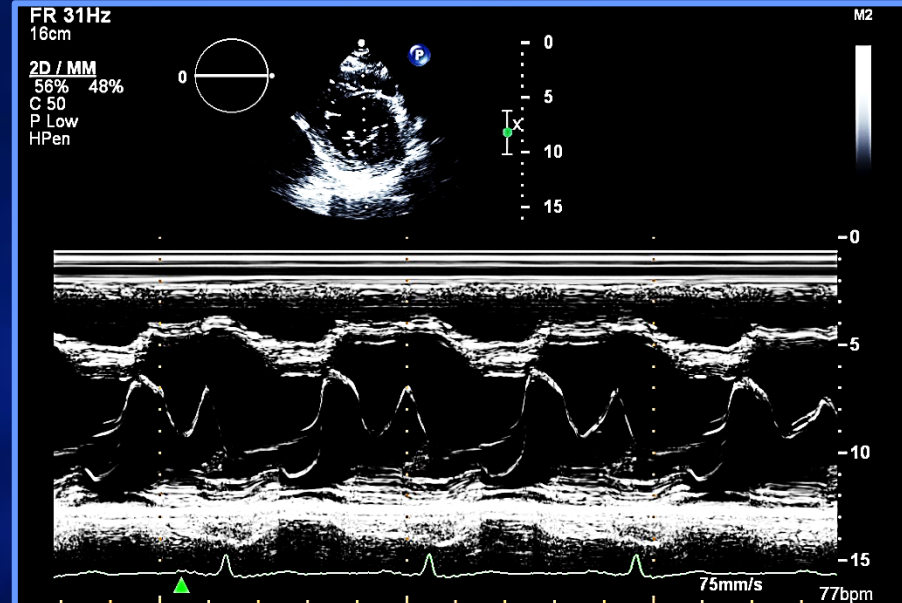
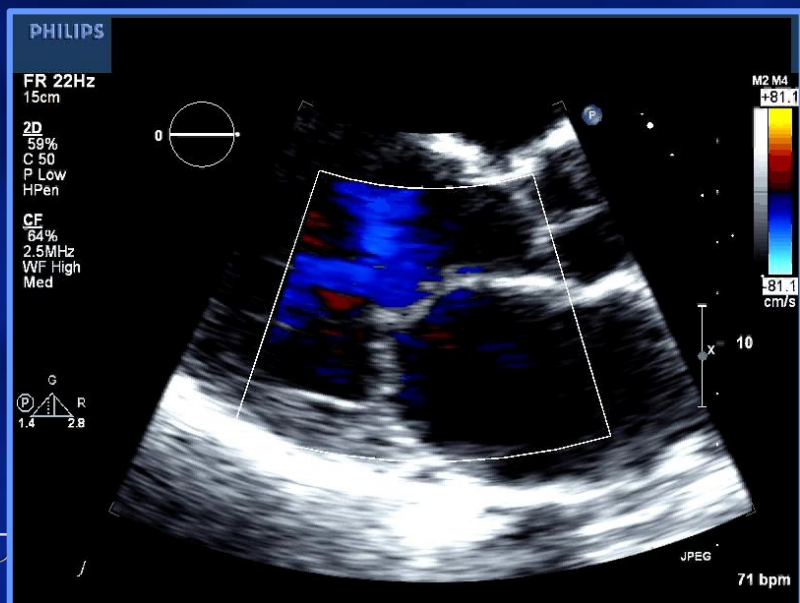
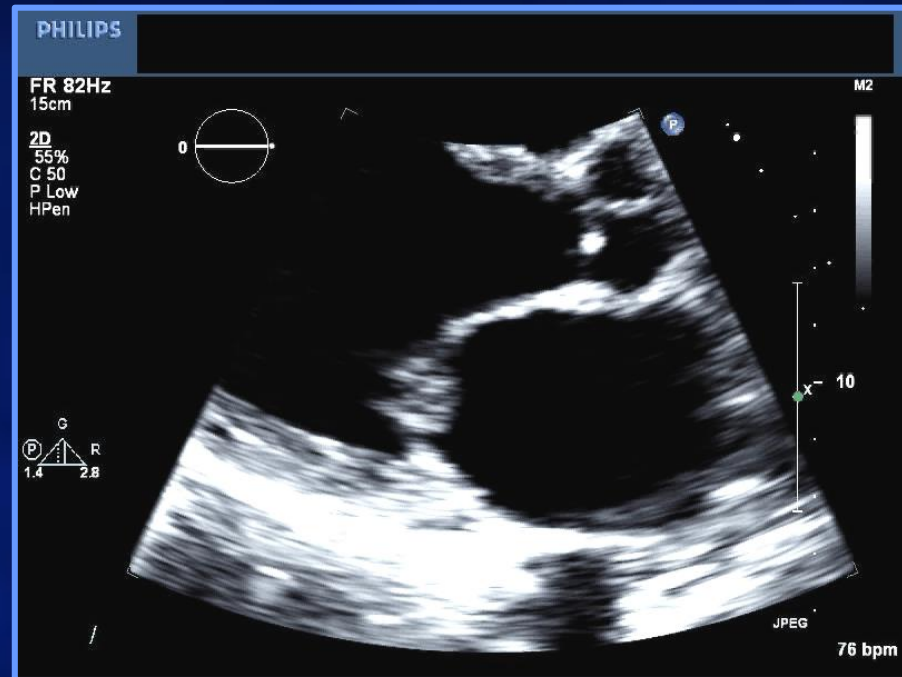
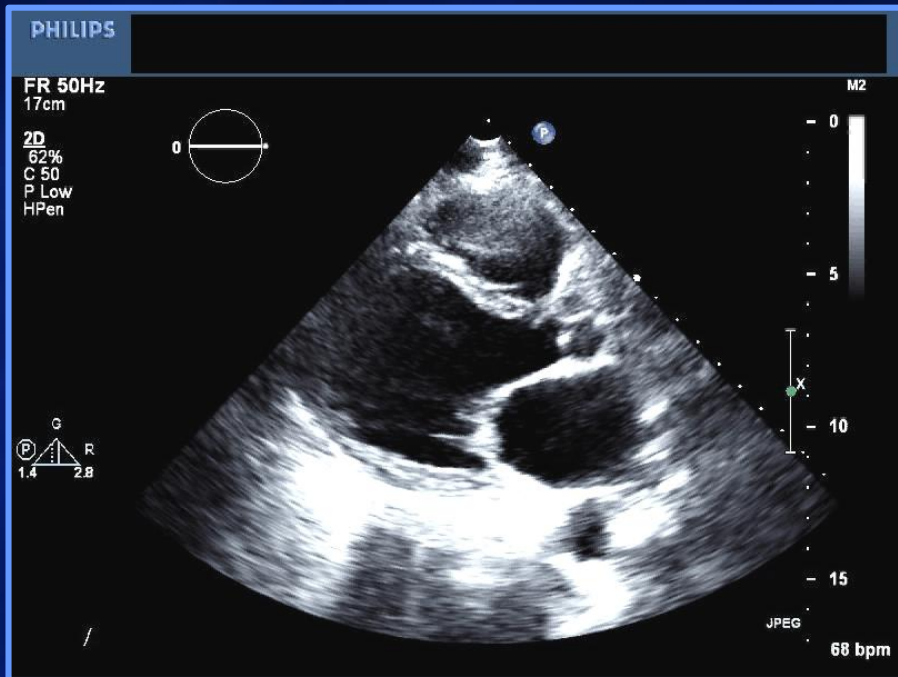
None

Off Label Usage

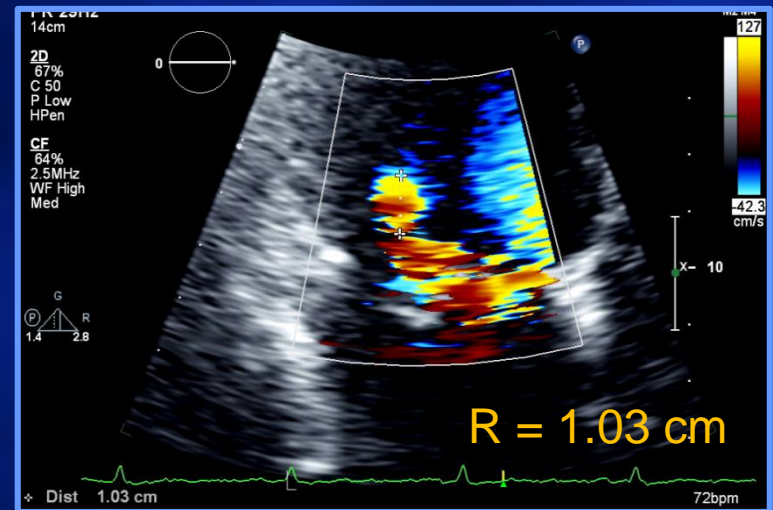
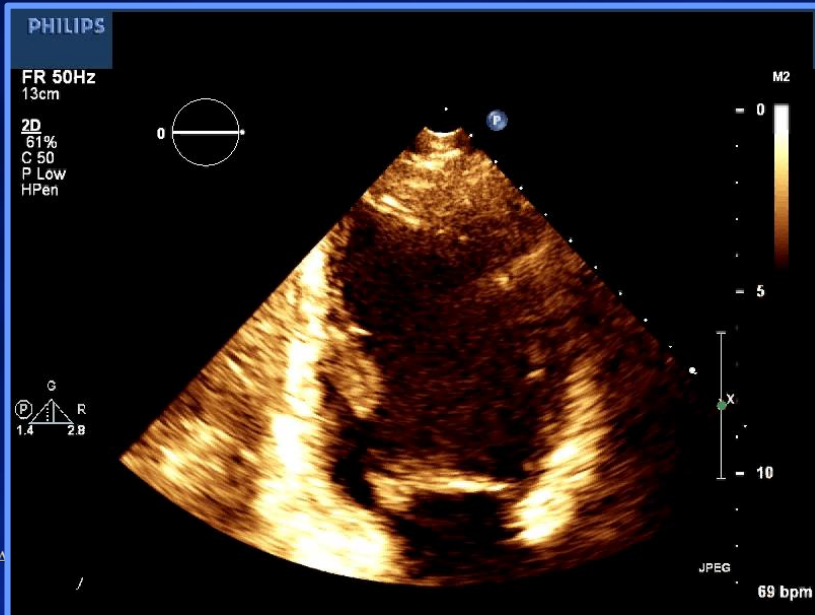
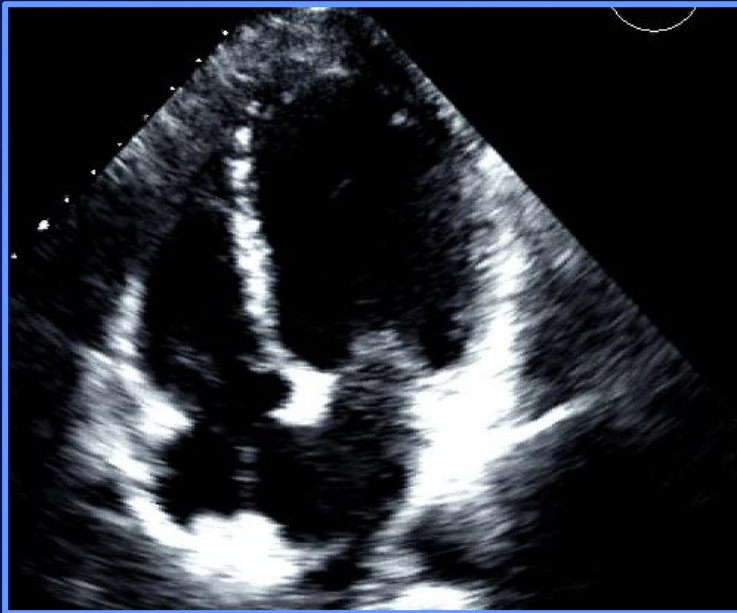
**Paravalvular Leak Closure Devices
Valve in Valve Procedures**

Pre Test Question

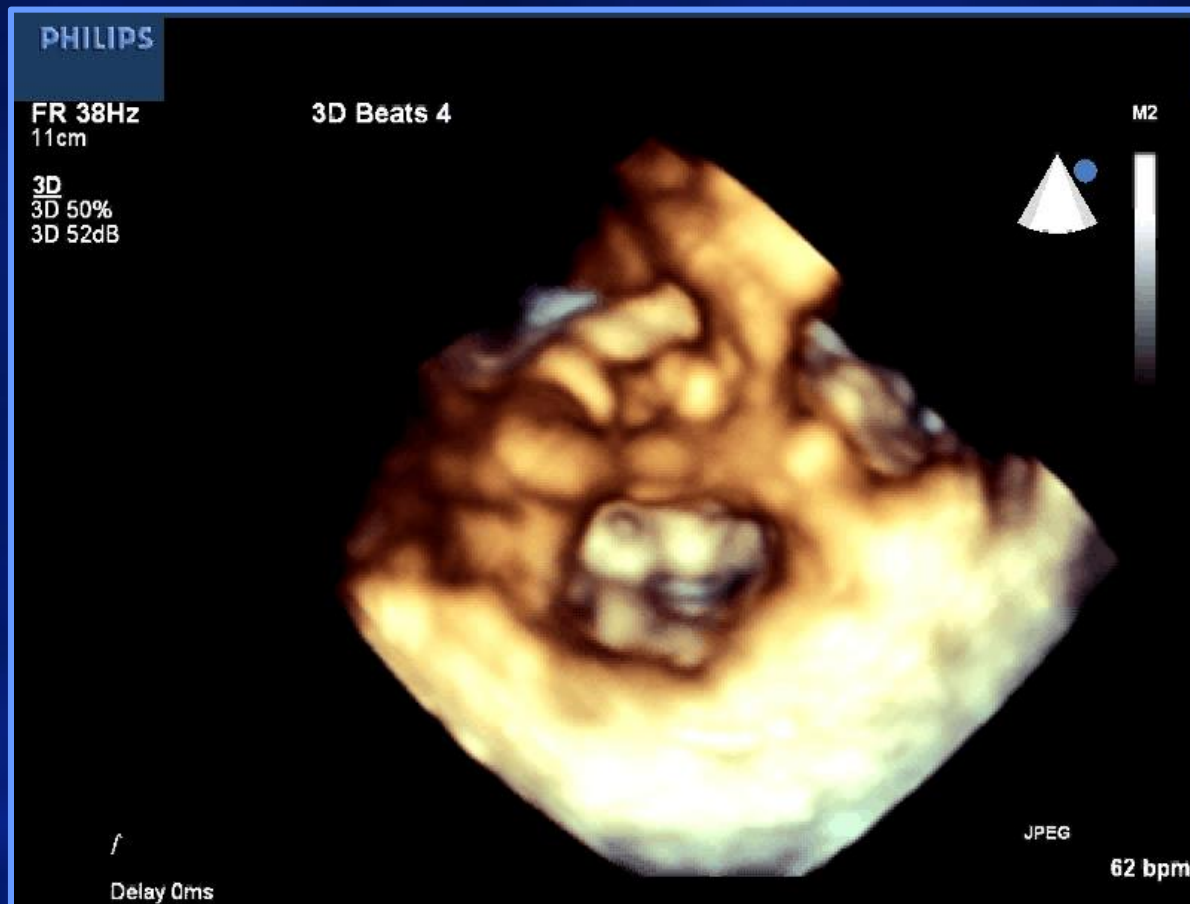
Parasternal Views: What's wrong with MV?



Apical Views

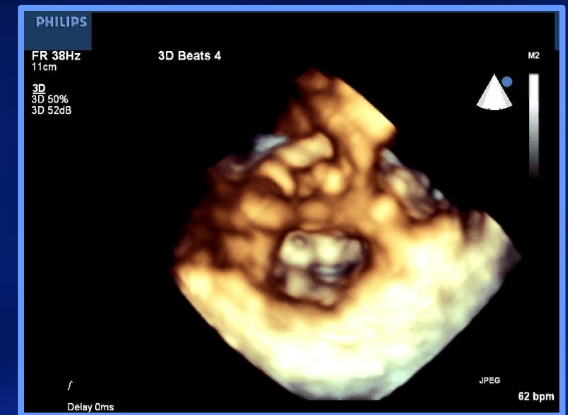


3D Echocardiography: View from the Left Atrium (Surgeon's View)



Question

- What is the specific mitral abnormality shown?
 1. Flail/prolapse middle scallop of posterior leaflet (P2)
 2. Flail/prolapse middle scallop of anterior leaflet (A2)
 3. Mitral valve vegetation
 4. Flail/prolapse medial scallop of posterior leaflet (P3)
 5. Flail/prolapse medial scallop of anterior leaflet (A3)



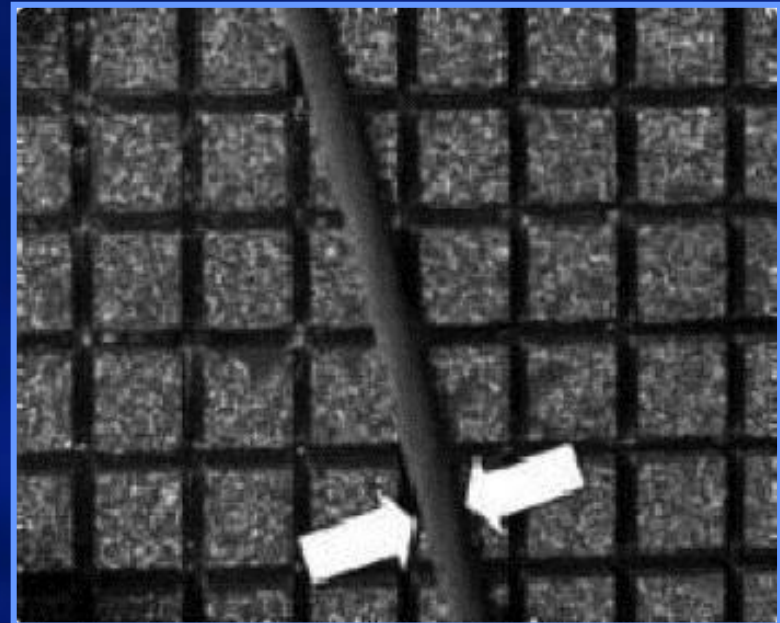
View from LA

Advantages of 3D Echo

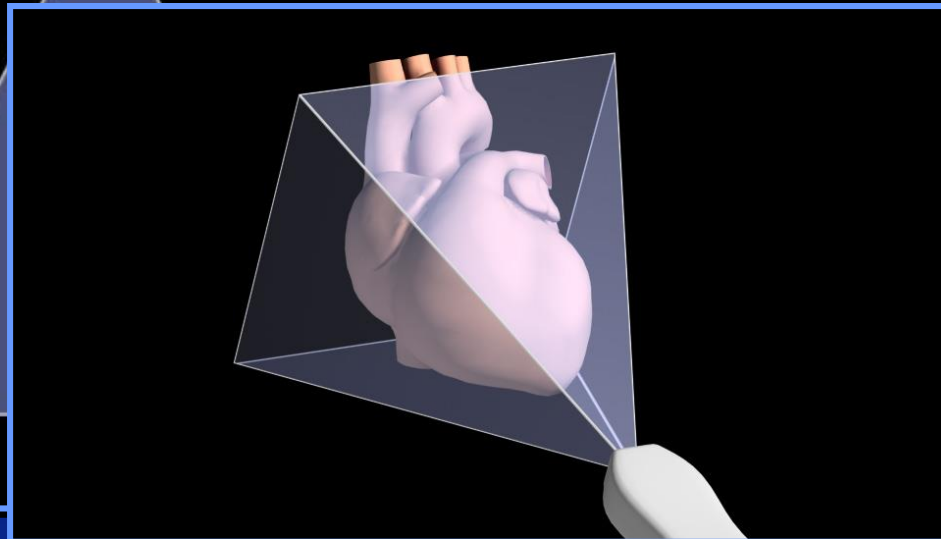
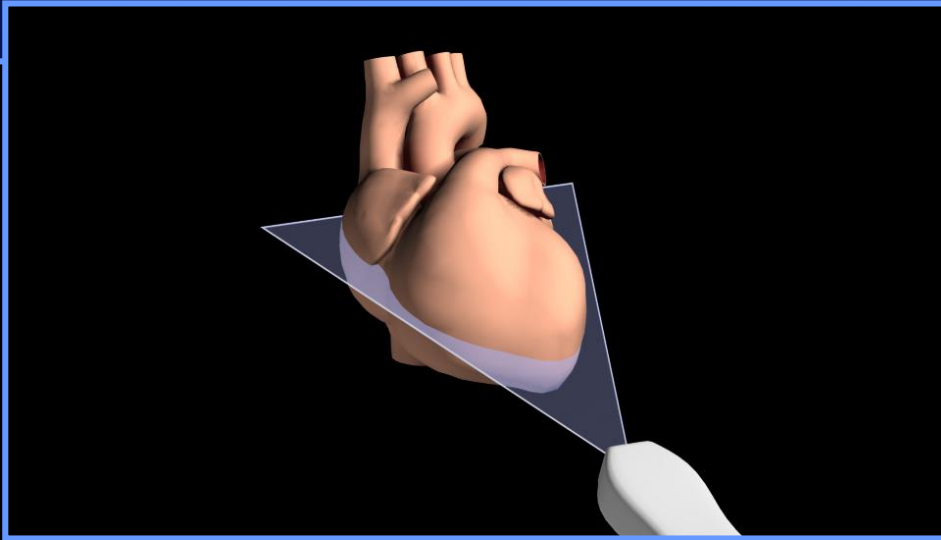
- Ventricular volumes and ejection fraction (EF)
 - More accurate
 - Better reproducibility
- Valve assessment
 - Unique visualization of anatomical structures
 - “*En Face*” views of valves

3D Echocardiography

- Second generation full matrix-array probe
 - allows online real-time 3D imaging and rendering
 - parallel processing to scan a pyramidal volume



2D vs 3D Echocardiography



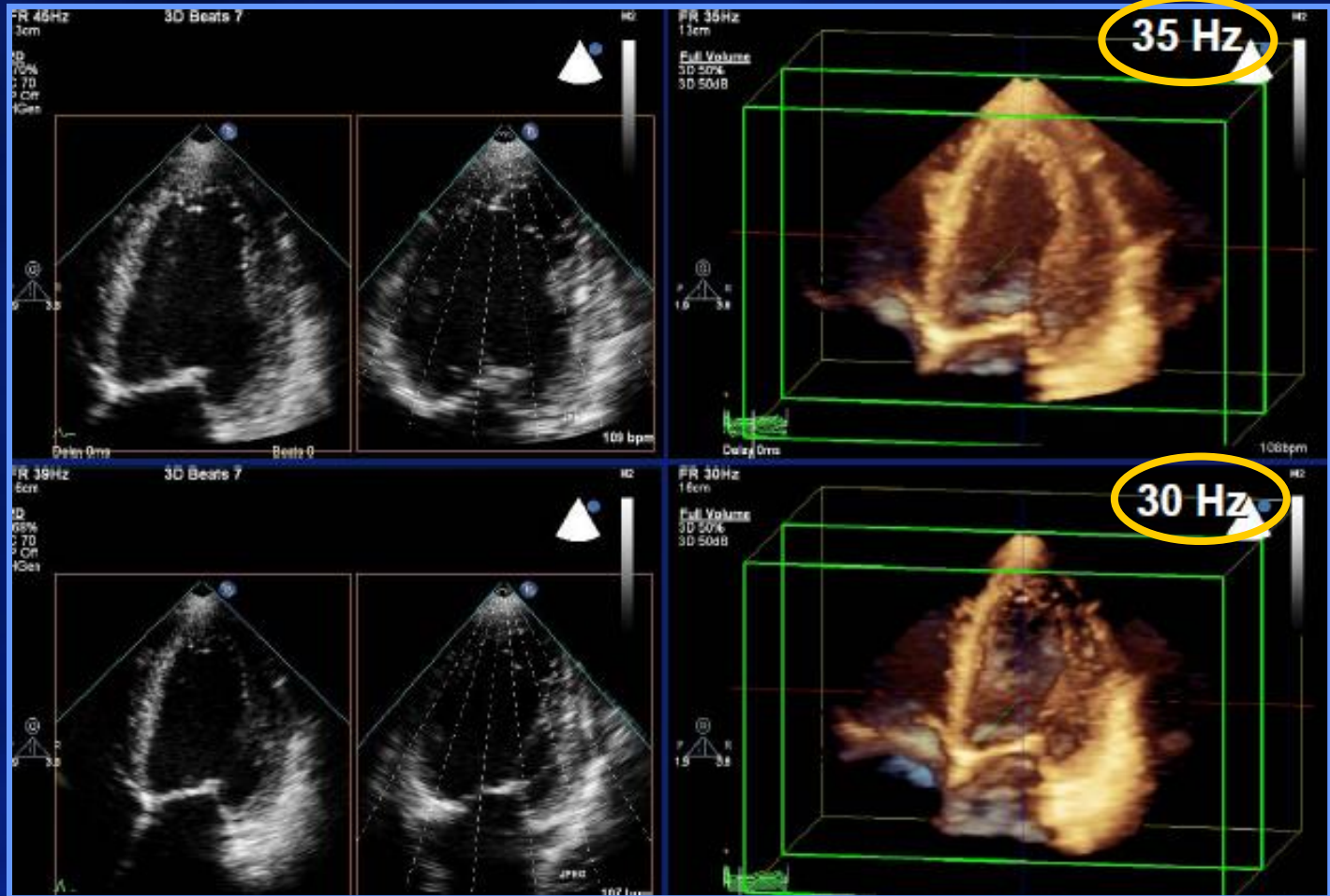
Breath-hold Imaging: Stitch Artifact



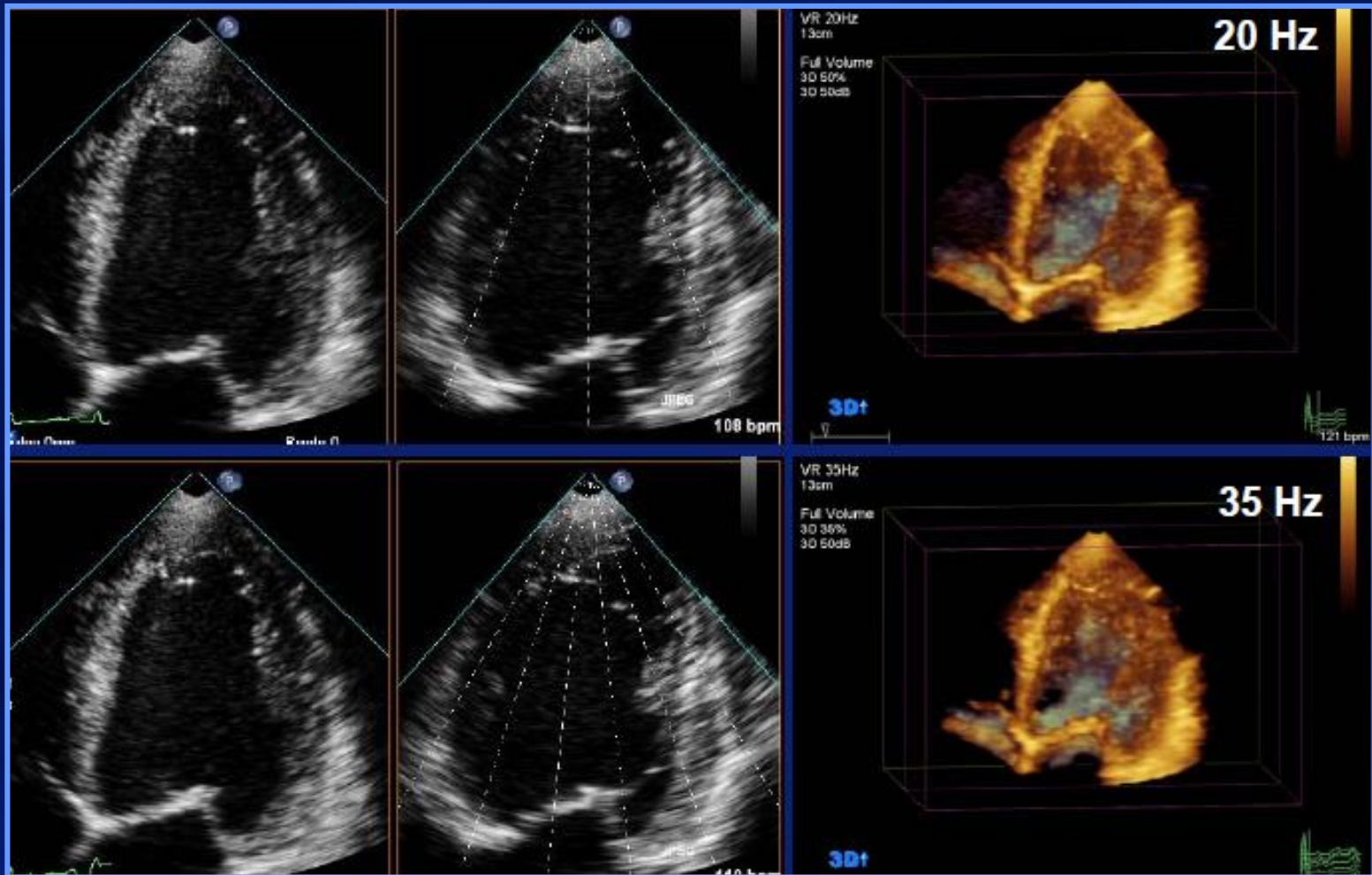
↓ Depth = ↑ Frame Rate

Depth
13 cm

Depth
16 cm



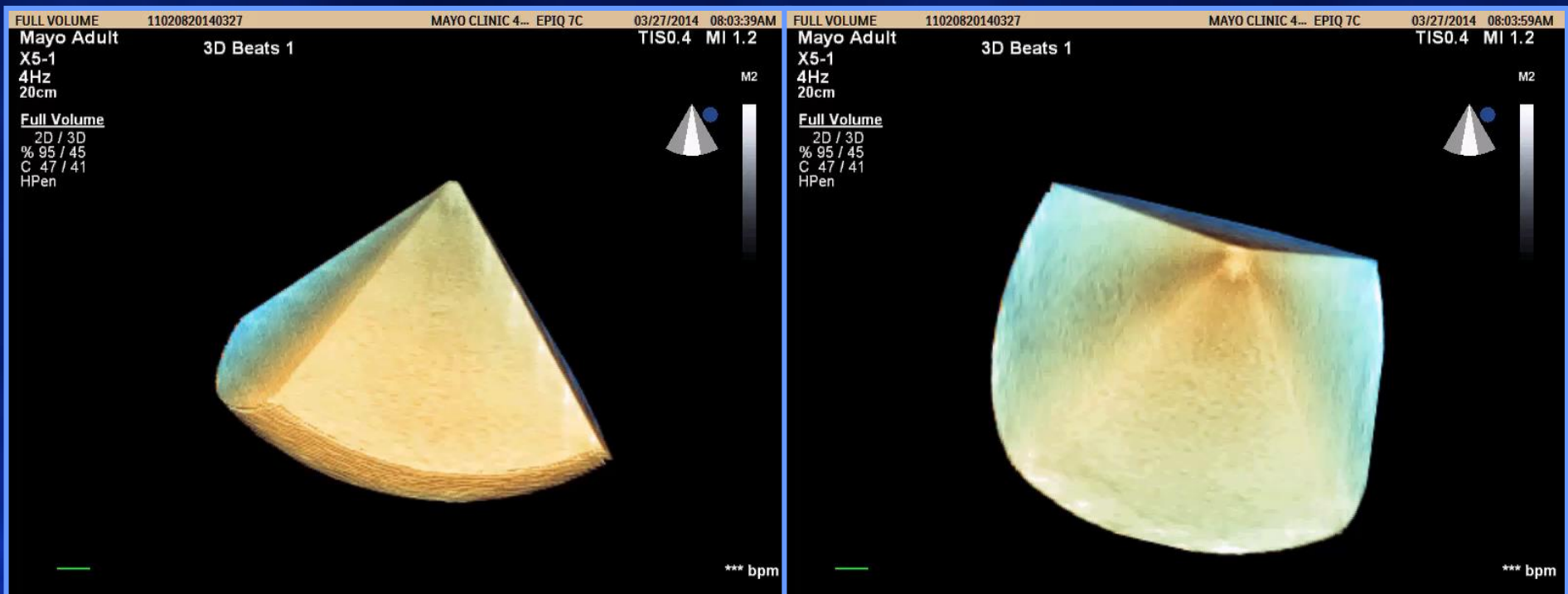
↑ Number of Subvolumes = ↑ Frame Rate



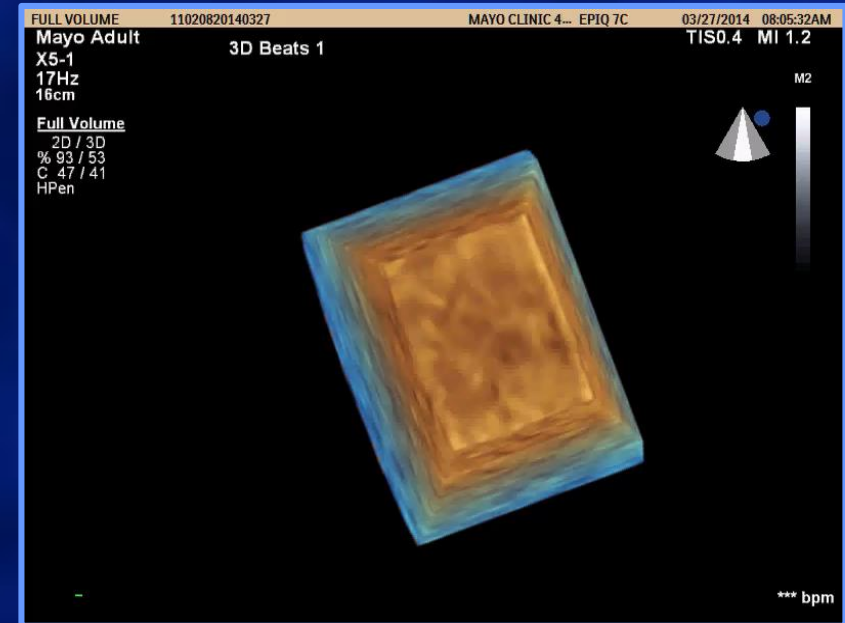
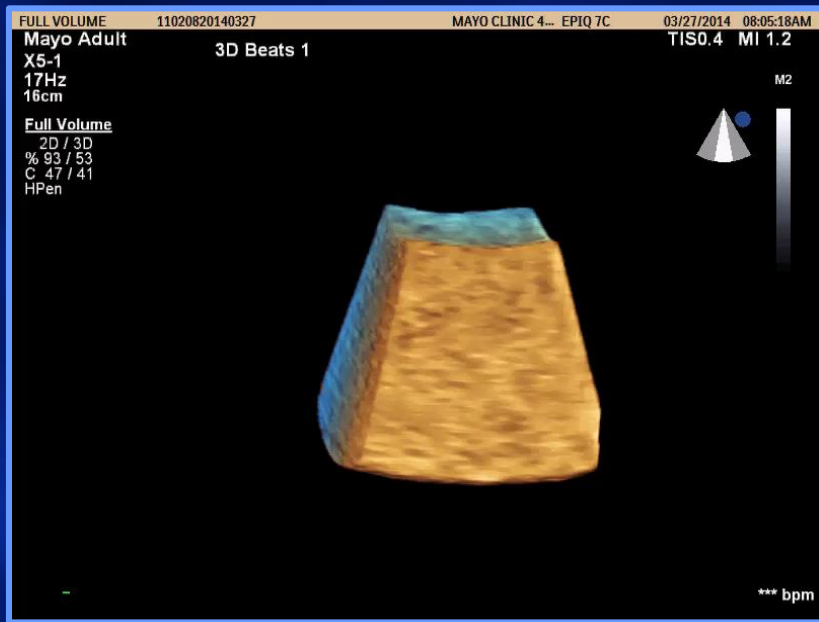
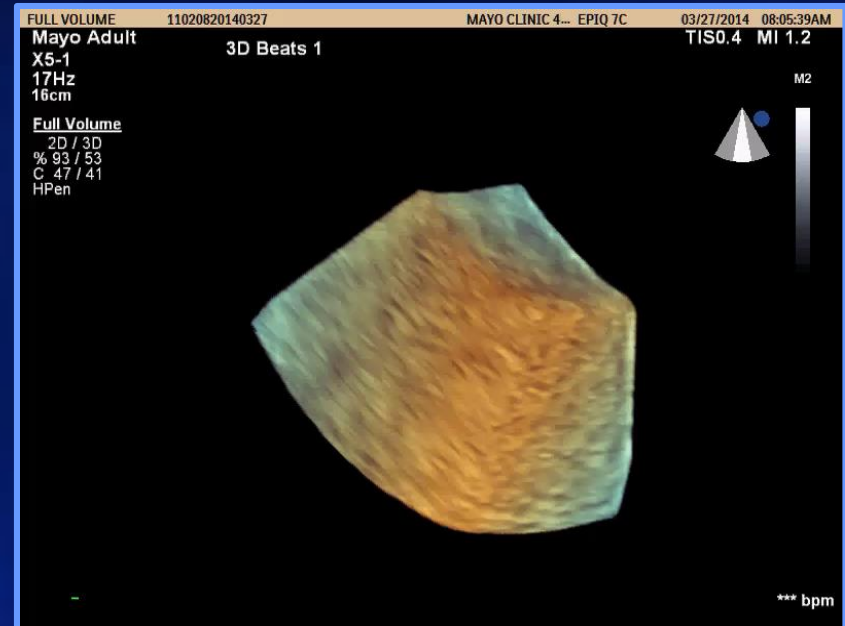
Different Modes of 3D Imaging



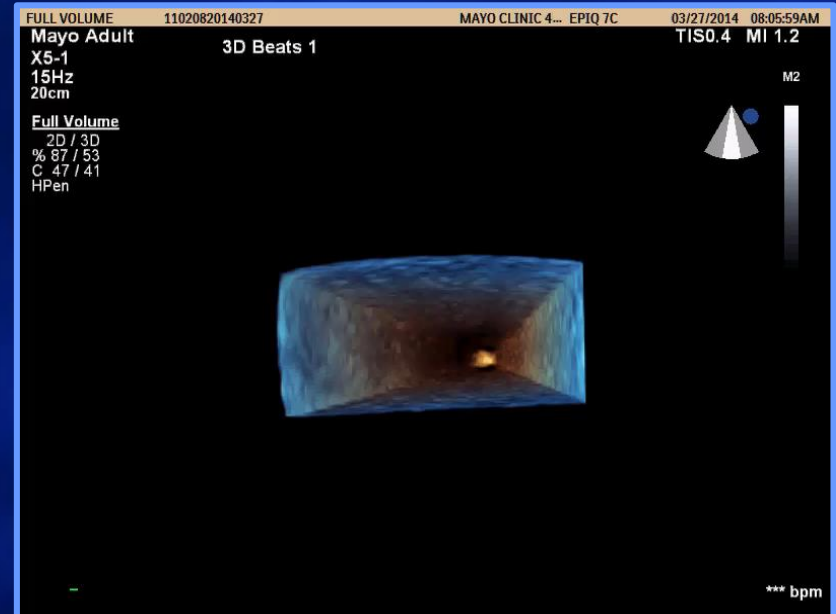
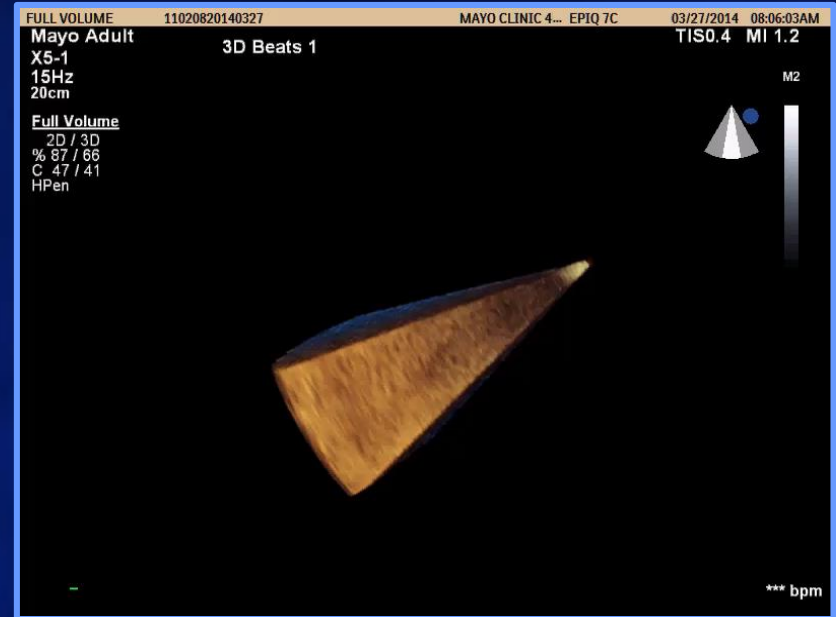
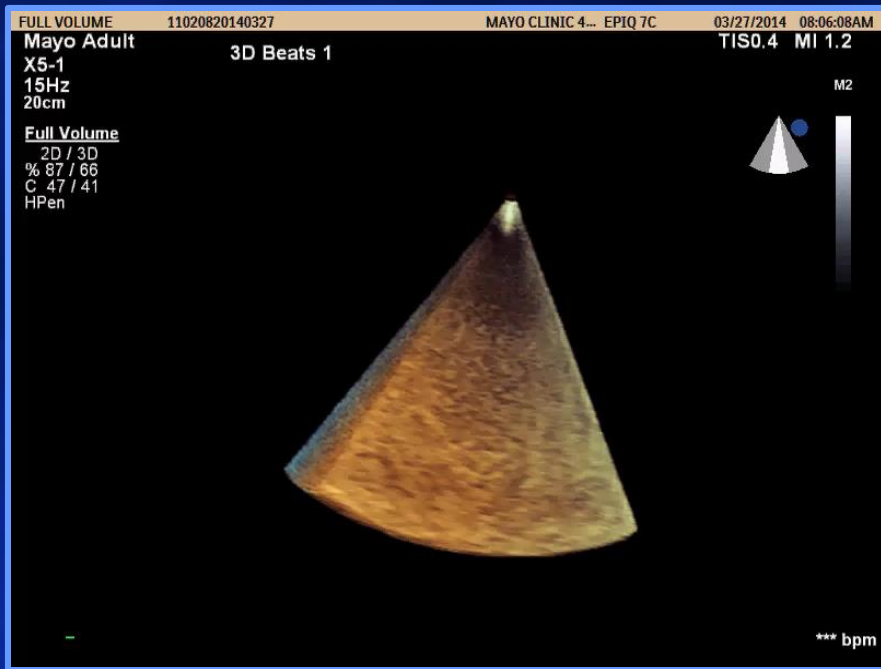
3D Full Volume Acquisition



3D Zoom Acquire



3D Live Mode



Different Modes of Acquisition

Live 3D



NY Style Pizza

Full Volume 3D



Chicago Style Pizza

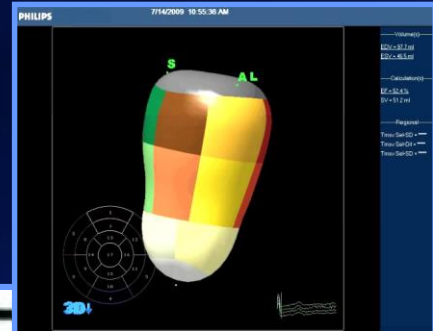
3D Zoom



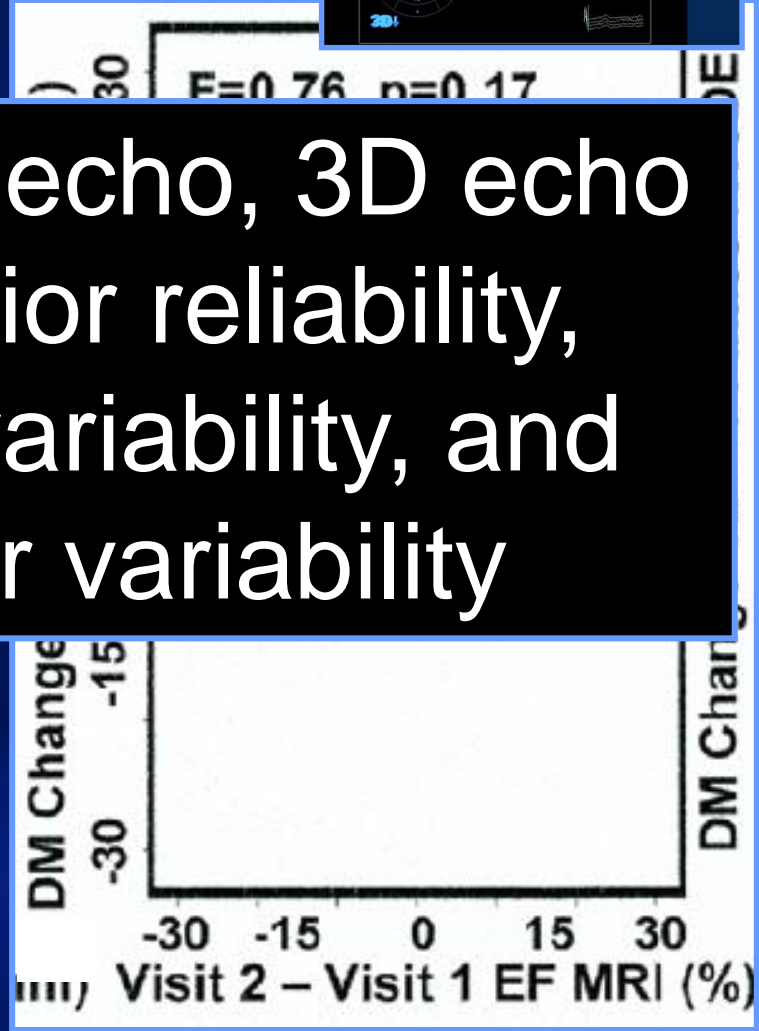
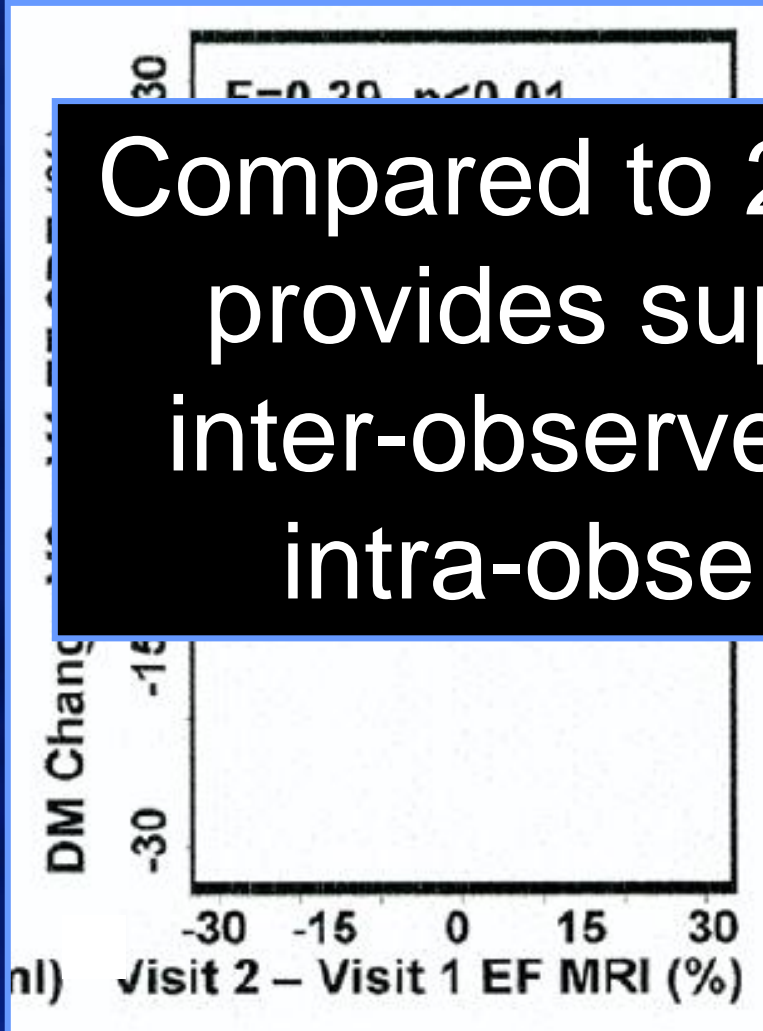
Importance of LV EF

- Prognosis
 - Post-MI
 - Heart failure
- Medication decisions
- Device therapy
 - ICD
 - Biventricular pacemaker/ICD

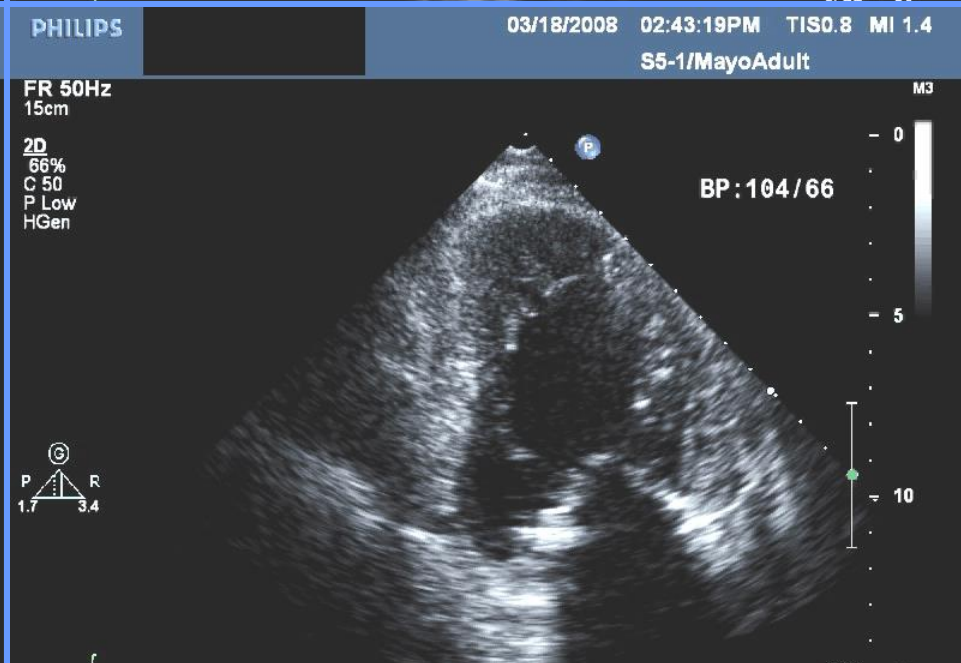
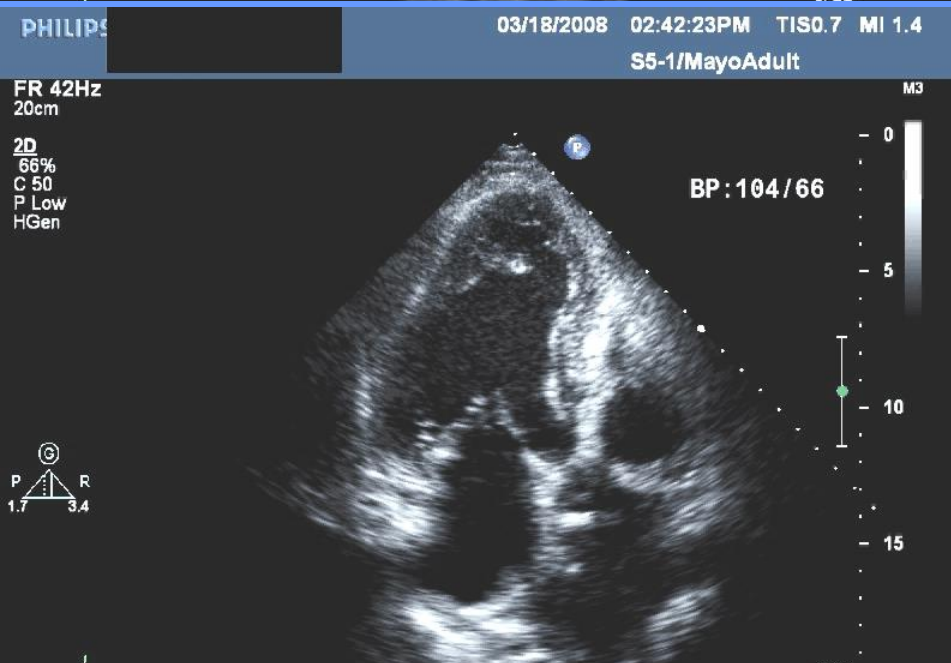
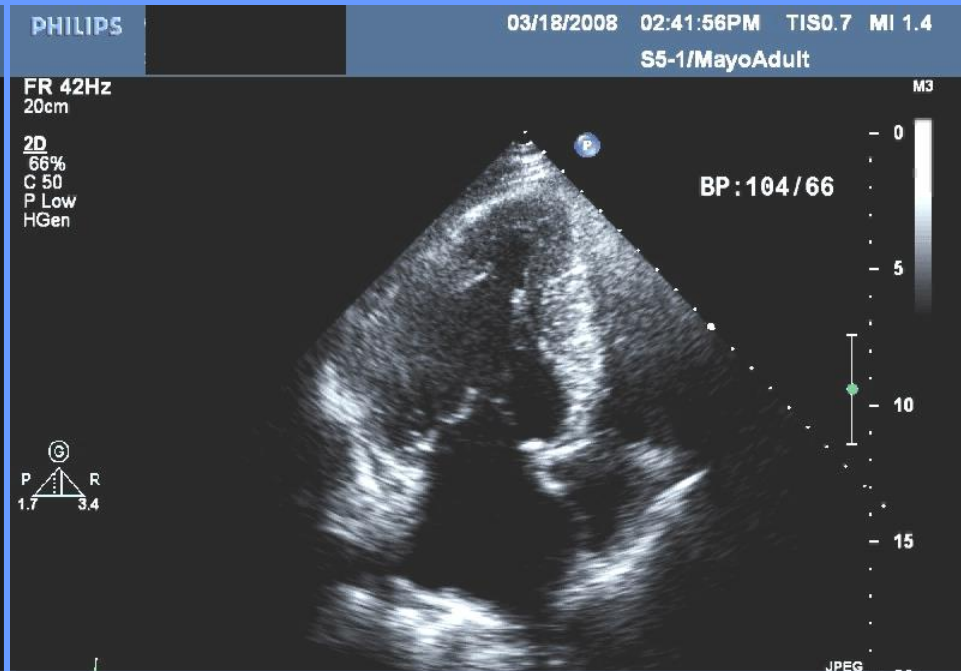
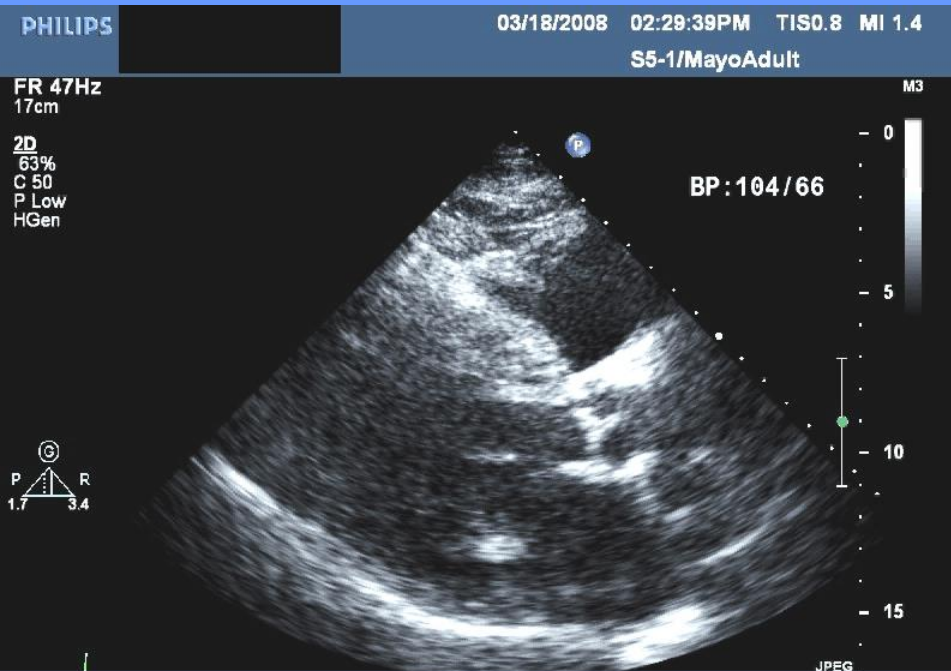
2D Echo vs. 3D Echo



Compared to 2D echo, 3D echo provides superior reliability, inter-observer variability, and intra-observer variability

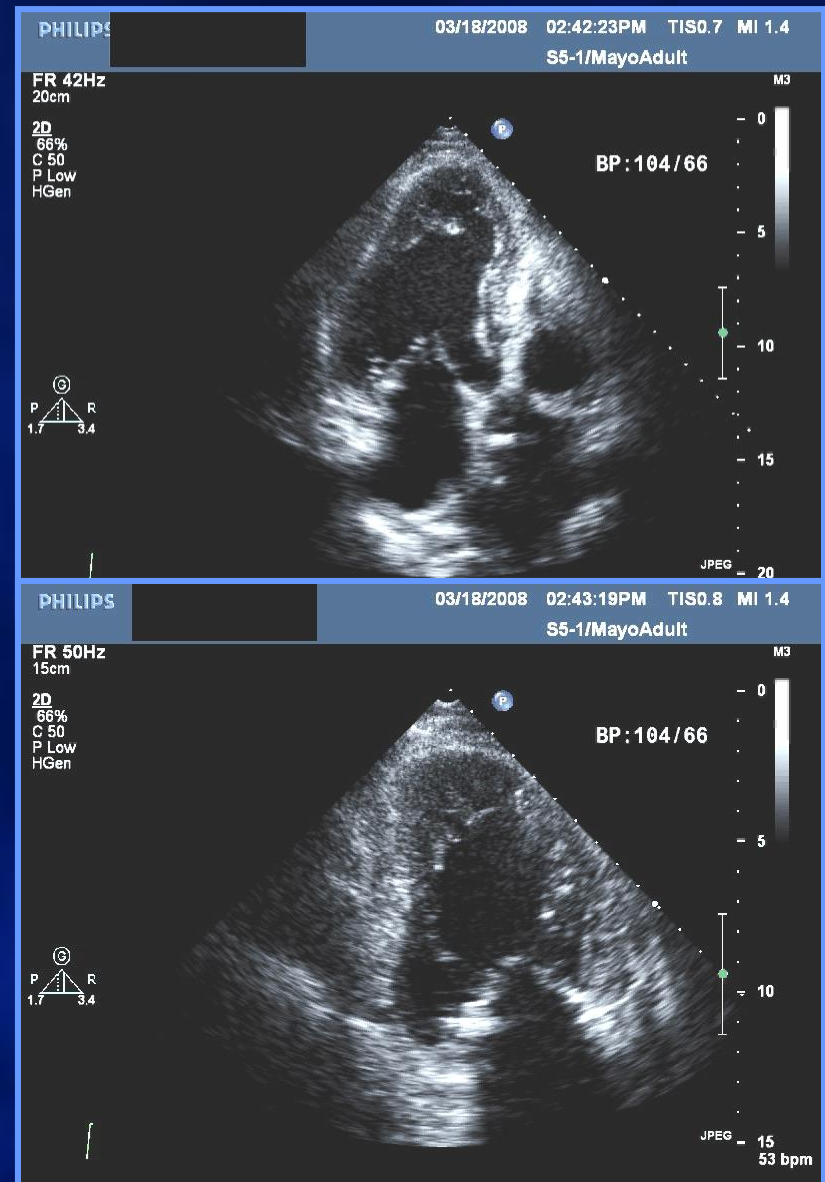


What is the EF?



What is the EF?

1. $> 55\%$
2. $45-55\%$
3. $35-44\%$
4. $25-34\%$
5. $<25\%$



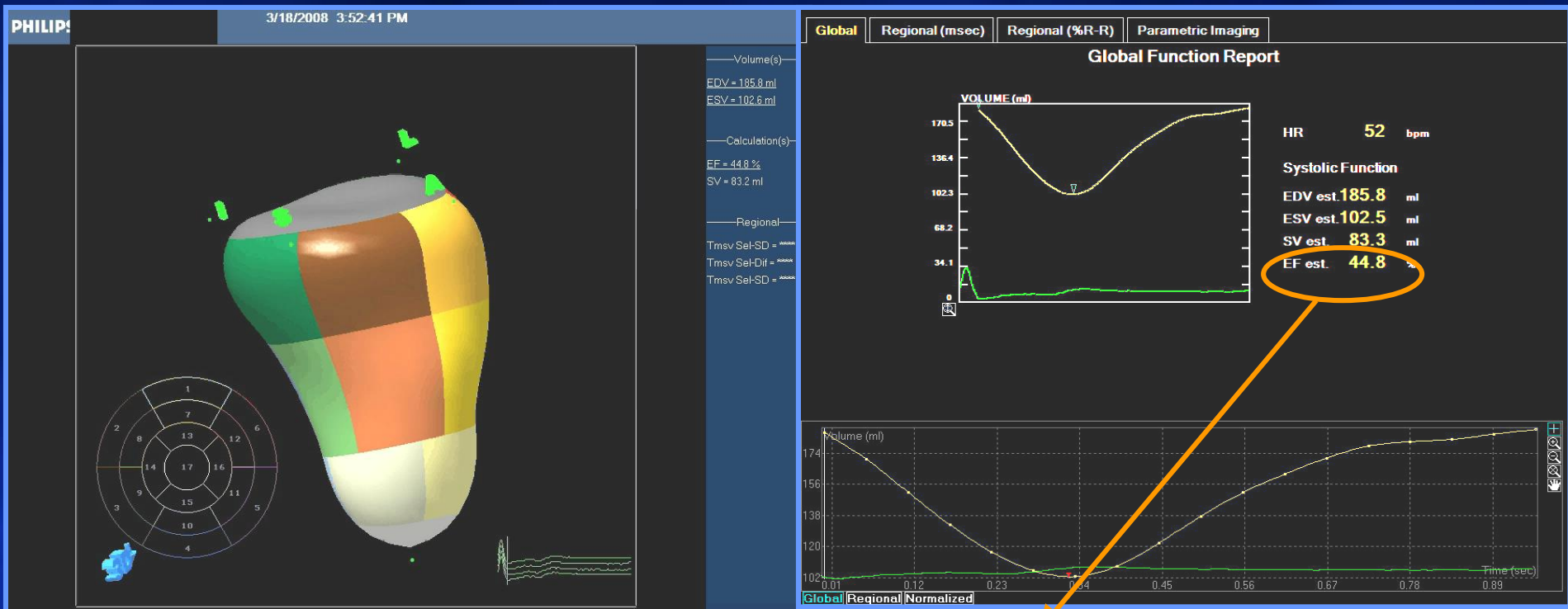
2D Method (single plane)

EF = 56 %

2D Biplane EF

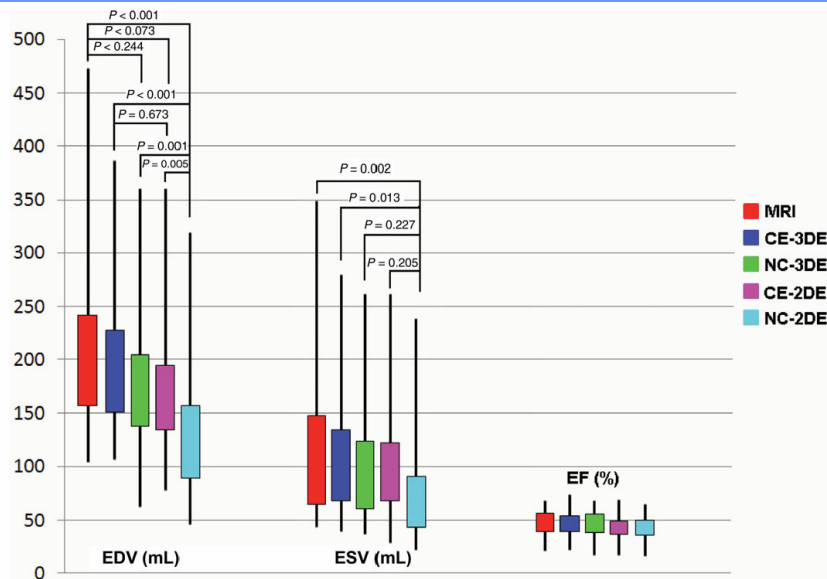
EF = 36 %

3D EF (Volumetric)

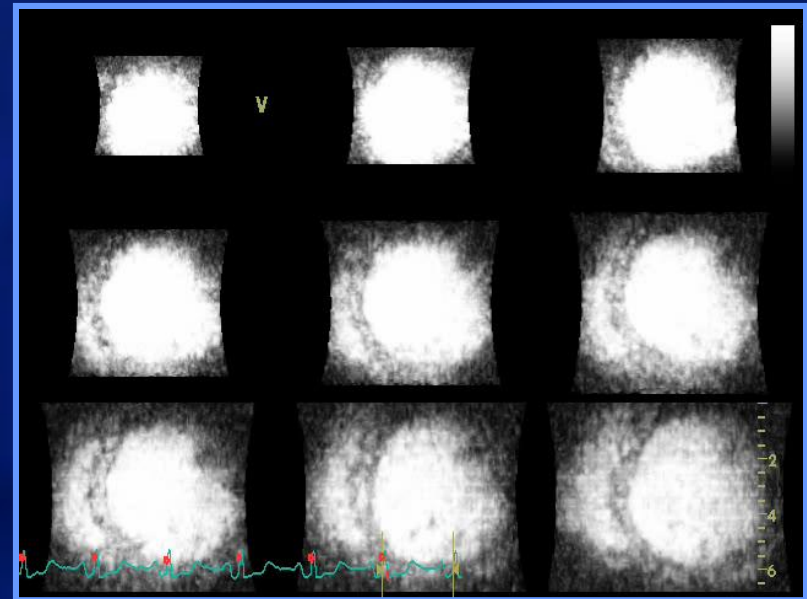


3D EF = 44 %

3D with Contrast → Closest to MRI



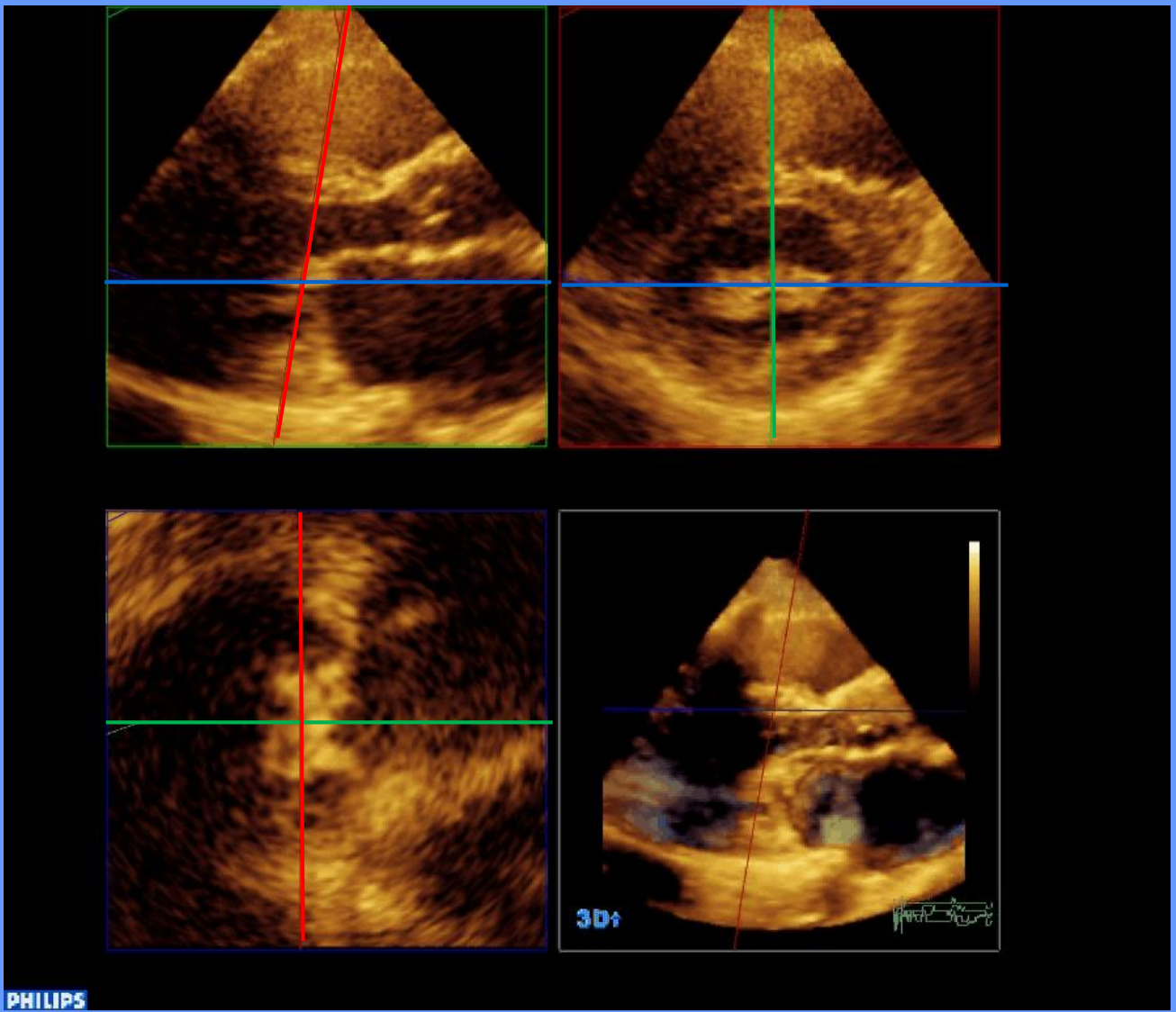
EDV (207 ± 79 mL)	ESV (117 ± 71 mL)	EF (47 ± 13 %)	MRI
-41 ± 21	-22 ± 18	-2 ± 4	NC-2DE
-18 ± 19	-8 ± 16	-2 ± 4	CE-2DE
-15 ± 18	-9 ± 12	0 ± 3	NC-3DE
-6 ± 14	-3 ± 10	0 ± 3	CE-3DE



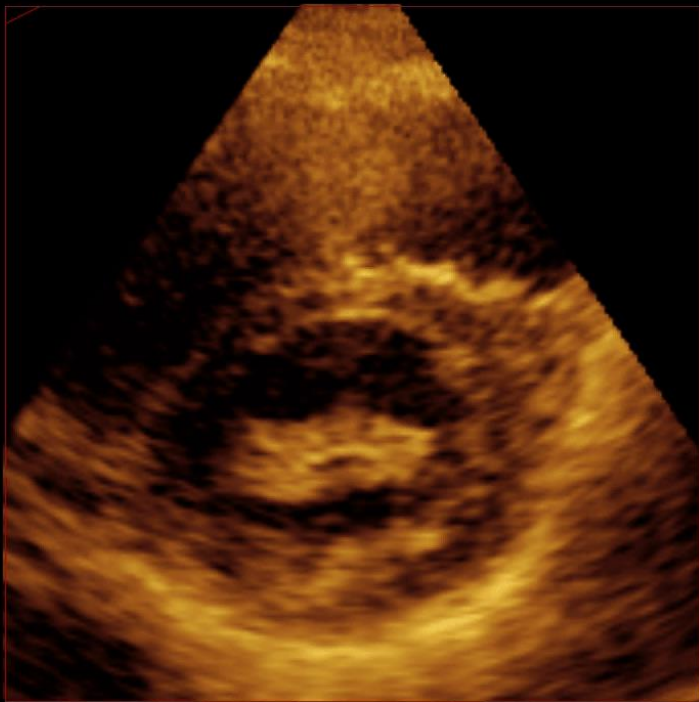
Jenkins C. et al. *Eur Heart J* 2009; 30:98-106

3D Echo Assessment of Valves

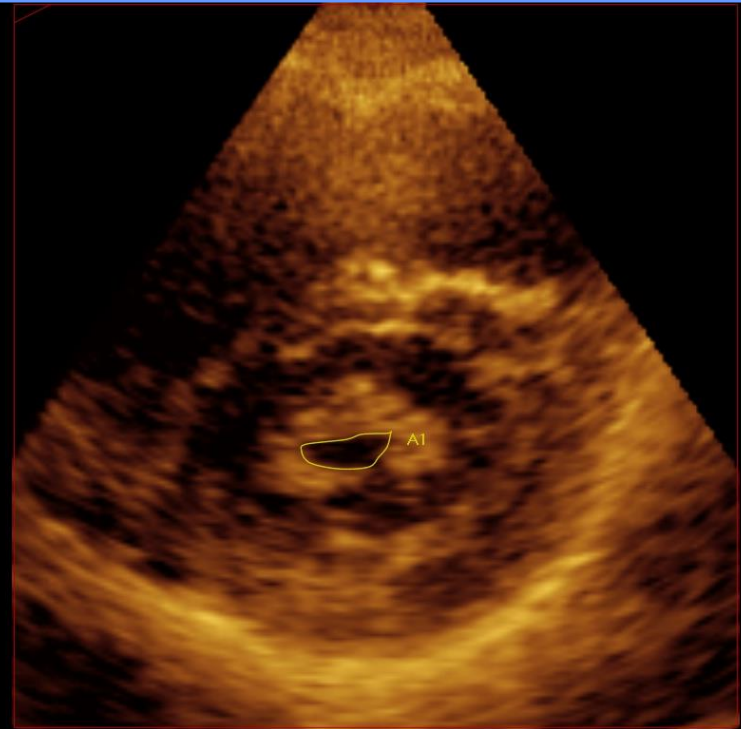
Use of 3D Echo in Mitral Stenosis



3D Guided 2D Planimetry



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Area(s)
A1 = 0.58 cm² I X

Mitral Stenosis: Different Results Depending on Method

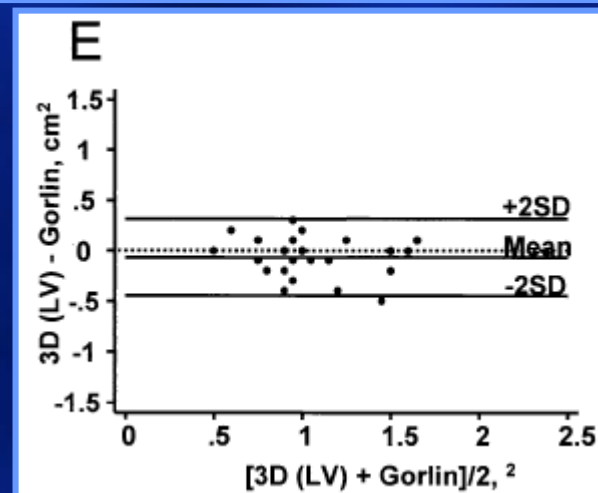
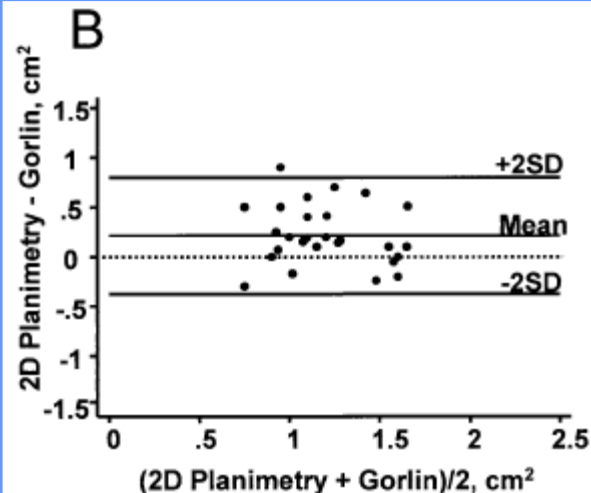
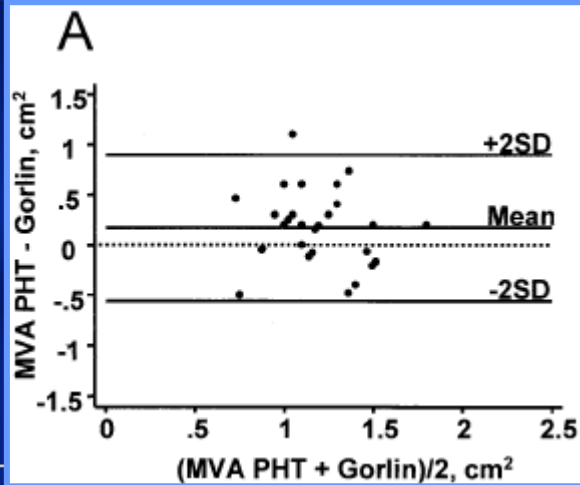
Sugeng L...Lang RM. *J Am Soc Echocardiogr* 2003;1292-1300

Table 1 Mitral valve area obtained by all methods

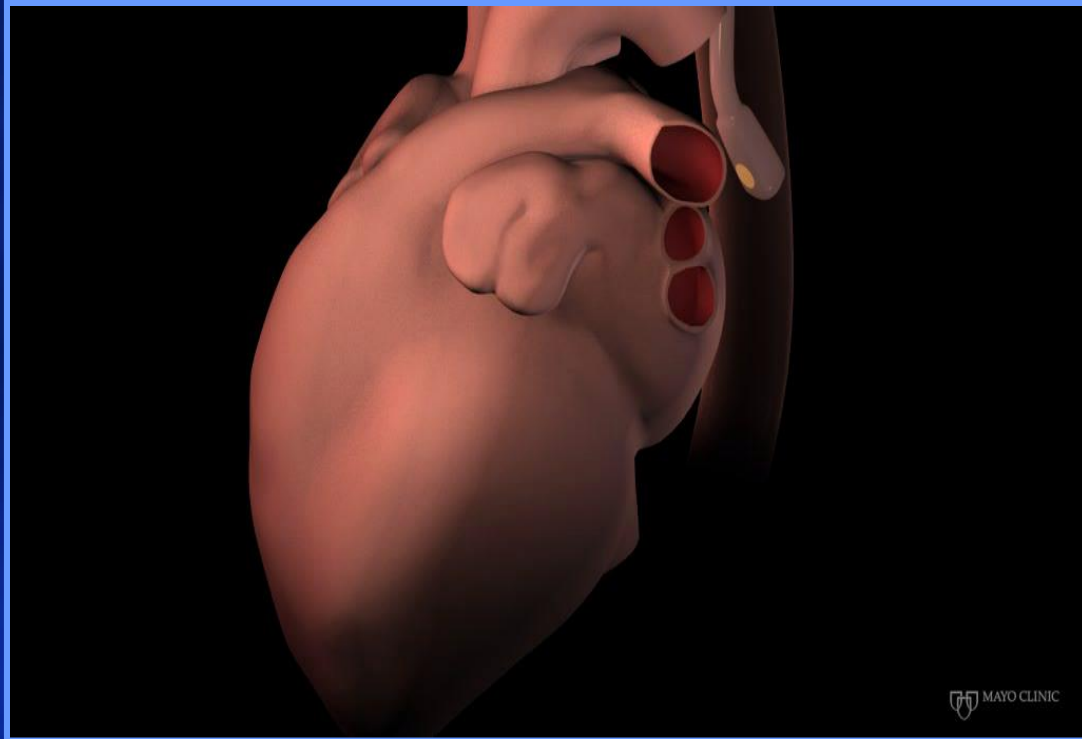
	Mitral valve area		Difference from Gorlin method			
	n	Mean \pm SD (cm ²)	Bias \pm SD (cm ²)	P*	Limits of agreement (cm ²)	ICC
Gorlin	29	1.09 \pm 0.33	—			
2D planimetry	29	1.30 \pm 0.29	0.21 \pm 0.29	.001	(-0.37, 0.80)	0.391
PHT	29	1.26 \pm 0.29	0.17 \pm 0.36	.02	(-0.56, 0.90)	0.225
PISA	29	1.18 \pm 0.39	0.09 \pm 0.34	.15	(-0.59, 0.78)	0.536
3D (LV)	29	1.03 \pm 0.29	-0.06 \pm 0.19	.09	(-0.44, 0.32)	0.797
3D (LA)	29	0.92 \pm 0.33	-0.17 \pm 0.25	.001	(-0.67, 0.33)	0.609

2D, Two-dimensional; 3D, 3-dimensional; ICC, intraclass correlation coefficient; LA, left atrium; LV, left ventricle; PHT, pressure half-time; PISA, proximal isovelocity surface area.

*Paired *t* test of whether the mitral valve area measured by the 5 methods differ from that measured by Gorlin method.



Transesophageal 3D Echocardiography



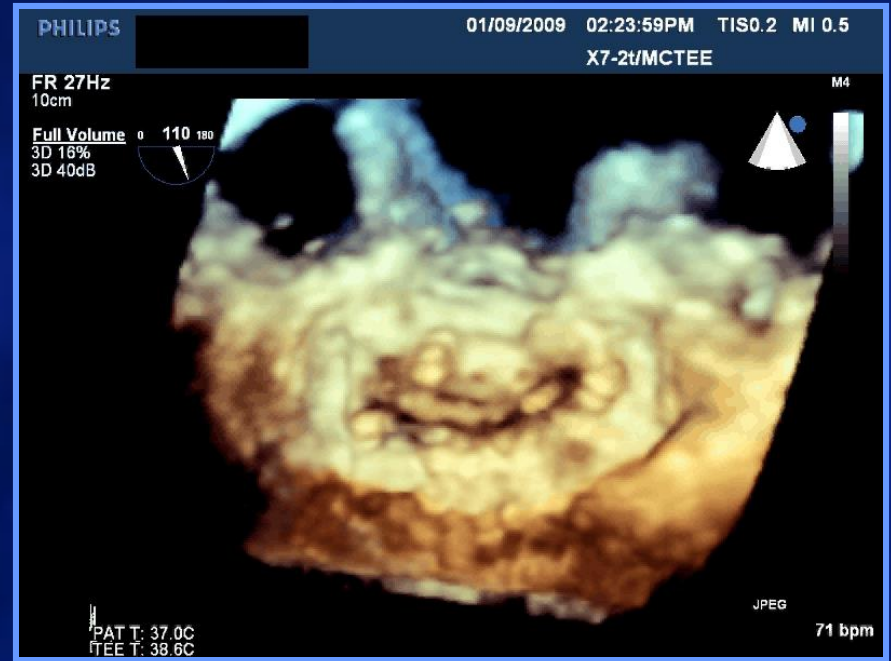
- Allows visualization of mitral valve leaflets, orifice, and submitral apparatus in a manner that is not possible using conventional 2D echo
- “*En face*” views of the MV from atrial and ventricular perspective
- Fully sampled volume, not mechanically rotated

3D TEE

View from LA



View from LV



Impact of Degree of Commissural Opening After Percutaneous Mitral Commissurotomy on Long-Term Outcome

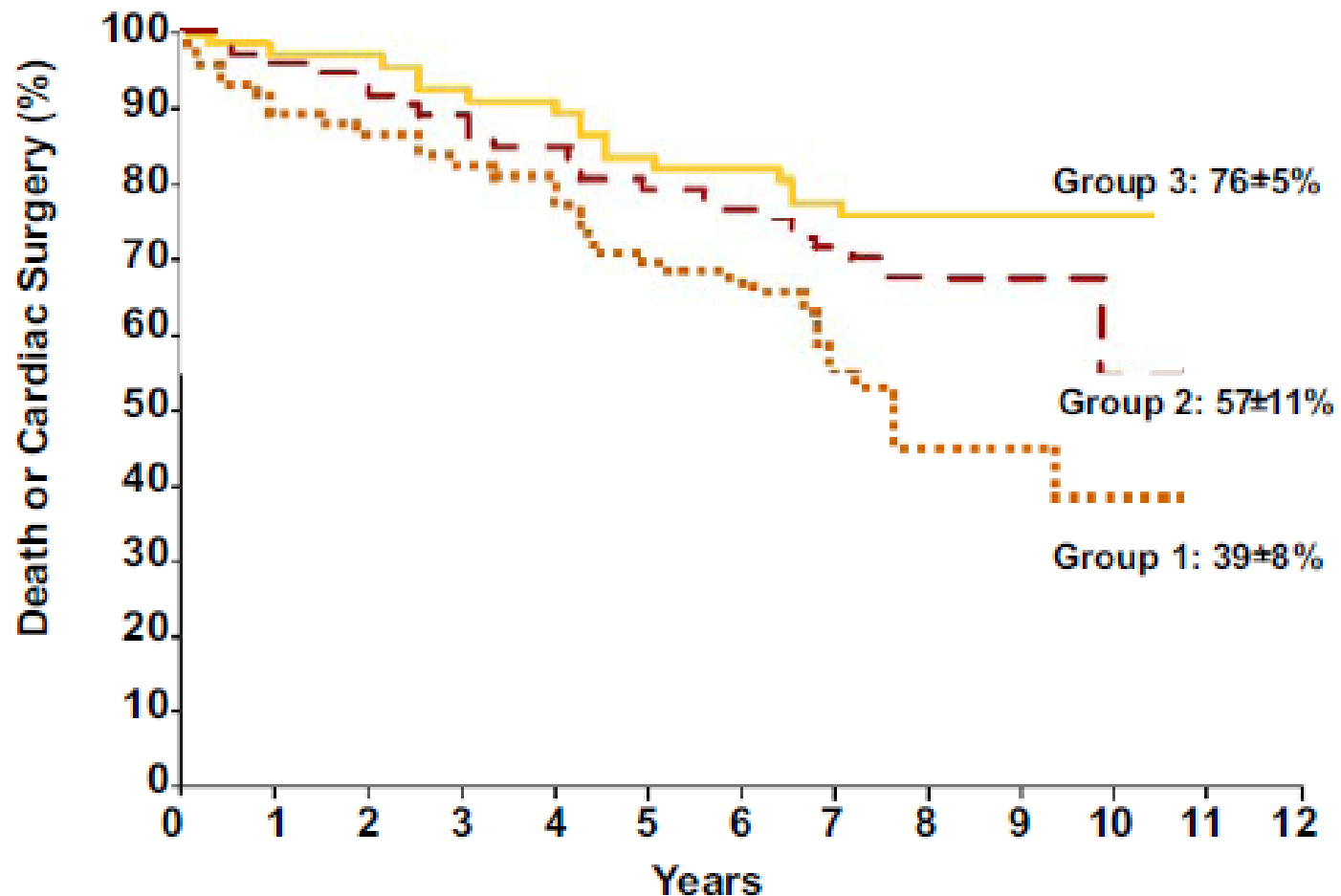


Figure 2. Differ

Post-procedure r
increased and m

gressively

Figure 3. 10-Year Rates of Good Functional Results in the 3 Groups

Real-time 3-D TTE and Mitral Balloon Valvuloplasty

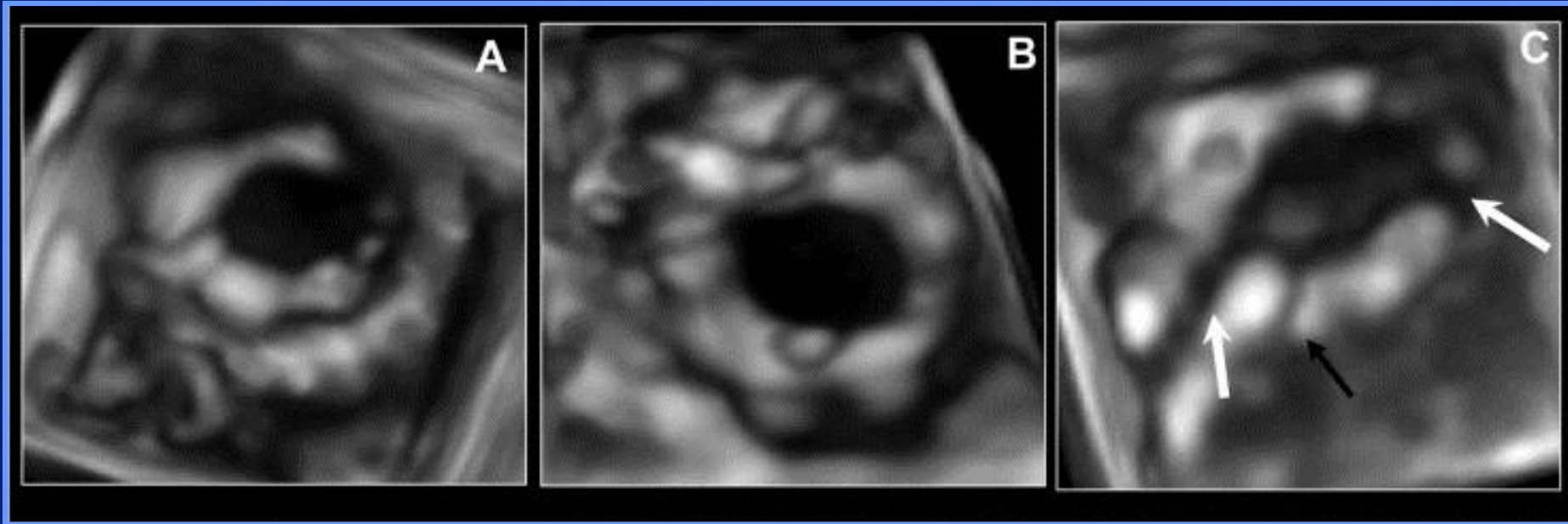


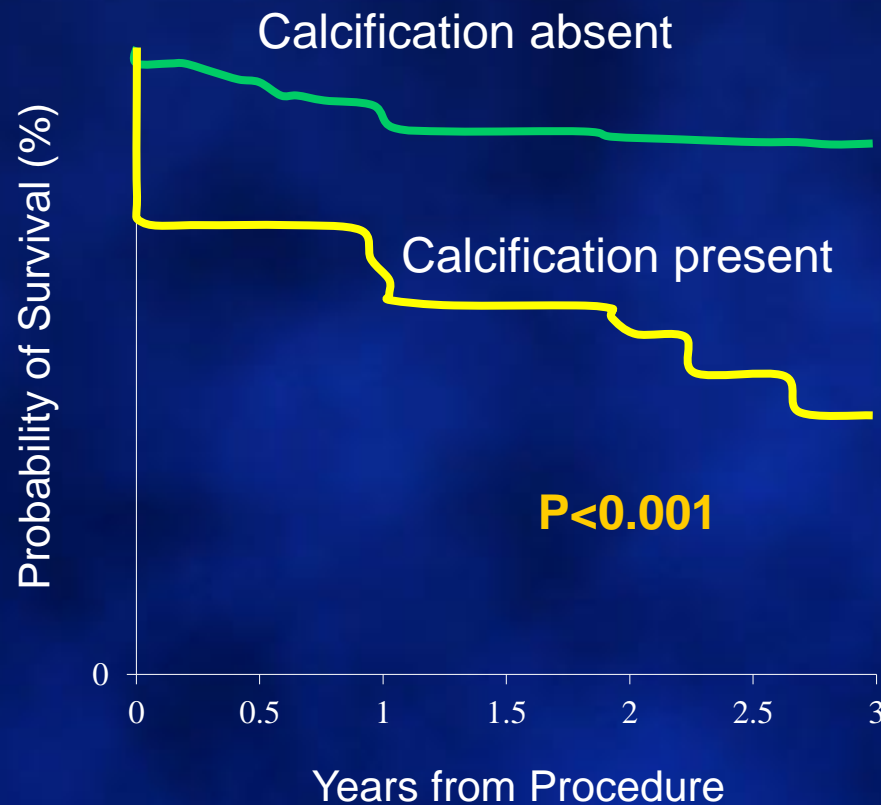
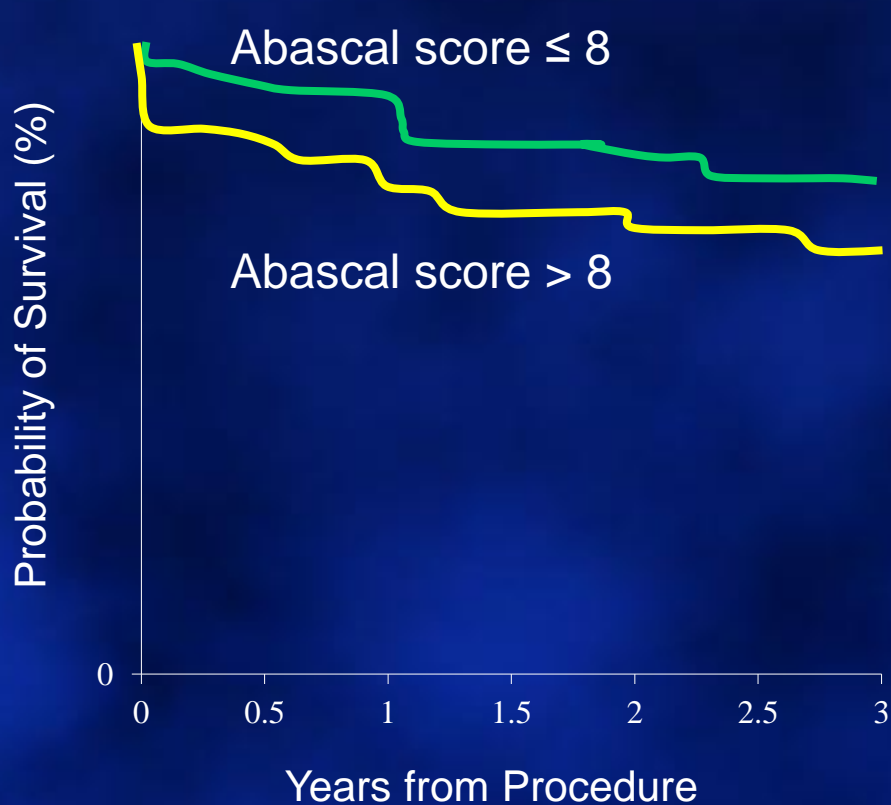
Figure 6 Real-time 3-dimensional echocardiography reconstructions of patient with mitral stenosis undergoing percutaneous balloon mitral valvuloplasty. **A**, Stenotic valve at baseline. After one balloon inflation mitral valve orifice appears slightly larger, hence, only stretching of valve occurred (**B**) and finally after second balloon inflation, both commissures are torn (*white arrows*) and there is tear of posterior leaflet (*black arrow*).

Sugeng L...Lang RM. *J Am Soc Echocardiogr* 2006;19:413-421

View from LV Perspective



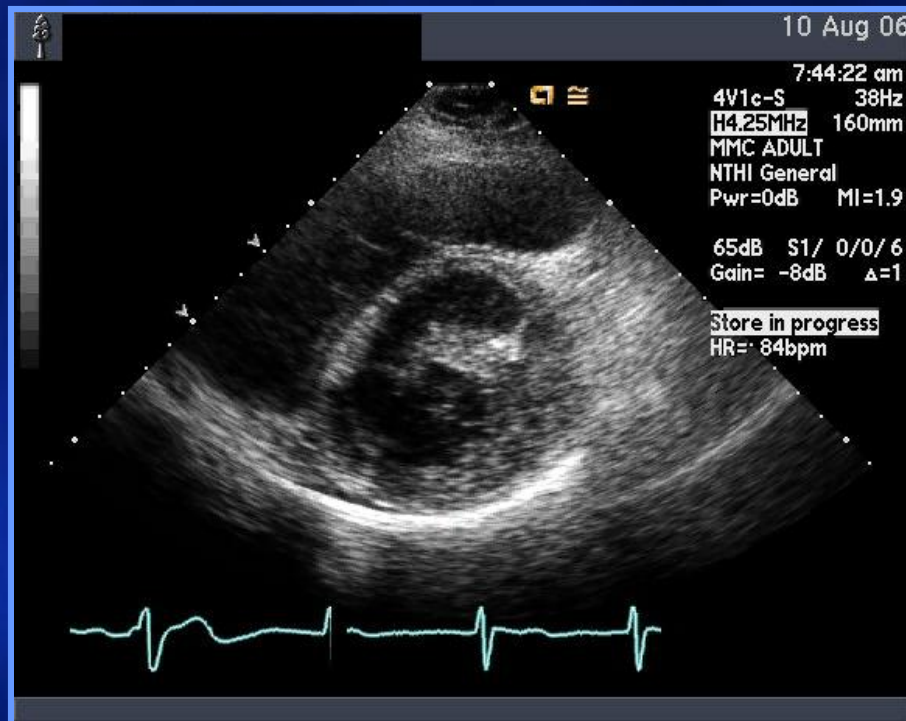
Echocardiographic Assessment of Commissural Calcium



Cannan CR, Nishimura RA, Reeder GS et al. *J Am Coll Cardiol* 1997;29:175-80

Commissural/Leaflet Calcification

2D Echo



3D Live TEE

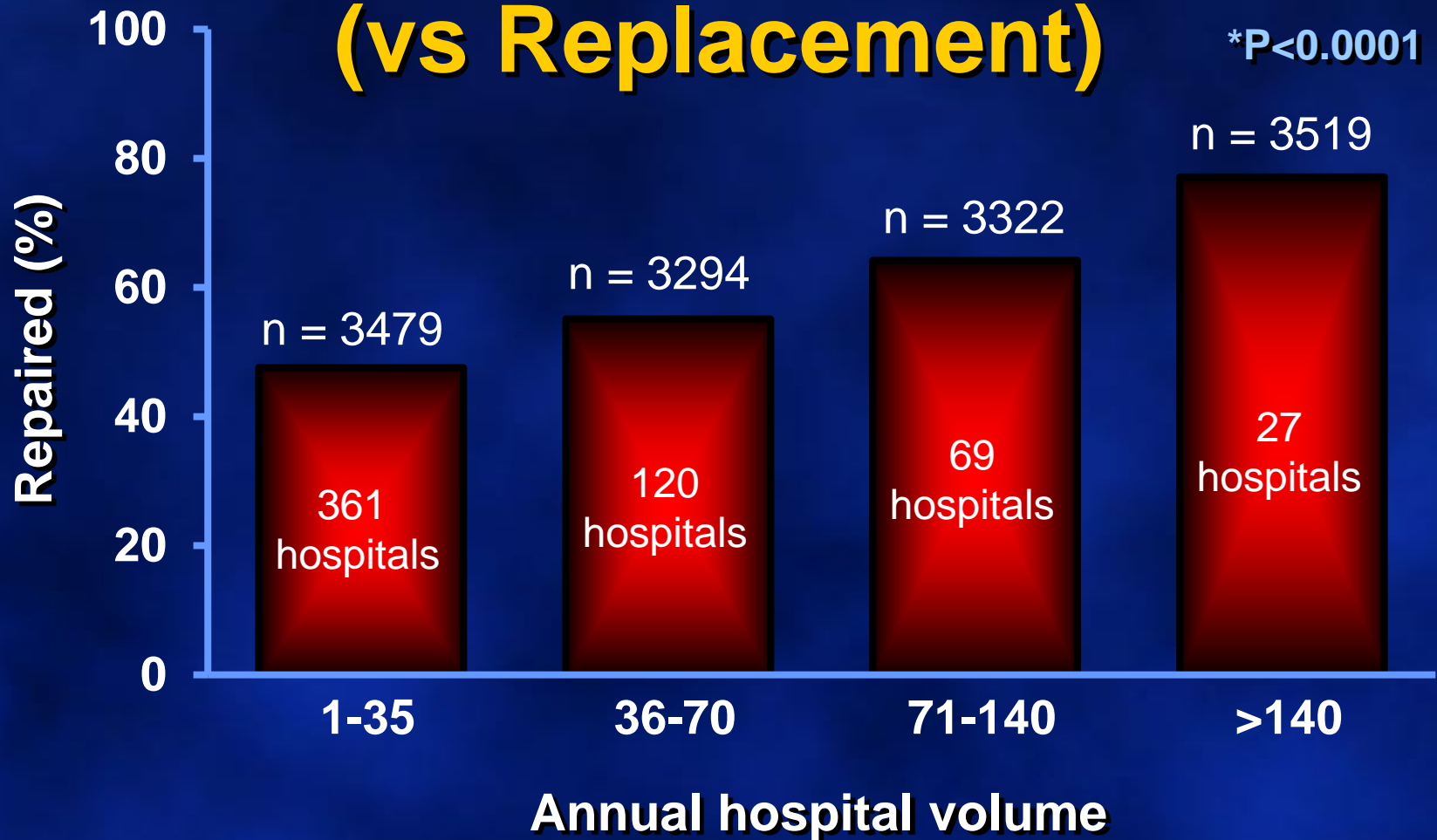


View from LV

2014 ACC/AHA Guidelines: Class IIa Indications for Surgery in Mitral Regurgitation

- Mitral valve repair is reasonable in asymptomatic patients with chronic severe primary MR with preserved LV function (**LVEF \geq 60% and LVEDD $<$ 40 mm**) in whom the likelihood of **successful repair without residual MR is $>$ 95%** with an **expected mortality less than 1%** when performed at a **Heart Valve Center of Excellence** (*Level of Evidence: B*)

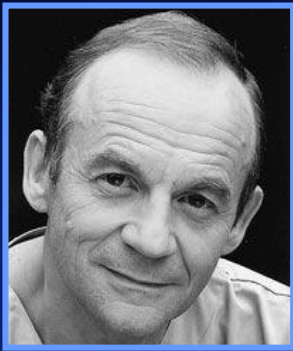
STS Database: Rate of Mitral Valve Repair (vs Replacement)



Adapted from Gammie JS et al. *Ann Thorac Surg* 2007 and 2009

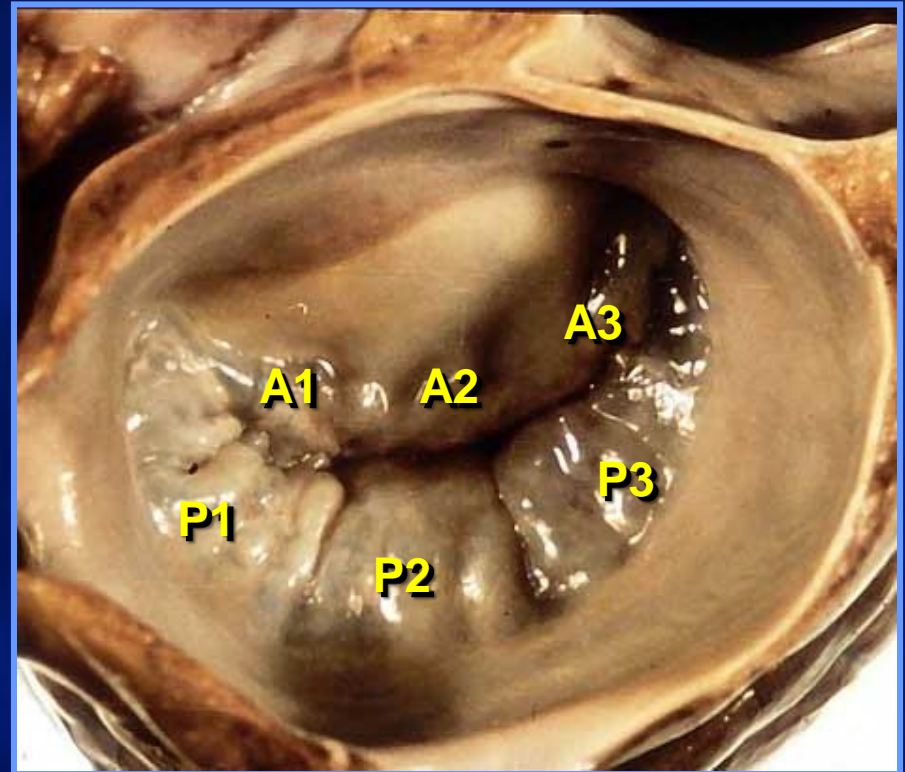
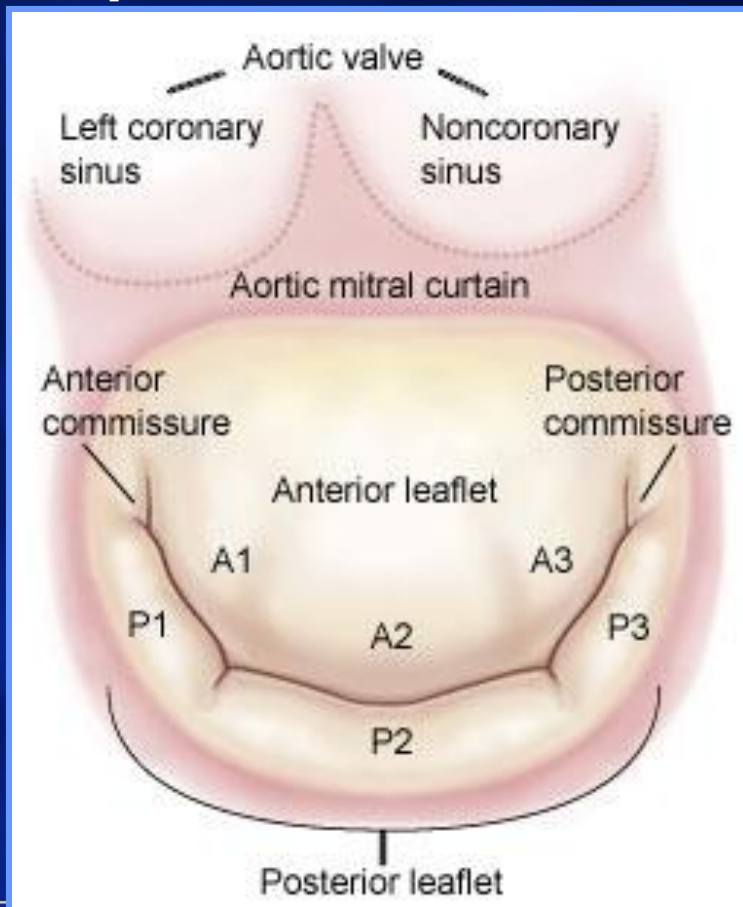
Feasibility of Mitral Repair

1. Surgeon's skill and experience
2. Accurate identification the anatomic lesions of the mitral valve
 - Echocardiography is pivotal in defining the functional anatomy of the mitral valve
 - Surgeon and Echocardiographer
 - Speaking a common language
 - Mutual respect and honesty
 - Team based approach



Mitral Valve Anatomy: View from the Left Atrium

Carpentier Nomenclature

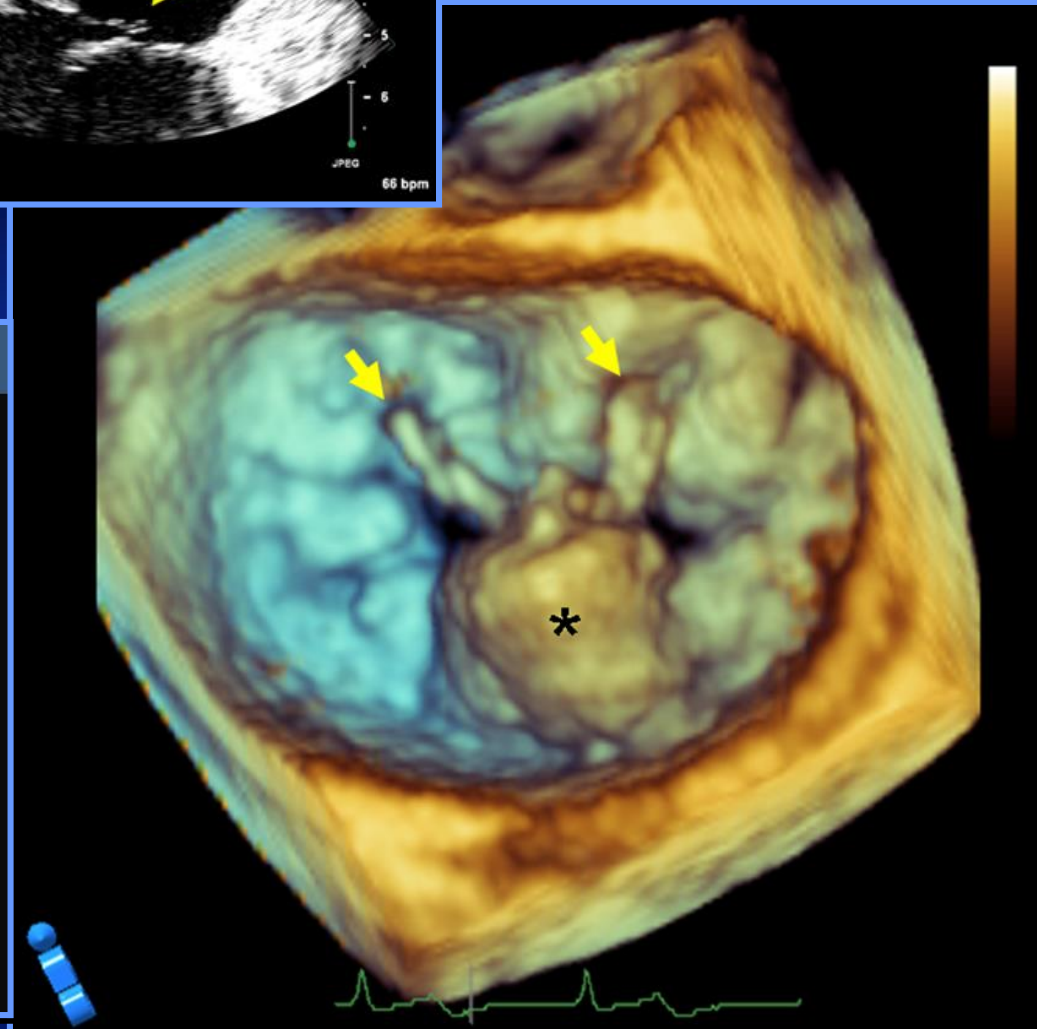


Flail Posterior Leaflet (P2)

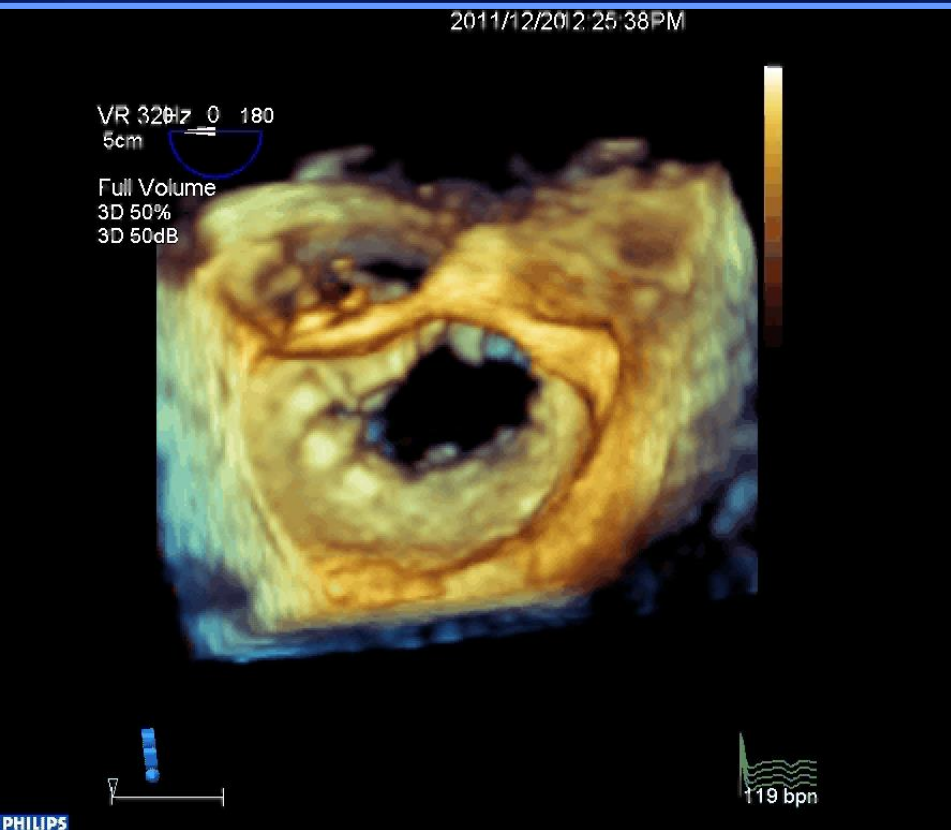


↓ 3D TEE ↓

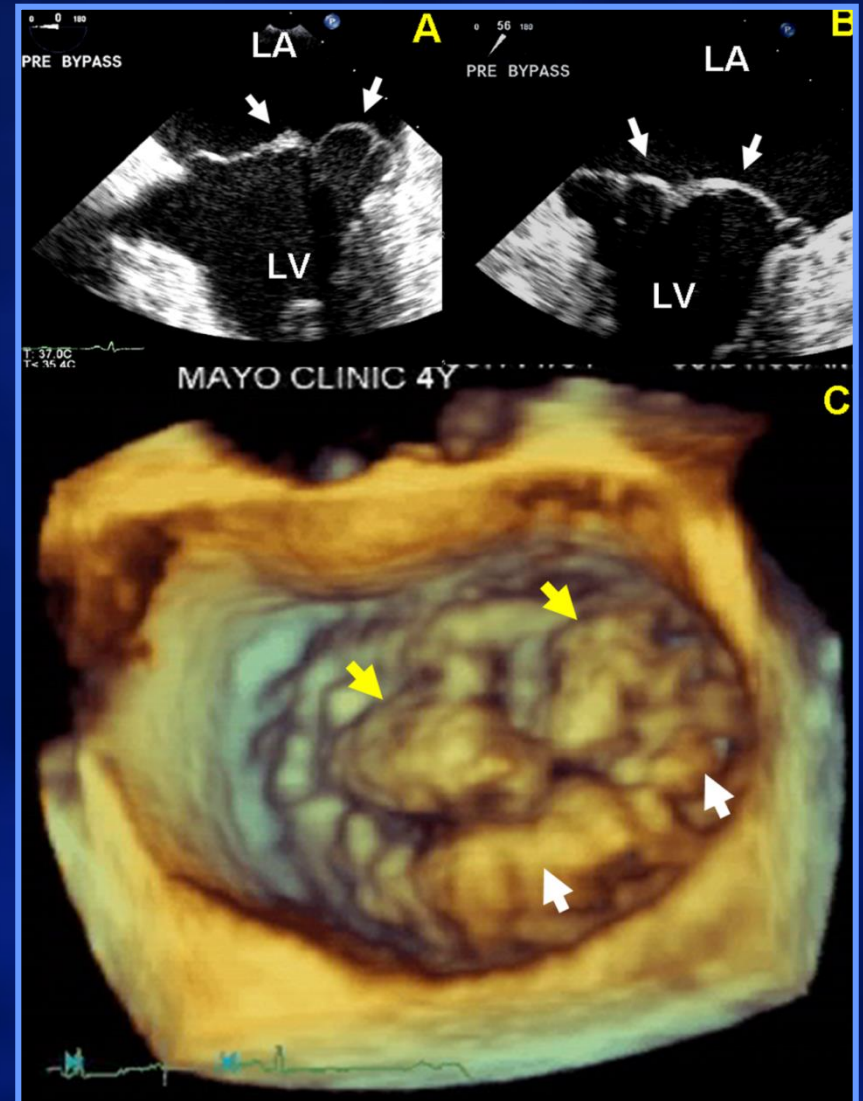
↓ 2D TEE ↓



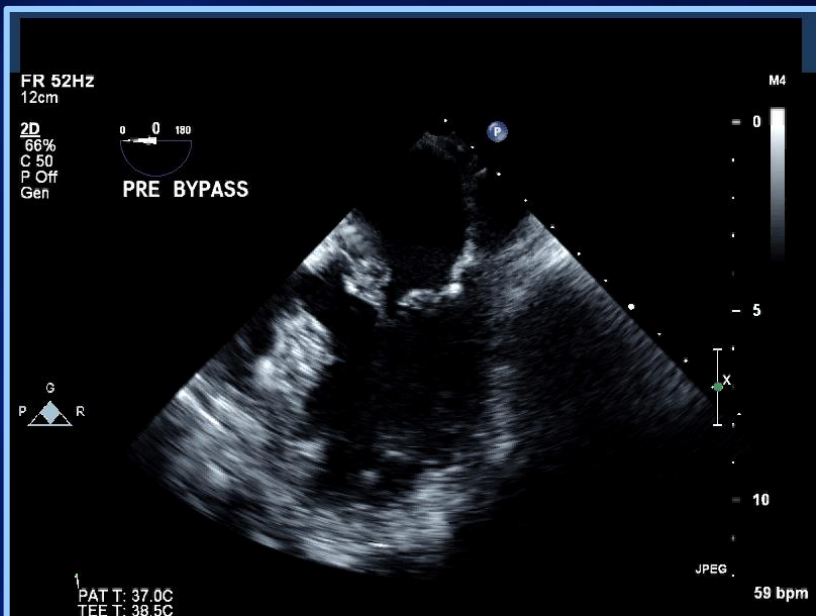
“All Flail Anterior Leaflets are Equal, But Some are More Equal than Others”



Barlow's MV Disease

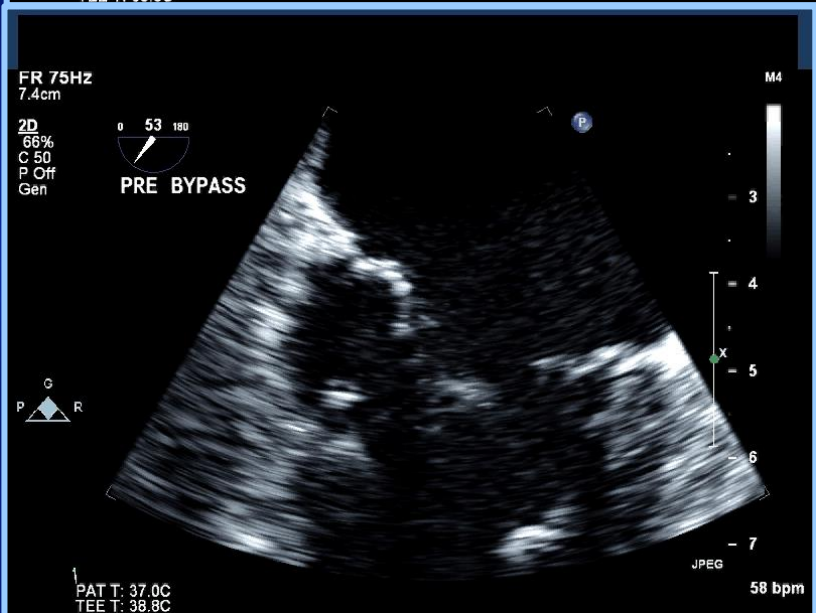


Flail P3



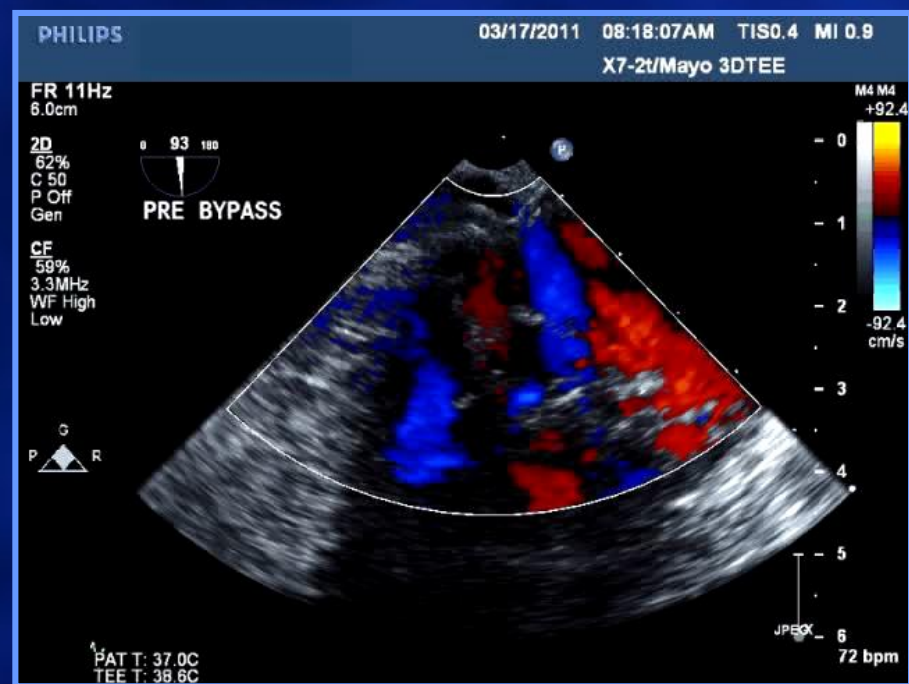
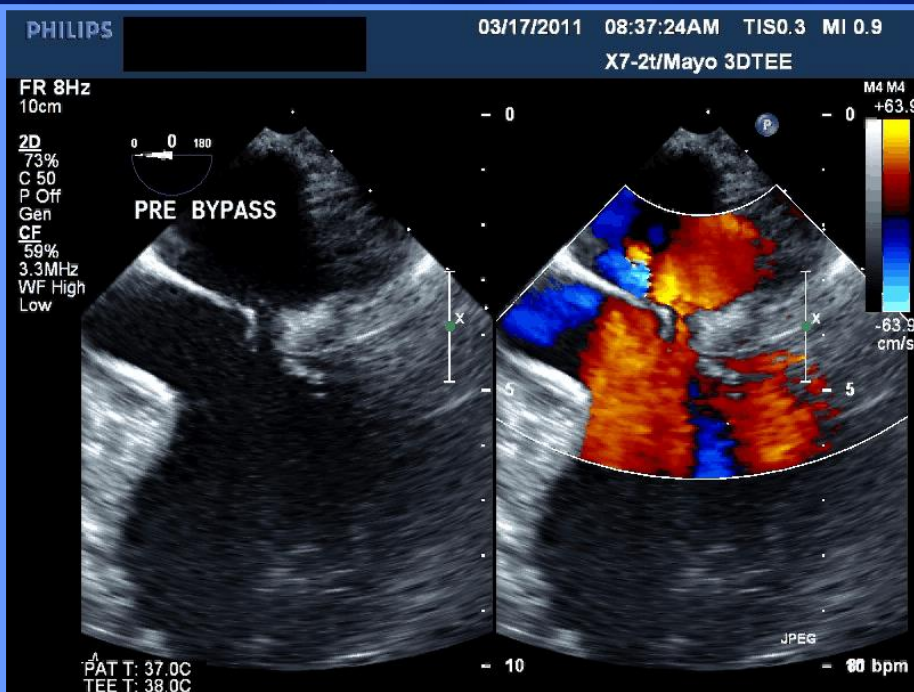
← 0° View

3D TEE



← 60° View

↑View from LA↑
“Surgeon’s View”



PHILIPS

03/17/2011 08:21:12AM TIS0.2 MI 0.5

X7-2t/Mayo 3DTEE

FR 44Hz

11cm

M4

Full Volume 0 50 100

3D 31%

3D 40dB

PRE BYPASS



JPEG

72 bpm

PAT T: 37.0C
TEE T: 36.3C

PHILIPS

03/17/2011 08:21:12AM TIS0.2 MI 0.5

X7-2t/Mayo 3DTEE

FR 44Hz

11cm

M4

Full Volume 0 50 100

3D 21%

3D 40dB

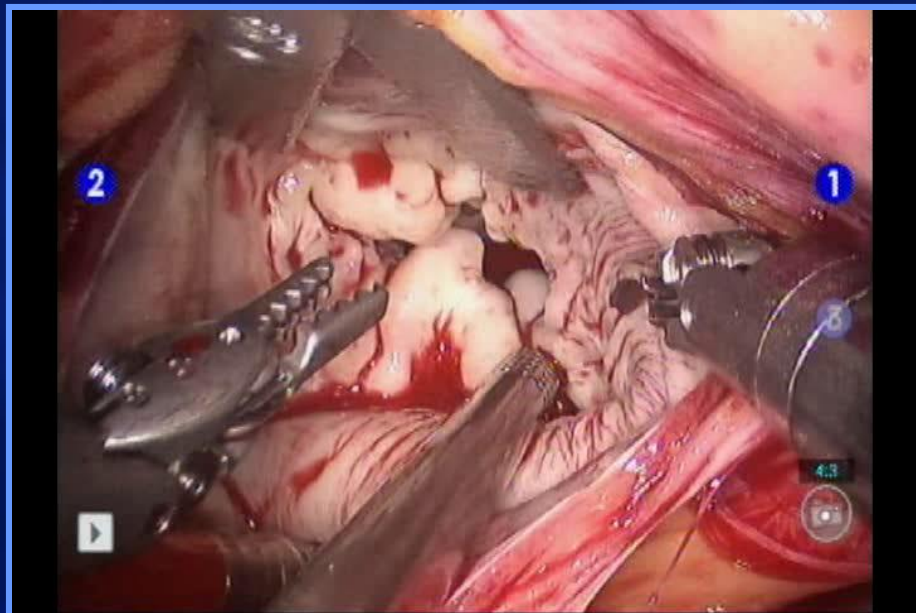
PRE BYPASS



JPEG

72 bpm

PAT T: 37.0C
TEE T: 36.3C



Objectives

CLINICAL INVESTIGATIONS

VALVULAR HEART DISEASE

J Am Soc Echocardiogr 2009;22:34-41

Real-Time Three-Dimensional Transesophageal Echocardiography in the Intraoperative Assessment of Mitral Valve Disease

Jasmine Grewal, MD, Sunil Mankad, MD, William K. Freeman, MD,
Roger L. Click, MD, PhD, Rakesh M. Suri, MD, Martin D. Abel, MD, Jae K. Oh, MD,
Patricia A. Pellikka, MD, Gillian C. Nesbitt, MD, Imran Syed, MD, Sharon L. Mulvagh, MD,
and Fletcher A. Miller, MD, *Rochester, Minnesota*

pathologic anatomy of the MV leaflets and apparatus

Detection of Pathology with 2D and Live 3D TEE

n = 42 patients

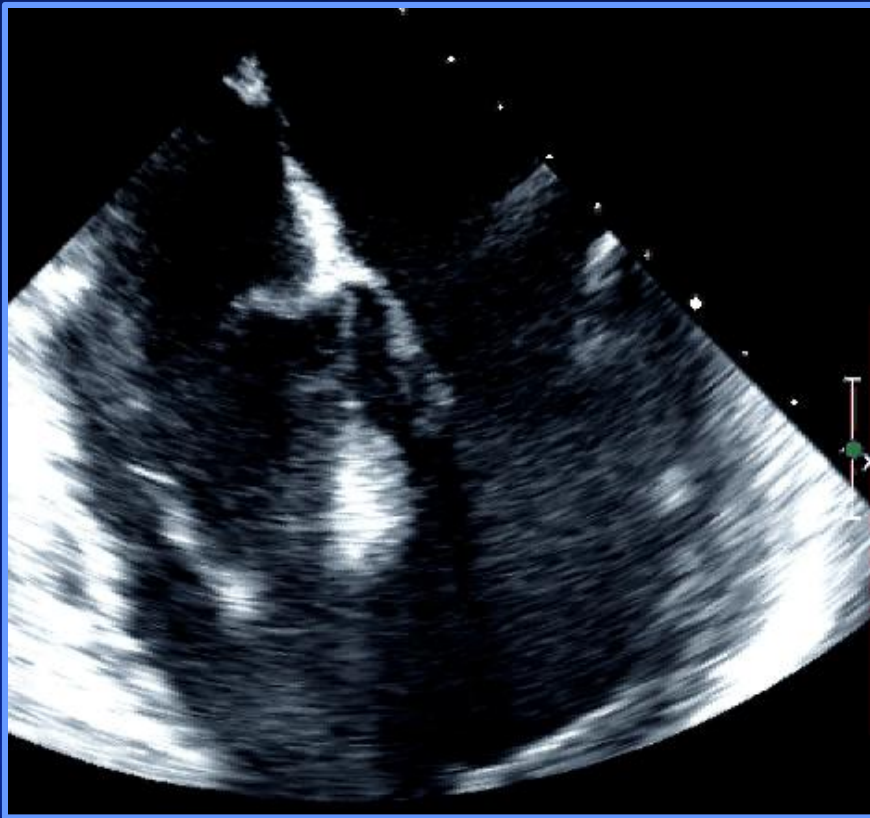
Sensitivity (%)		Specificity (%)		Accuracy (%)	
2D	3D	2D	3D	2D	3D

- The predominant MV pathology was correctly identified in **98%** vs. **90%** of patients for 3D TEE vs. 2D TEE ($p < 0.05$)

† $p < 0.05$ versus 2D TEE; BL= bileaflet involvement

What's wrong with this Mitral Valve?

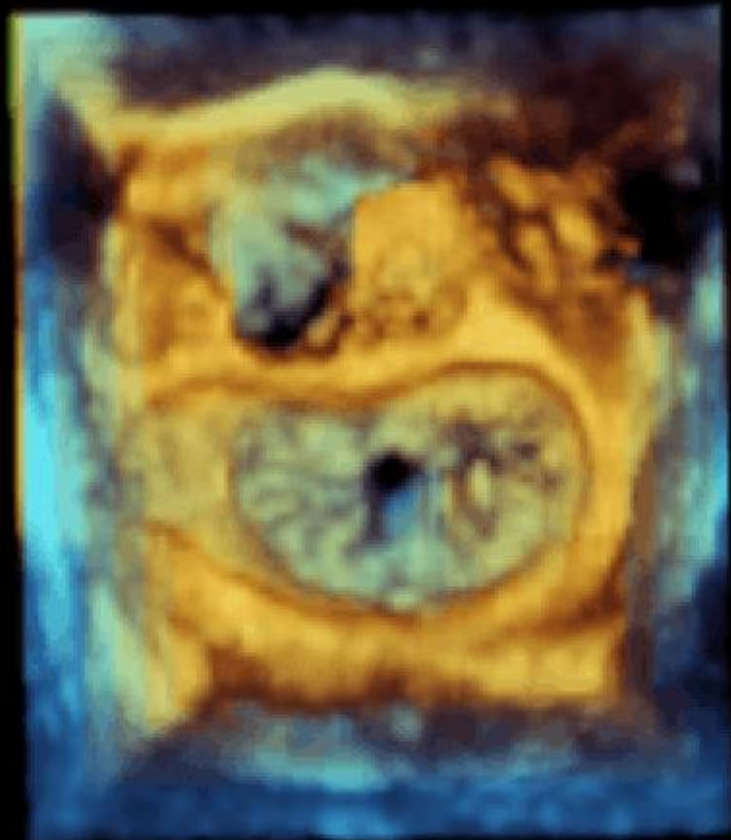
4 Chamber View (0°)



Commissural View (60°)



Flail P2 with P3 Prolapse



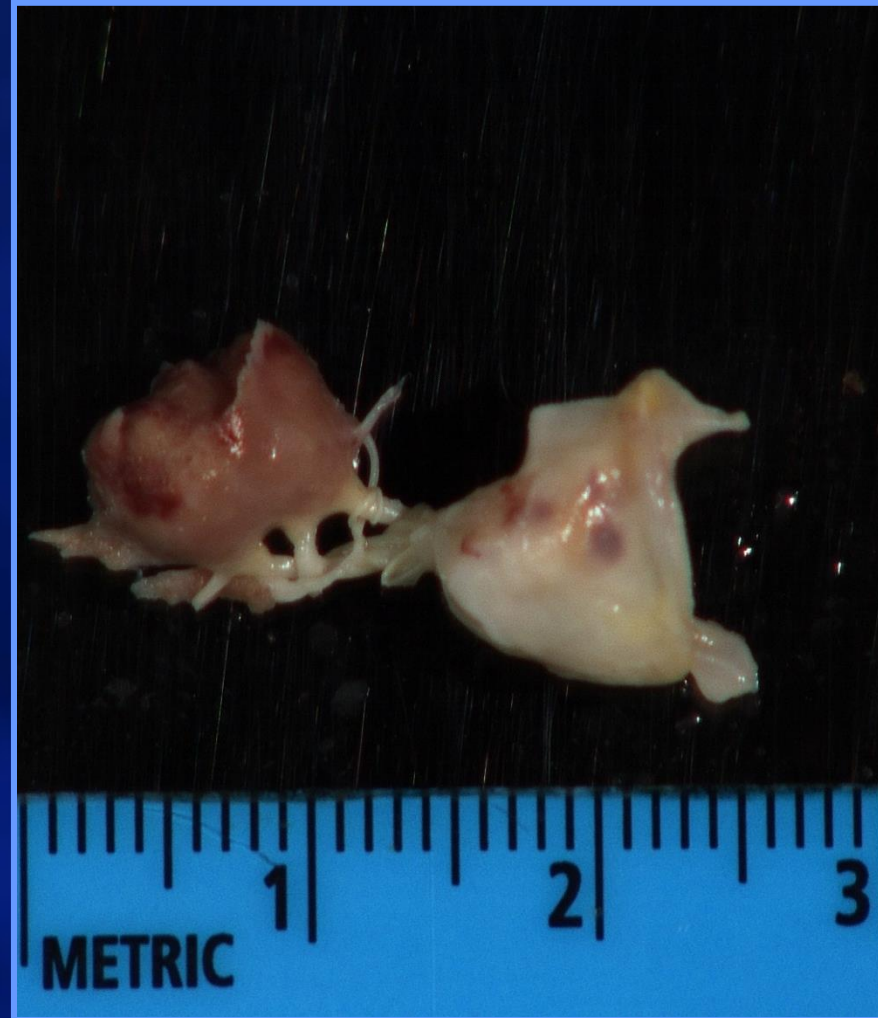
“We’re almost free my friends, I just felt a drop of rain”



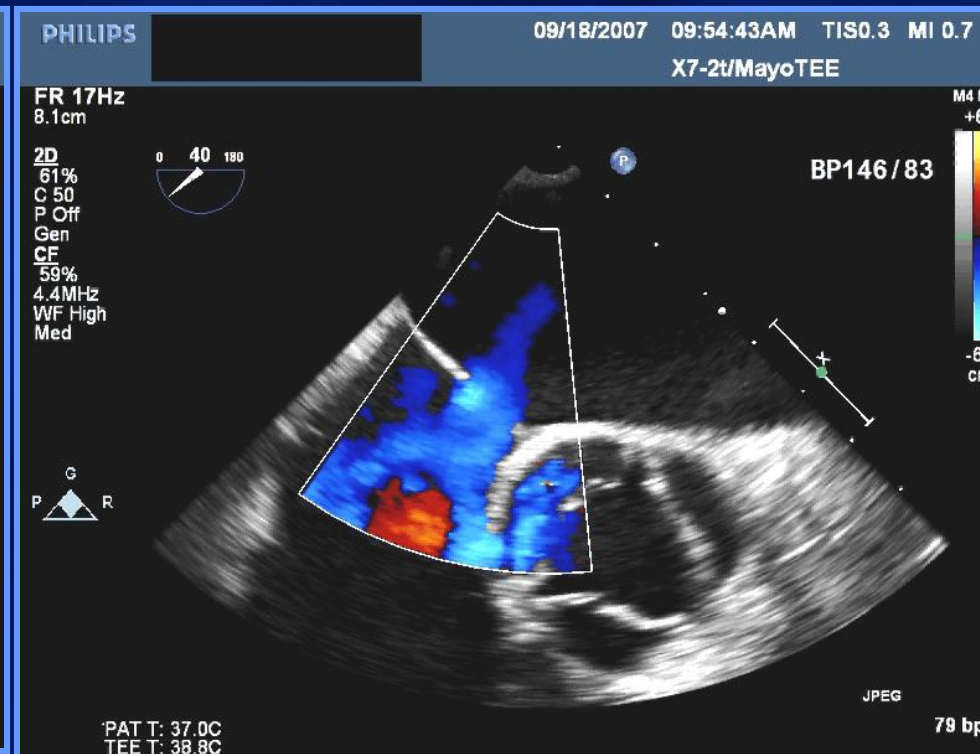
62 yo woman with chest pain and severe pulmonary edema



Papillary Muscle Rupture 3D TEE and Gross Pathology



Ostium Secundum ASD: 2D TEE



Ostium Secundum ASD: 3D TEE

“En Face” View from LA

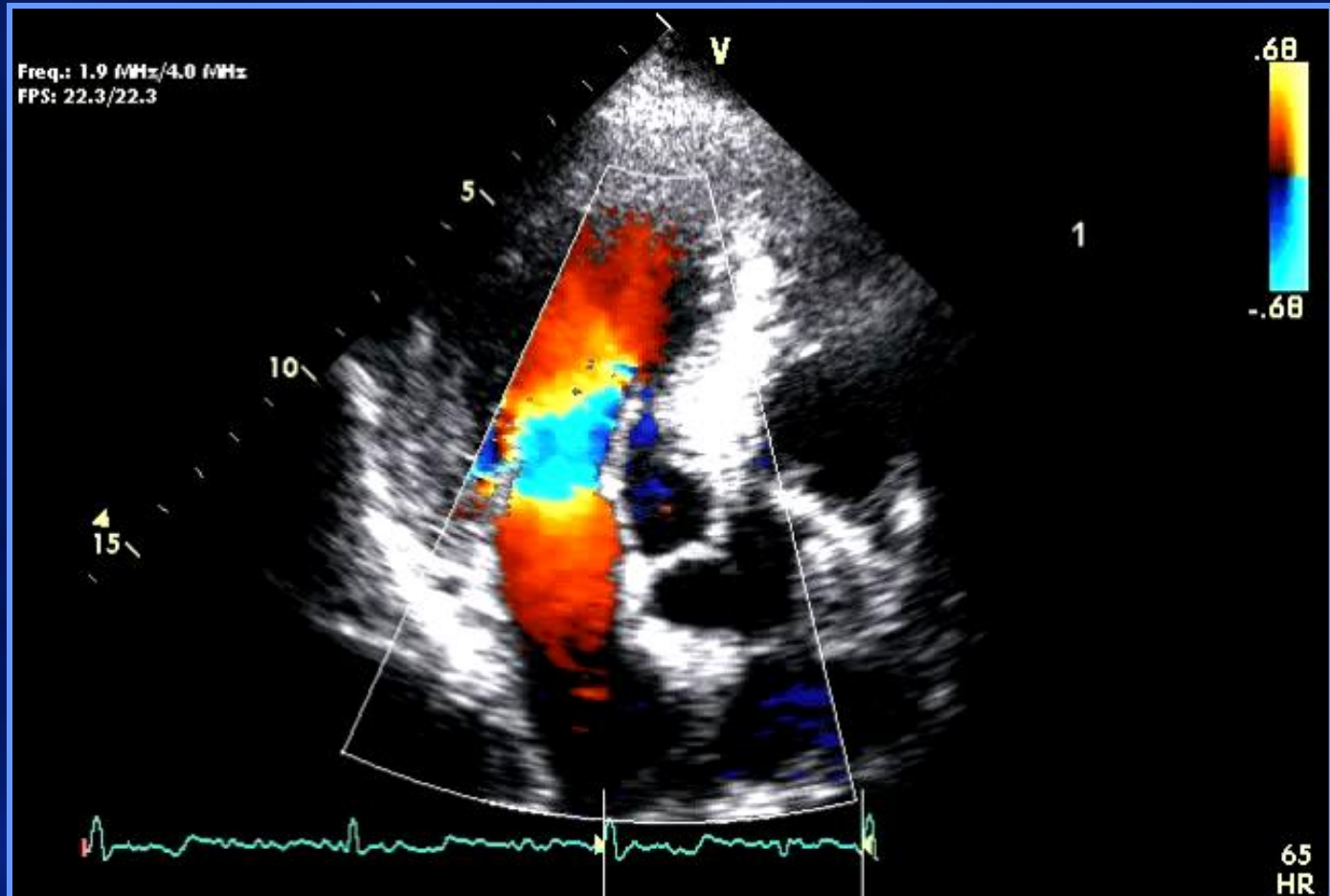
“En Face” View from RA



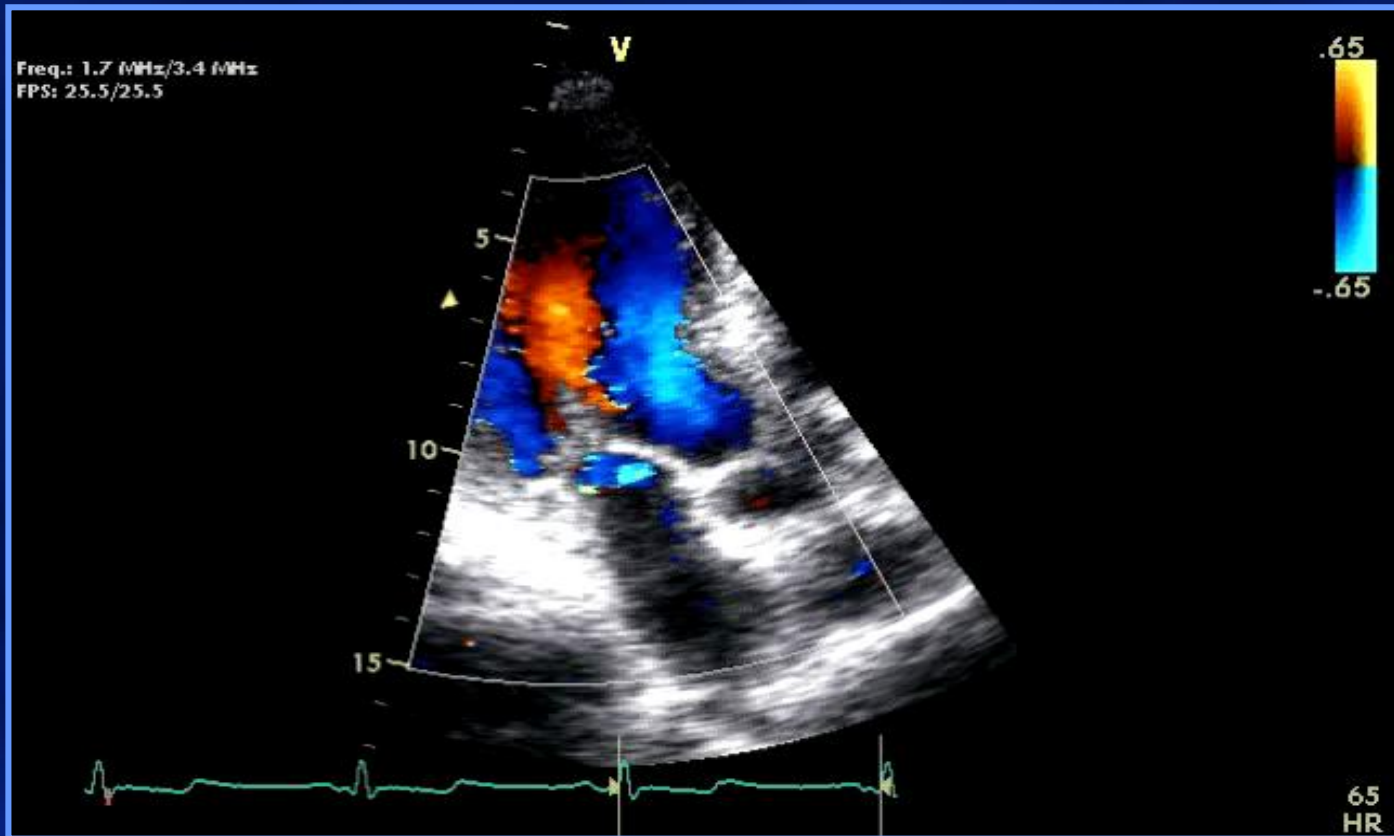
Case Study

- 58 year old male
- Amyloidosis
 - Renal Biopsy
- Severe Dyspnea on Exertion
- Referred to Mayo Clinic: Dr. Jae K. Oh
 - Transthoracic Echo Performed

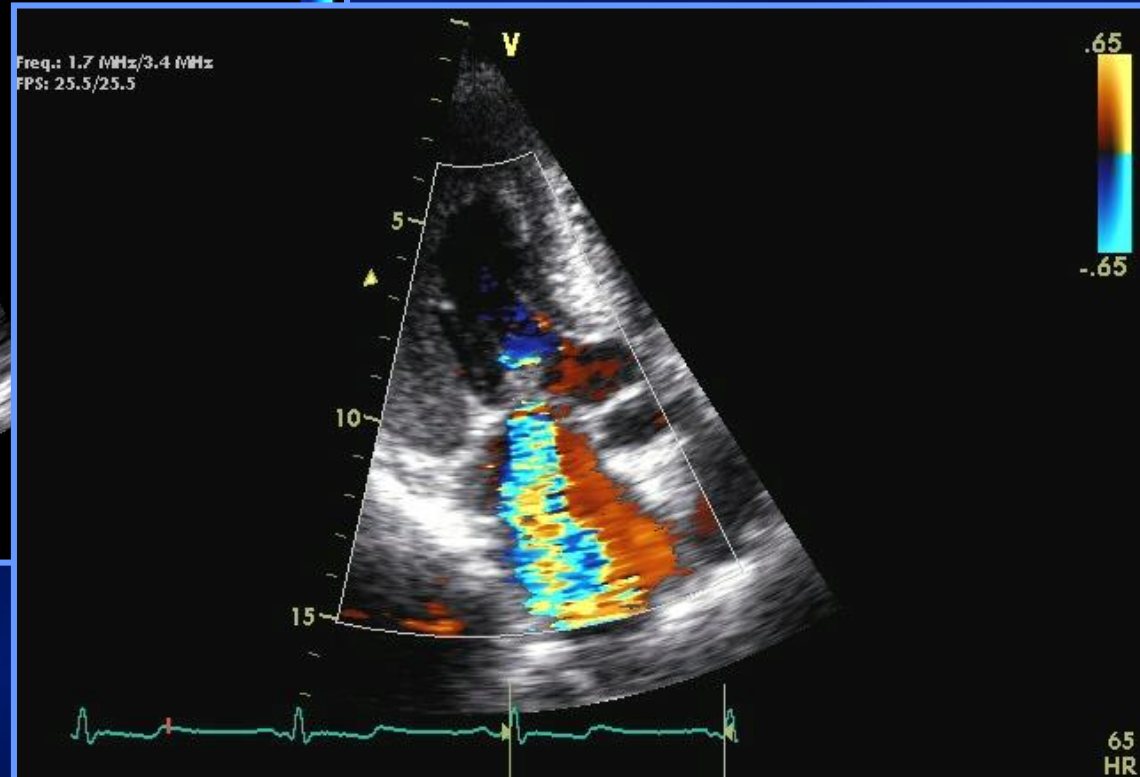
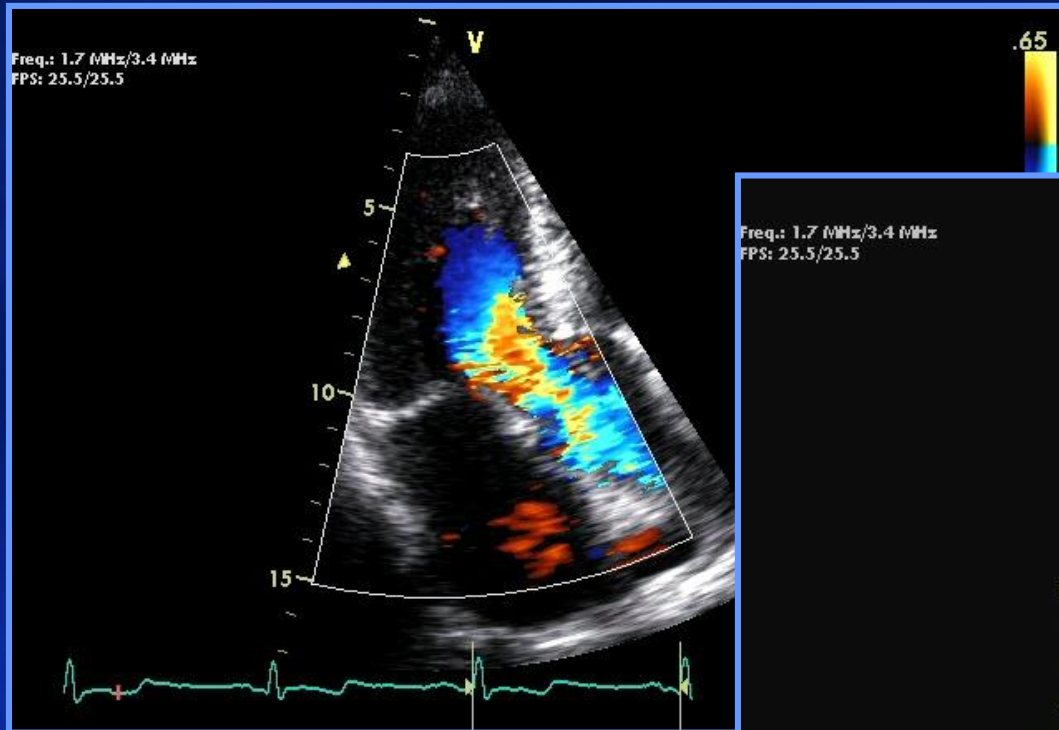
Trivial Mitral Regurgitation Early During Study



Severe Mitral Regurgitation Later in Study



Variable Mitral Regurgitation During Study



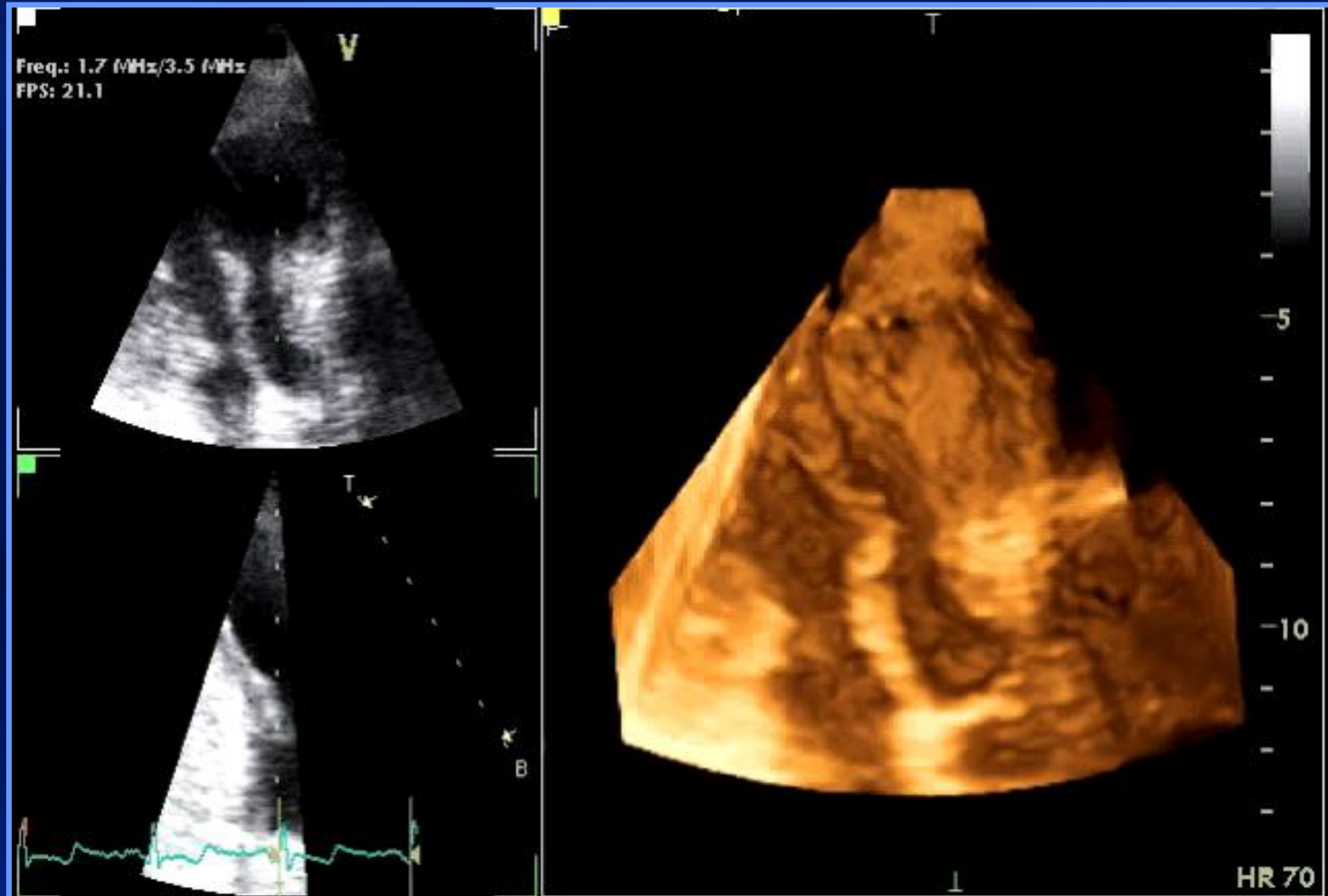
2D Echo of MV Apparatus

Trivial MR

Severe MR



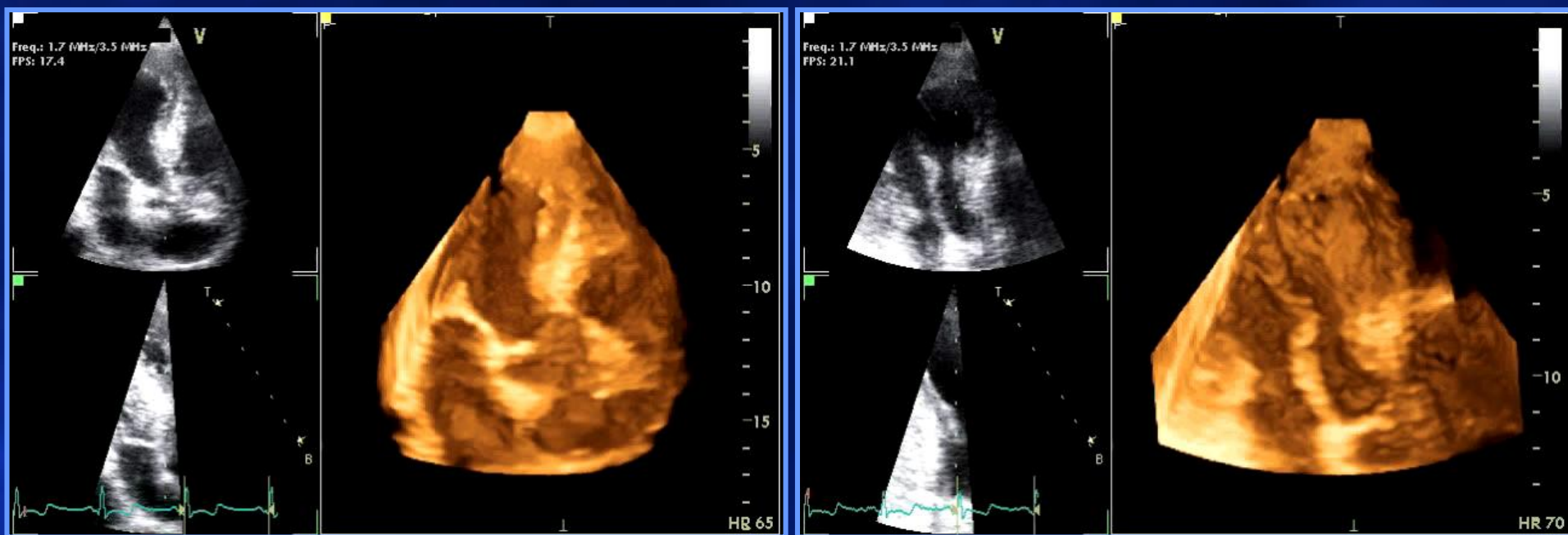
Etiology of Mitral Regurgitation is Revealed by 3D Echo



3D Echo during Valsalva Maneuver: Dynamic LVOT Obstruction

Trivial Mitral Regurgitation

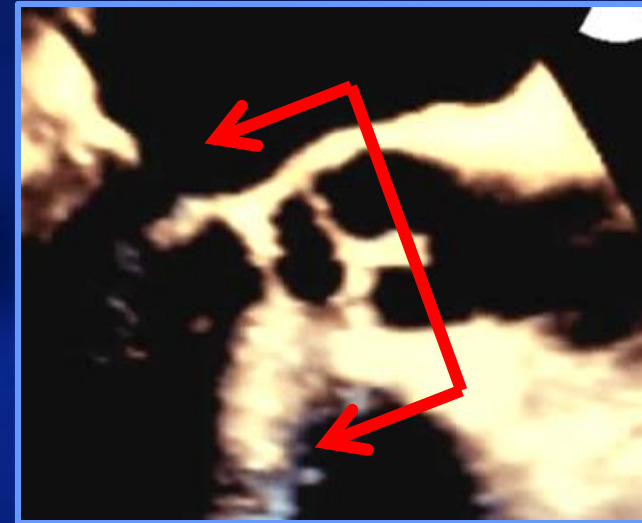
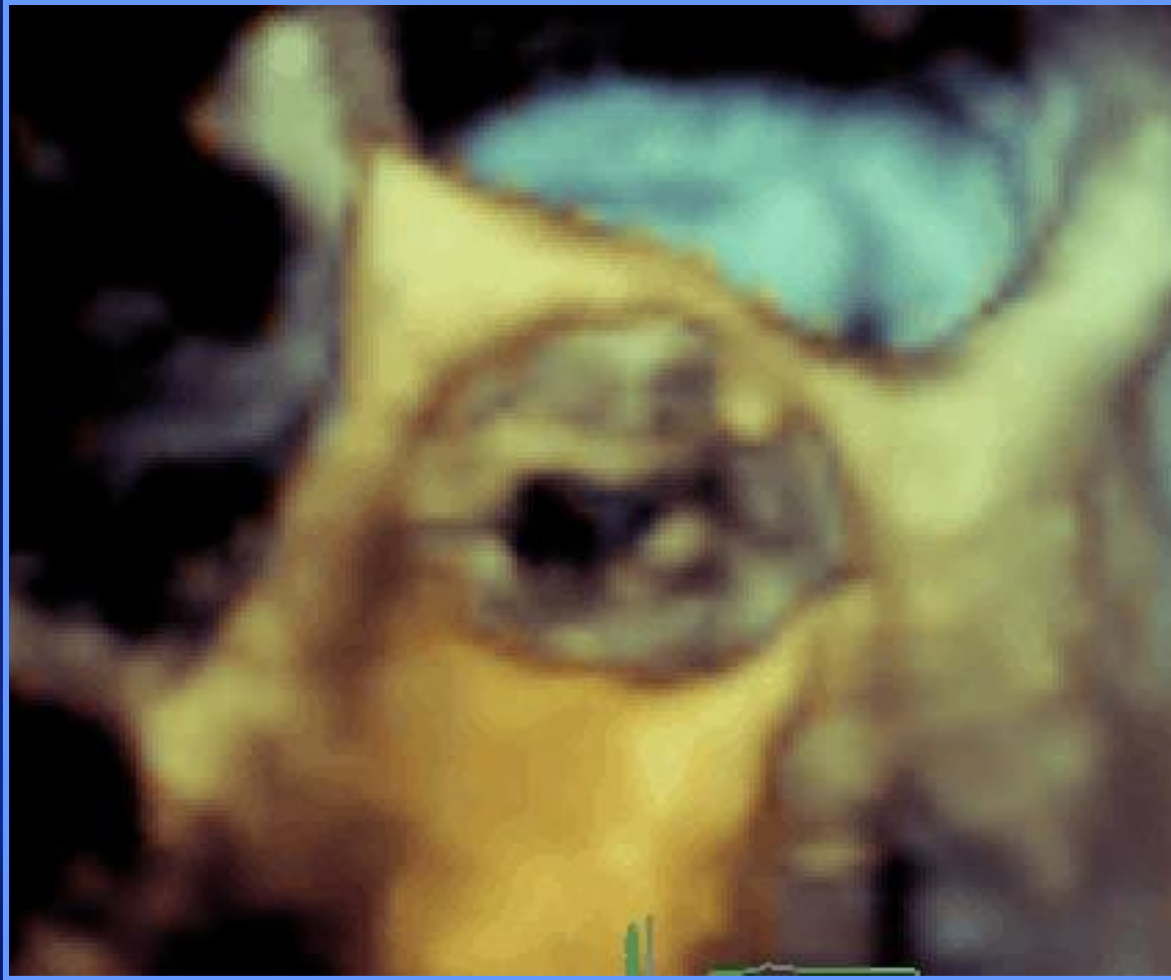
Severe Mitral Regurgitation



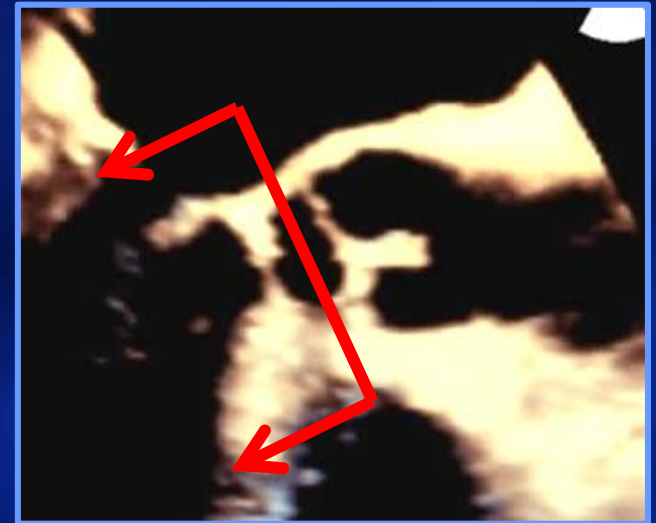
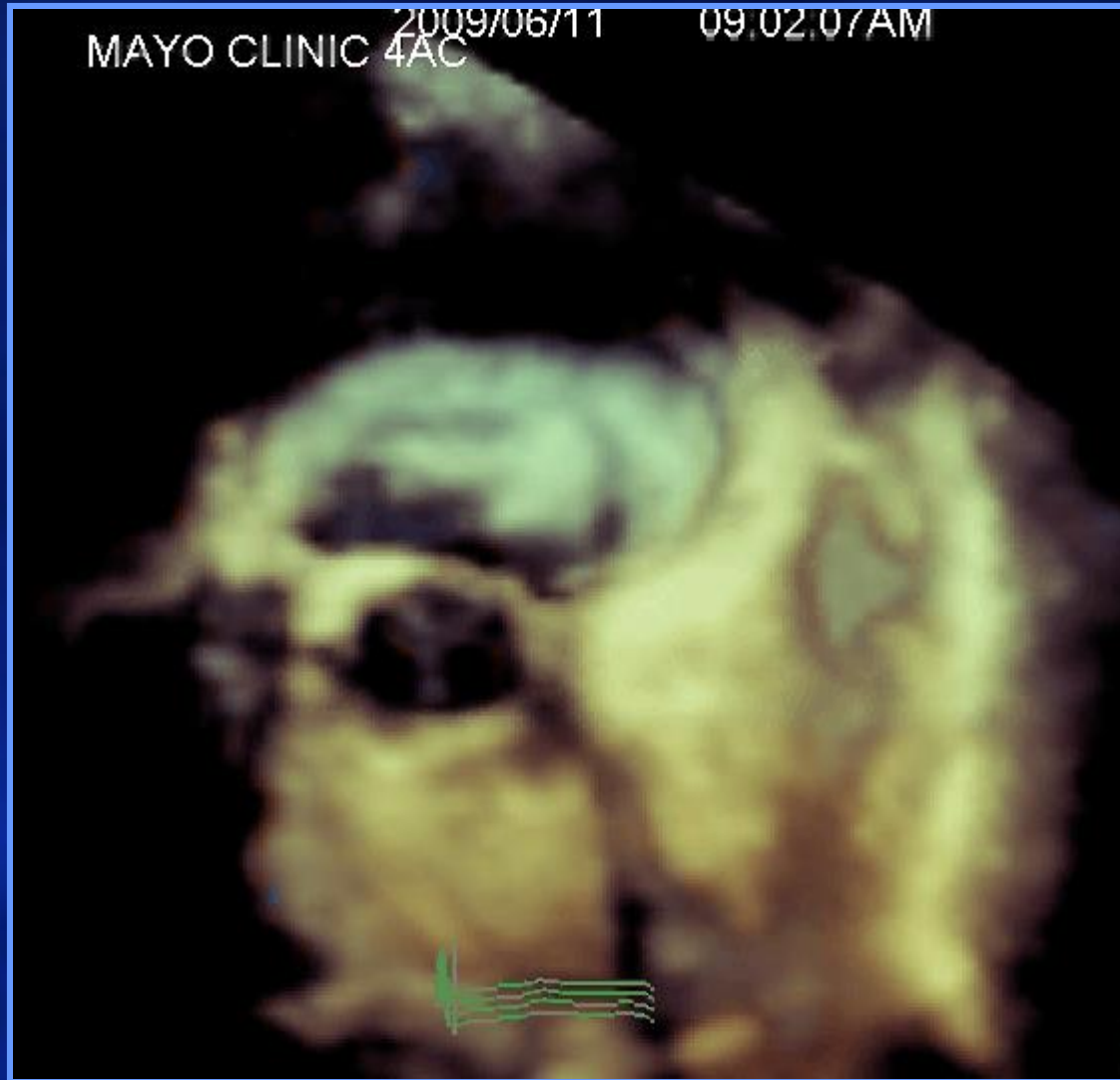
MV Systolic Anterior Motion and a Discrete Subaortic Membrane



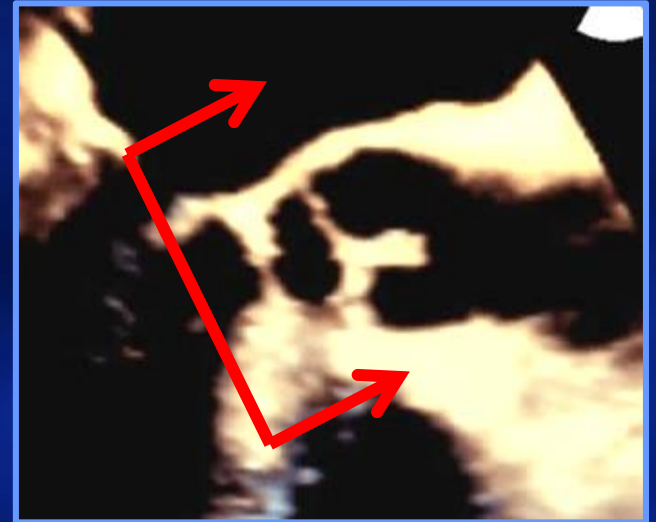
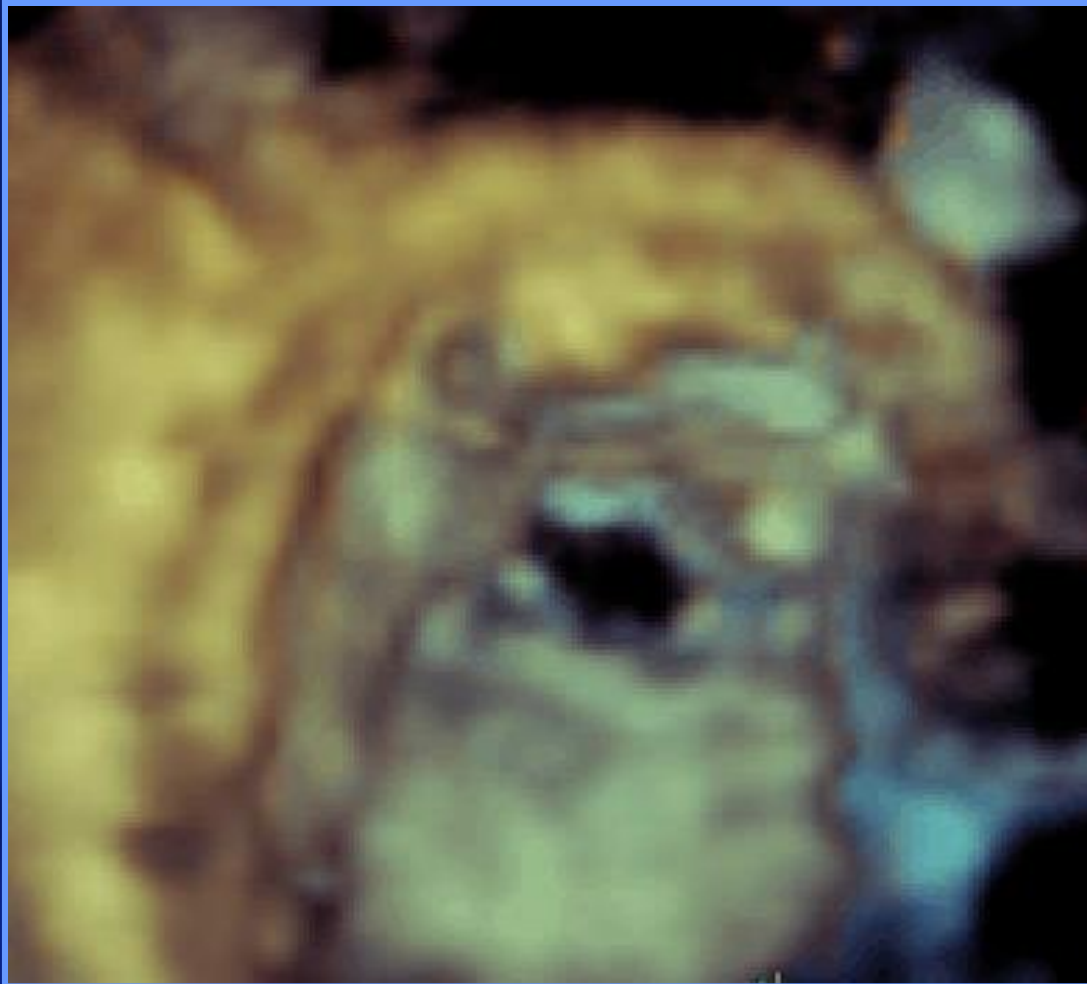
En Face View: Above/Through AV



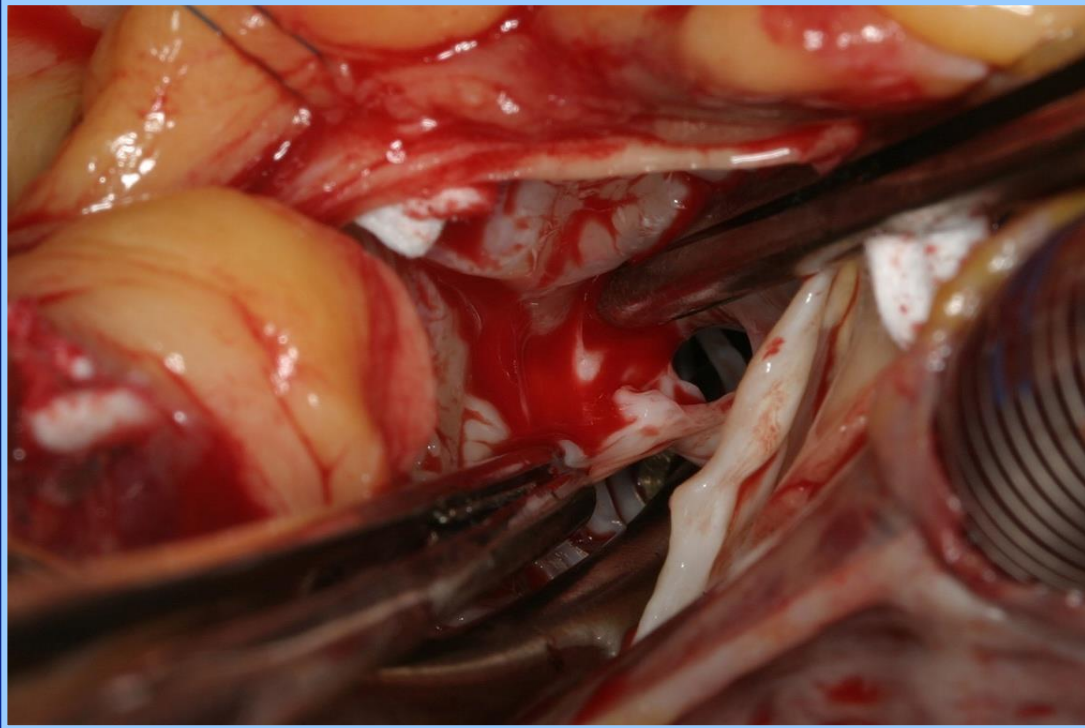
En Face View: Below AV



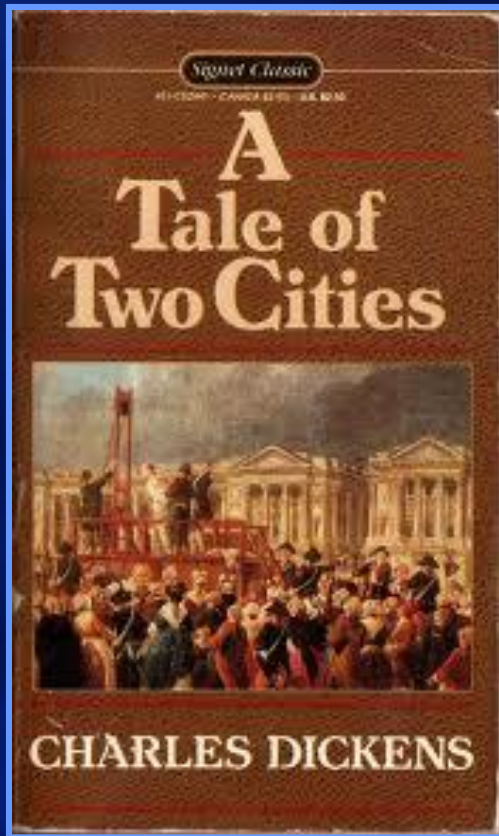
En Face View: From LVOT



Surgery

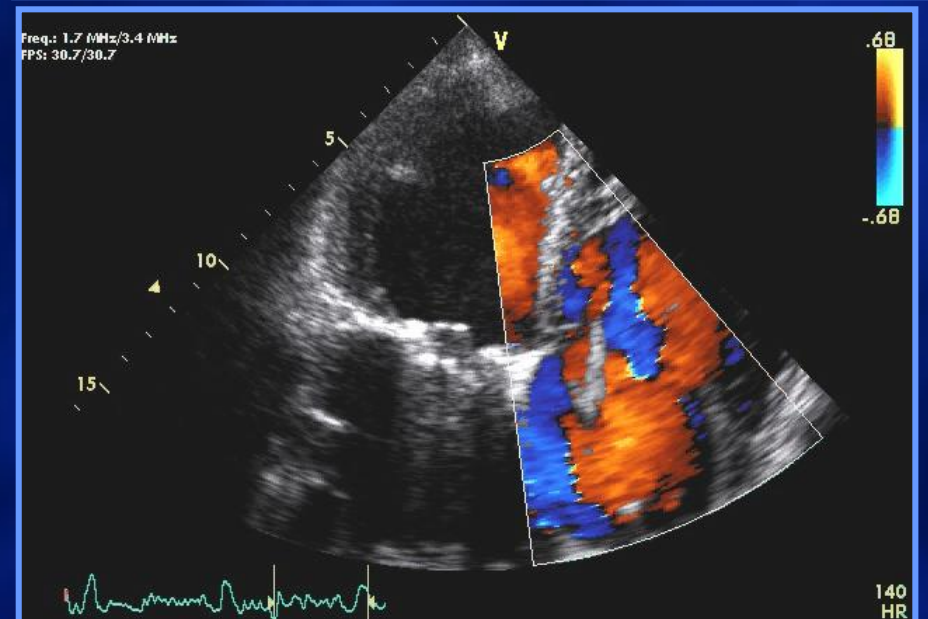
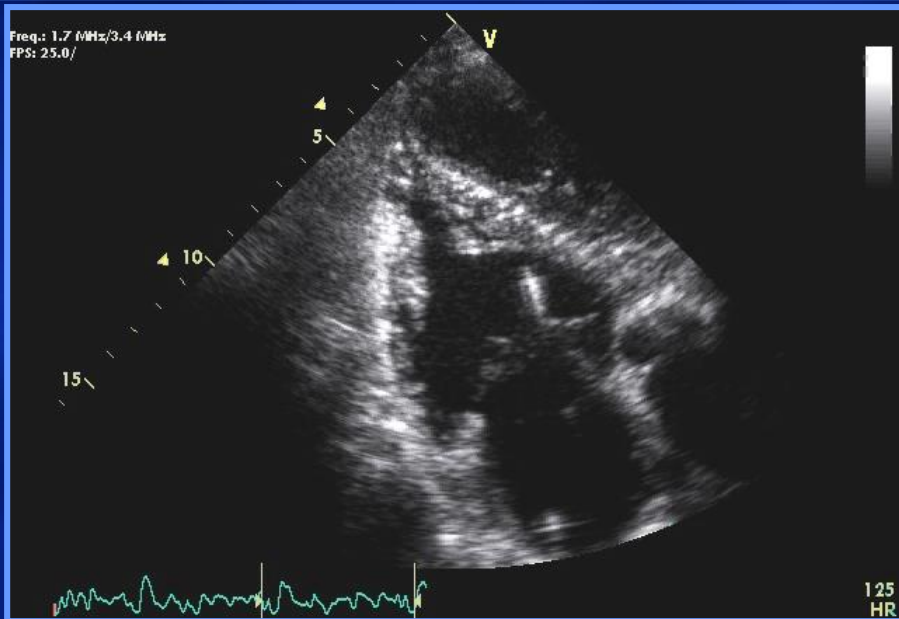
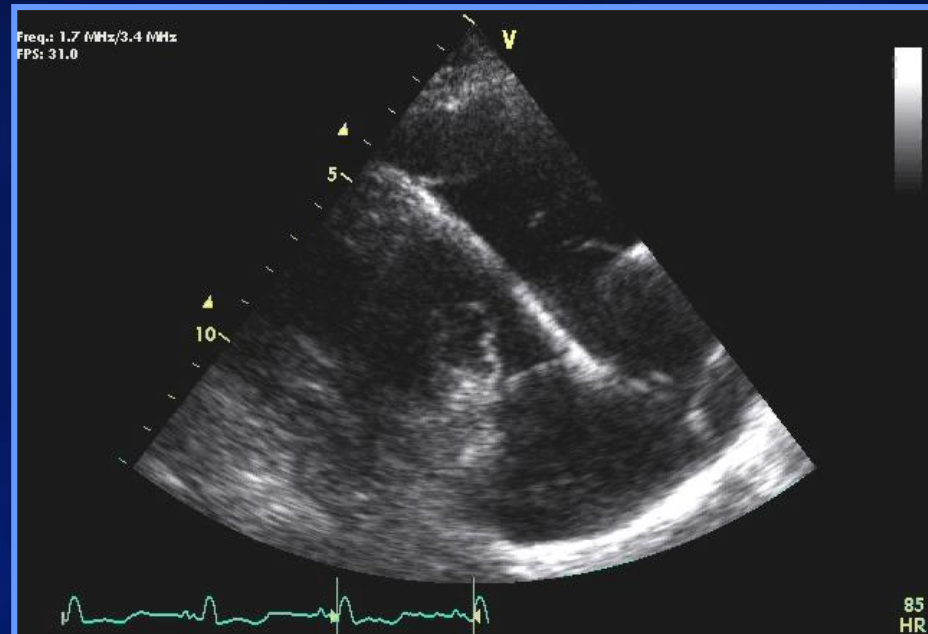
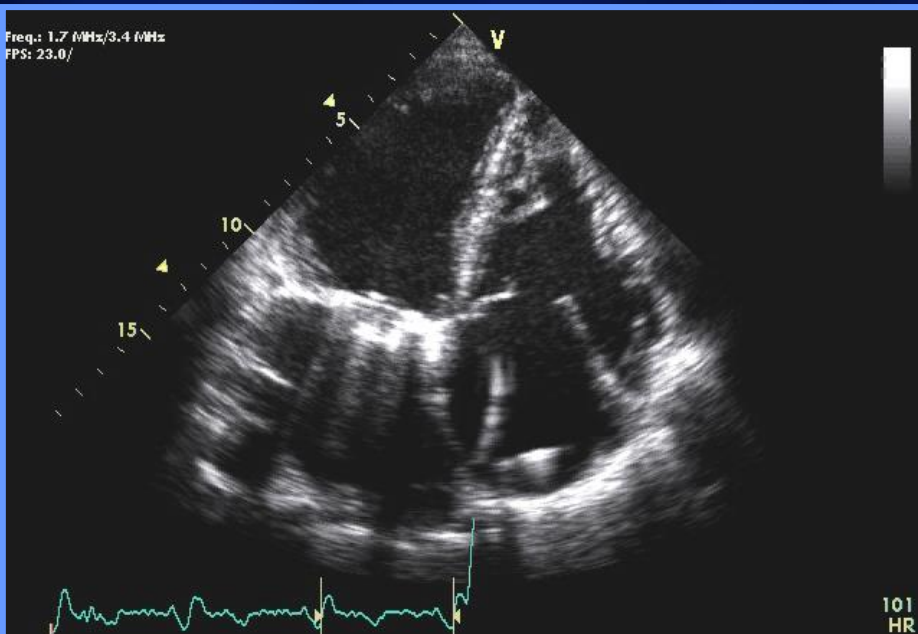


A Tale of 2 Tricuspid Valves

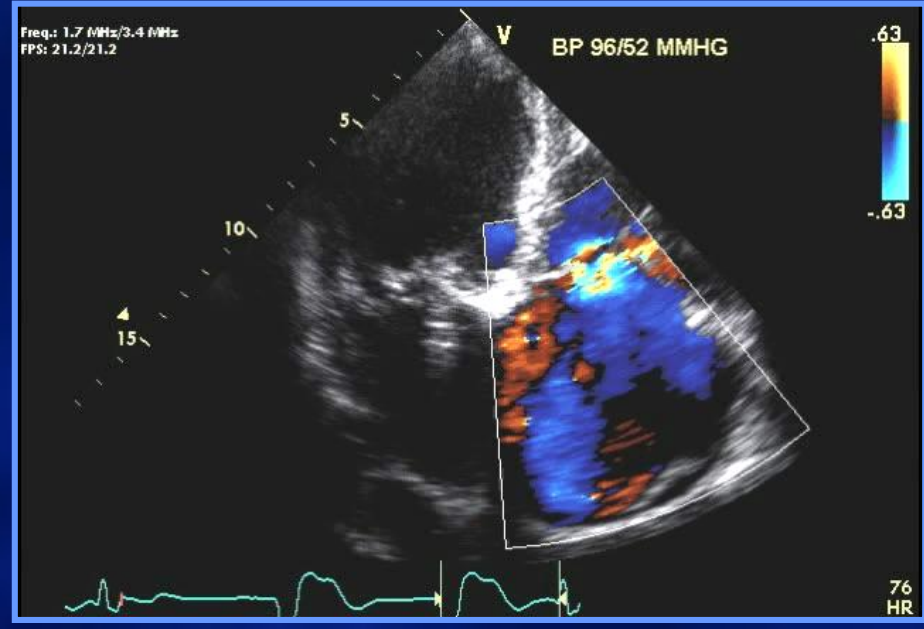
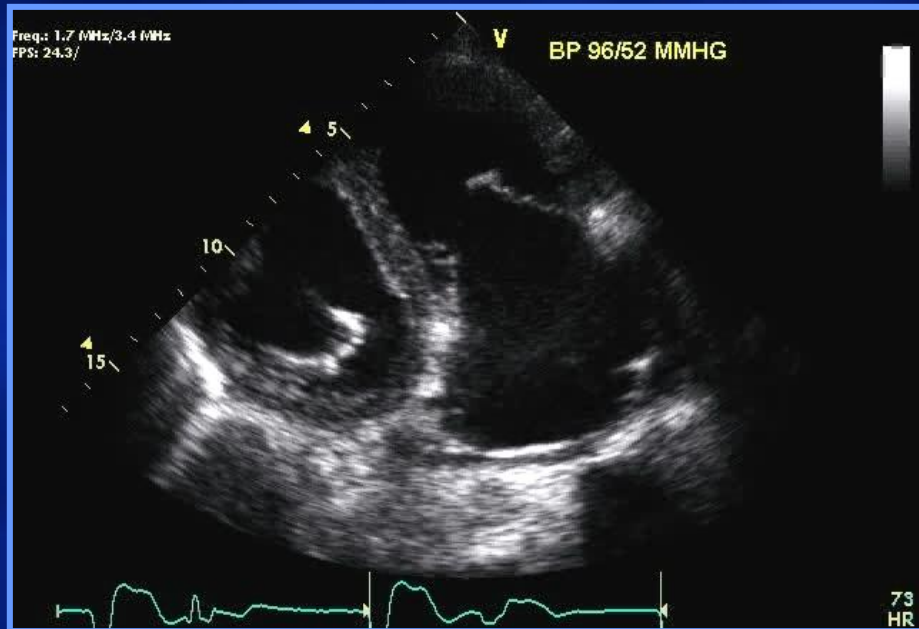
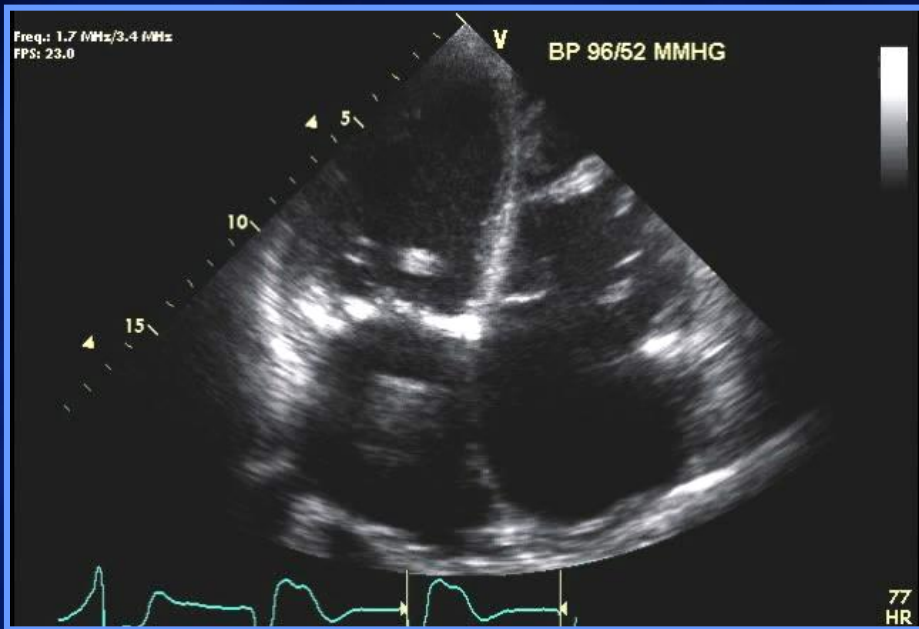


- 2 Patients
- Both have pacemakers
- Both have severe tricuspid regurgitation
 - ? mechanism

Patient #1



Patient #2



Heart Rhythm Disorders

Severe Symptomatic Tricuspid Valve Regurgitation Due to Permanent Pacemaker or Implantable Cardioverter-Defibrillator Leads

Grace Lin, MD,* Rick A. Nishimura, MD, FACC,* Heidi M. Connolly, MD, FACC,*
Joseph A. Dearani, MD,† Thoralf M. Sundt III, MD,† David L. Hayes, MD, FACC*
Rochester, Minnesota

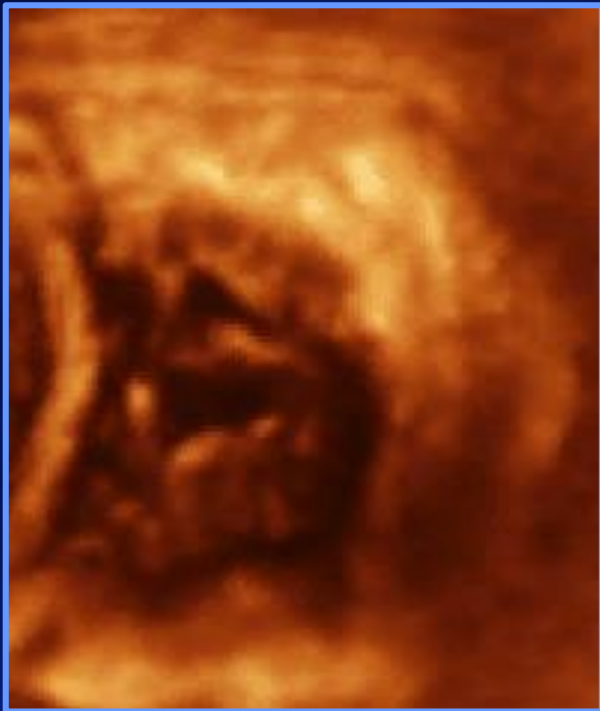
- **N= 41 patients w/**
- **severe TR secondary**
- **to PPM lead**
- **2D TTE diagnostic in**
- **only 5/41 patients**
- **(12%)**
- **2D TEE diagnostic in**
- **17/38 patients (45%)**

Table 3. Operative Findings

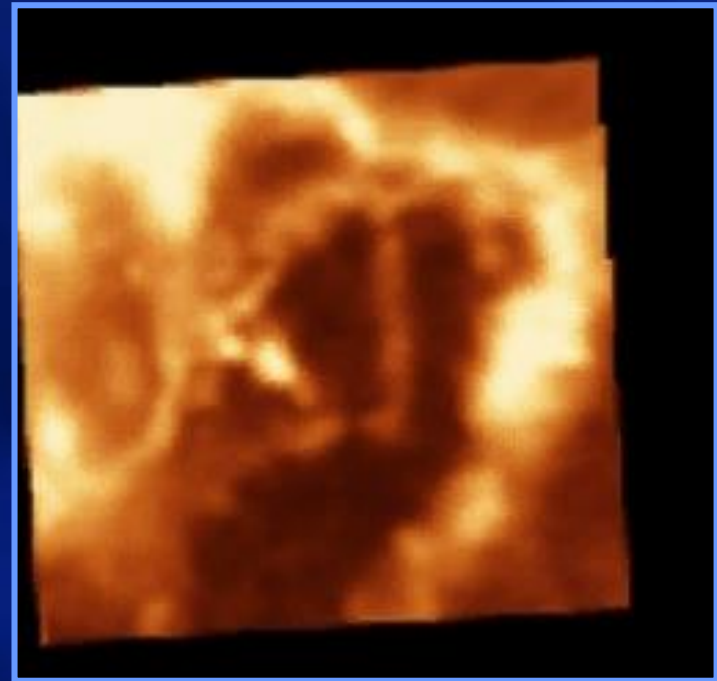
Operative findings: mechanism of tricuspid regurgitation	
Lead adherence	14
Lead entanglement	4
Lead perforation	7
Lead impingement	16

Etiology of Tricuspid Regurgitation Revealed by 3D Echo

Patient # 1



Patient # 2





ORIGINAL RESEARCH

3D Echocardiographic Location of Implantable Device Leads and Mechanism of Associated Tricuspid Regurgitation

Anuj Mediratta, MD, Karima Addetia, MD, Megan Yamat, RDCS, Joshua D. Moss, MD, Hemal M. Nayak, MD, Martin C. Burke, MD, Lynn Weinert, BS, Francesco Maffessanti, PHD, Valluvan Jeevanandam, MD, Victor Mor-Avi, PHD, Roberto M. Lang, MD

Chicago, Illinois

CONCLUSIONS: 3D TTE showed a clear association between device lead position and TR. To minimize TR induced by device-leads, 3D TTE guidance should be considered for placement in a commissural position.

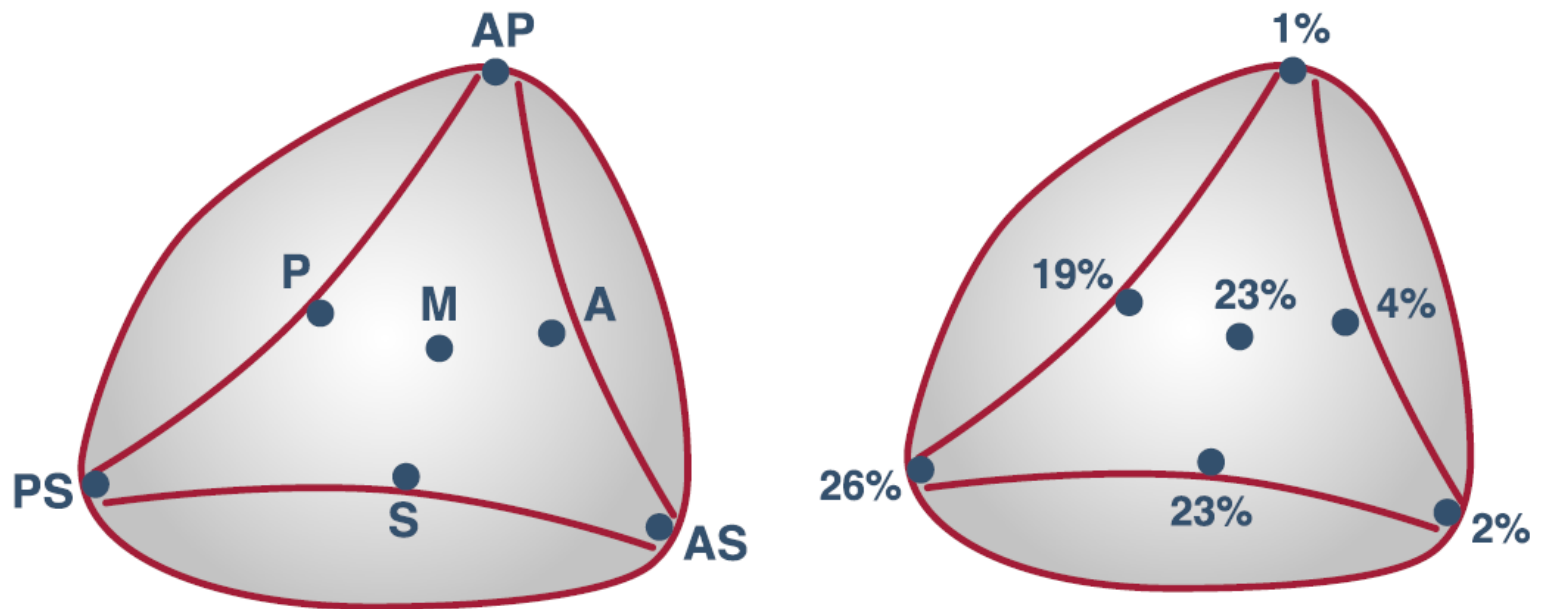


Figure 2. Device-Lead Positions and Percentage of Leads Located in Each Position

Device-lead positions (**left**) and percentage of leads (of a total of 121 patients studied) located in each position (**right**). A = anterior leaflet impingement; AP = device-lead in the anteroposterior commissure; AS = device-lead in the anteroseptal commissure; M = device lead in the center of the tricuspid valve orifice; P = posterior leaflet impingement; PS = device-lead in the posteroseptal commissure; S = septal leaflet impingement.

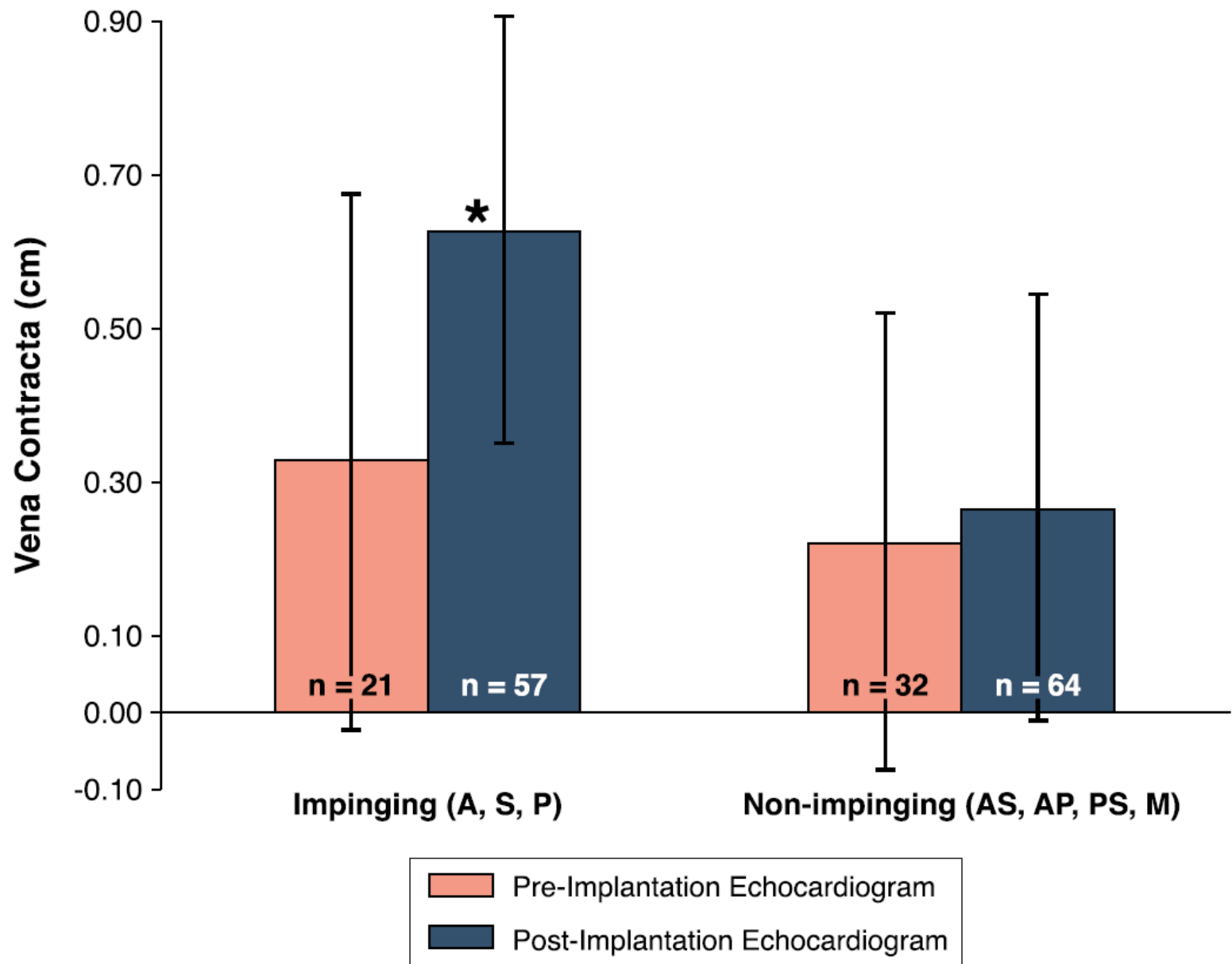
Device Lead Impingement

No

Yes



Mediratta A... Lang RM. *J Am Coll Cardiol Img* 2014;7:337-47



MitraClip Device

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ISSN 0735-1097/09/\$36.00
doi:10.1016/j.jacc.2009.03.077

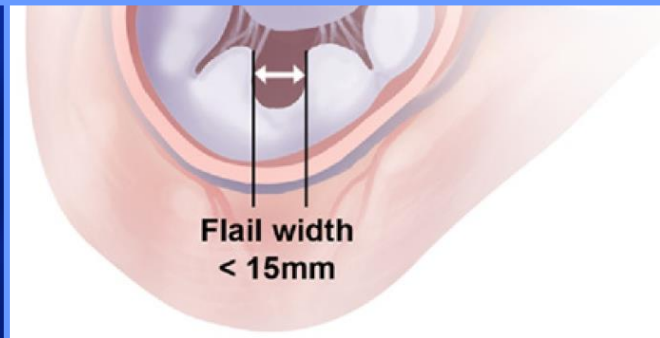
Valvular Heart Disease

Percutaneous Mitral Repair With the MitraClip System

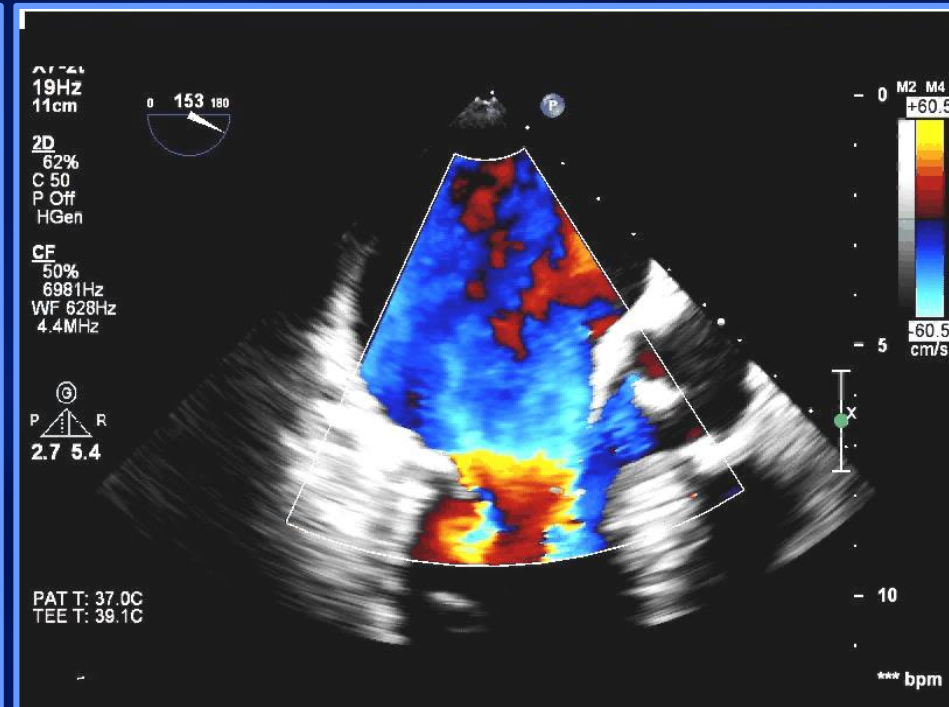
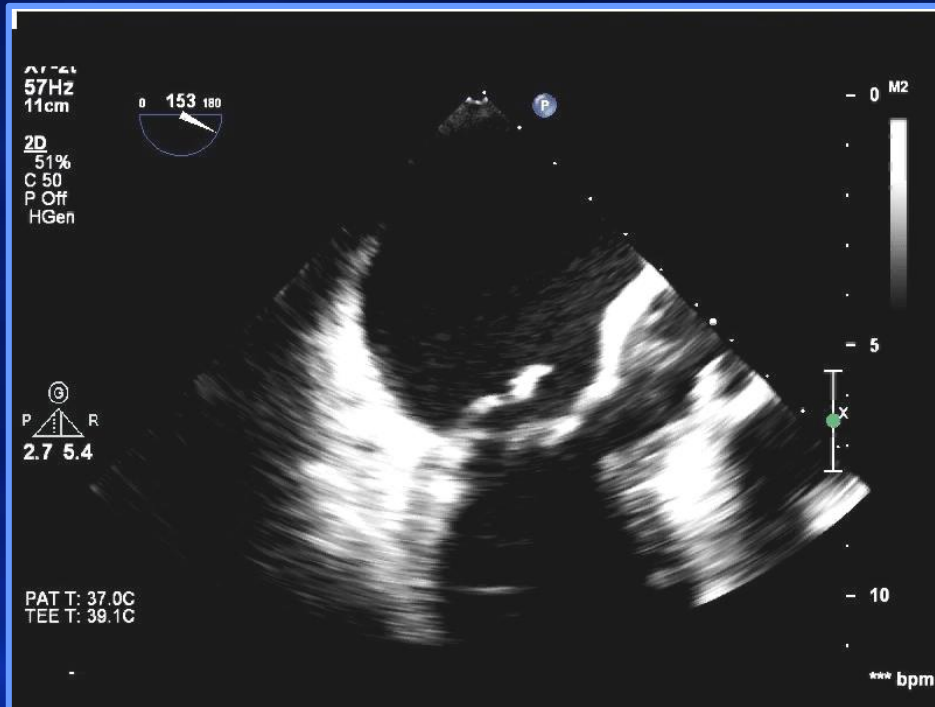
Safety and Midterm Durability in the Initial EVEREST (Endovascular Valve Edge-to-Edge REpair Study) Cohort

Ted Feldman, MD,* Saibal Kar, MD,† Michael Rinaldi, MD,‡ Peter Fail, MD,§
James Hermiller, MD,|| Richard Smalling, MD, PhD,¶ Patrick L. Whitlow, MD,#
William Gray, MD,** Reginald Low, MD,†† Howard C. Herrmann, MD,‡‡ Scott Lim, MD,§§
Elyse Foster, MD,|||| Donald Glower, MD,¶¶ for the EVEREST Investigators

*Evanston, Illinois; Los Angeles, Sacramento, and San Francisco, California; Charlotte and Durham,
North Carolina; Houma, Louisiana; Indianapolis, Indiana; Houston, Texas; Cleveland, Ohio;
New York, New York; Philadelphia, Pennsylvania; and Charlottesville, Virginia*



89 Year Old Female with severe MR Secondary to Flail Posterior Leaflet



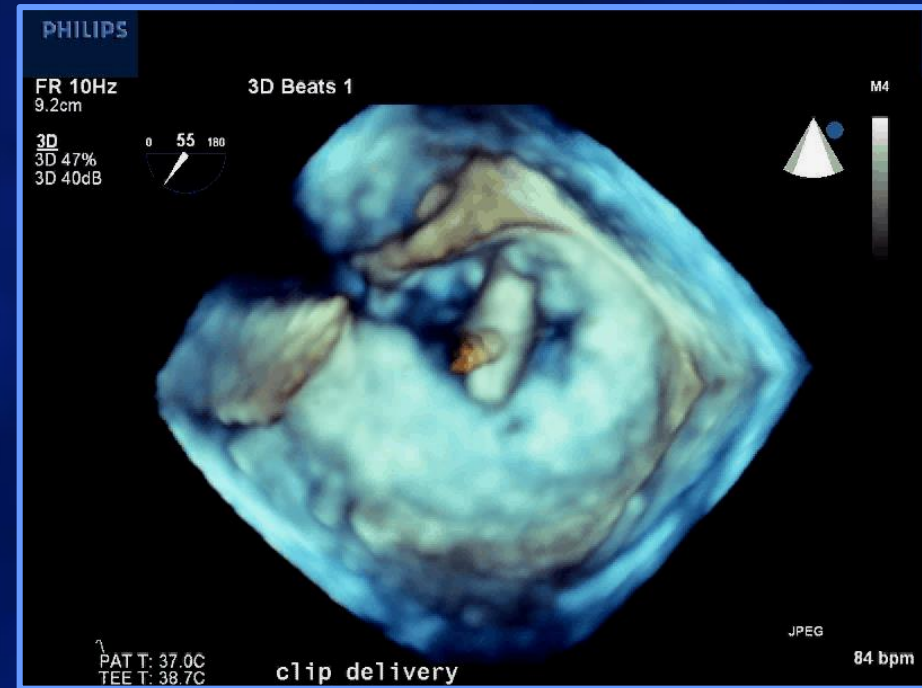
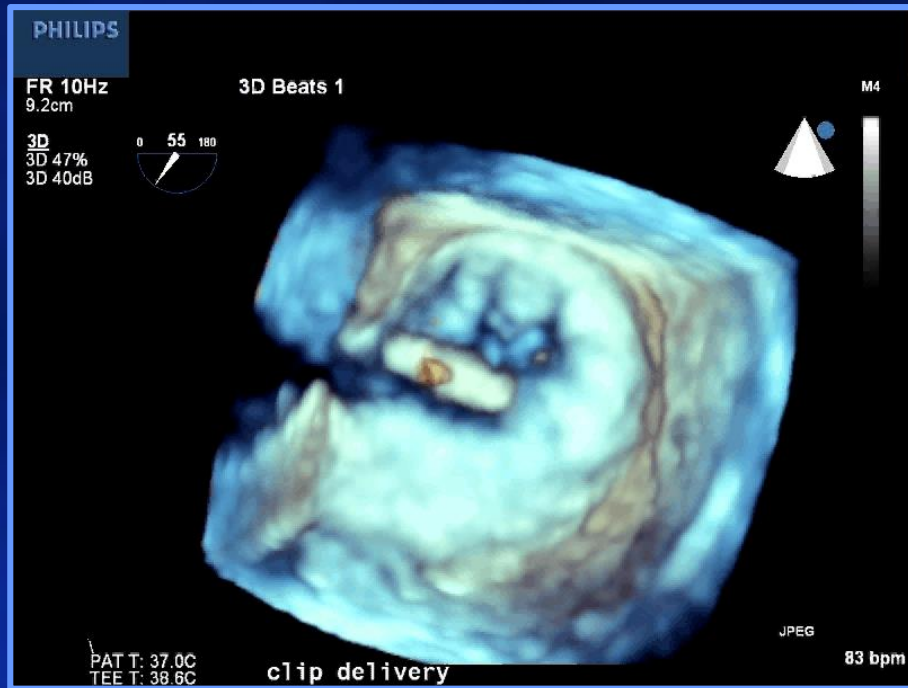
MitraClip Device Toward MV



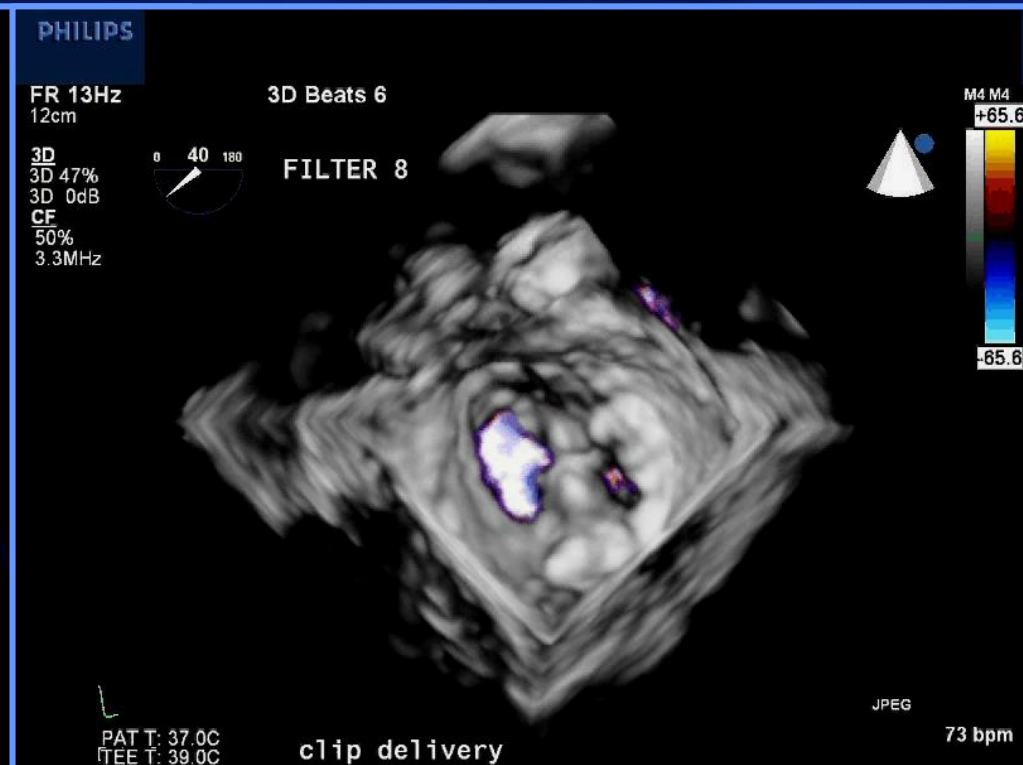
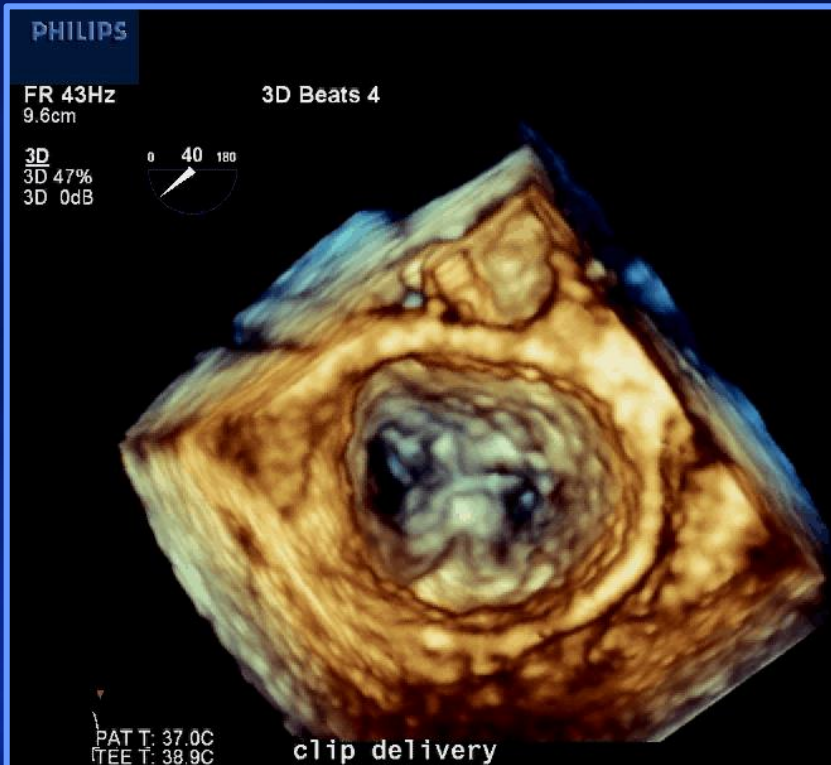
Importance of Clip Orientation

Wrong

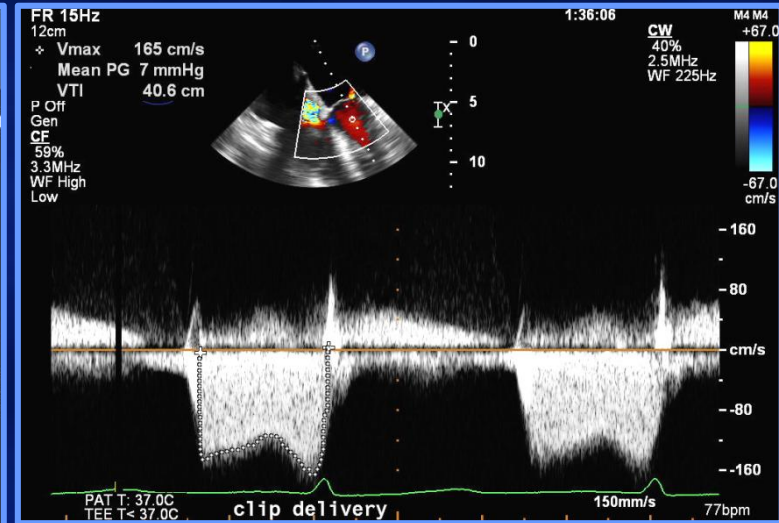
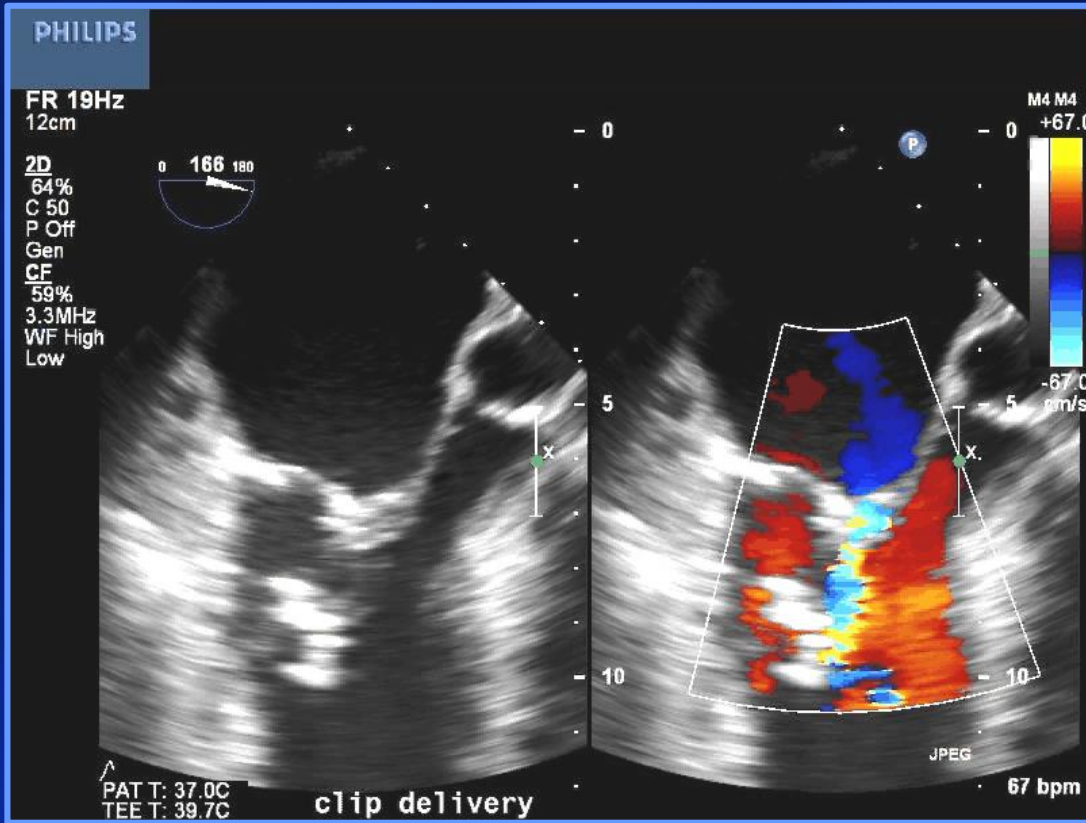
Correct



Final 3D Images

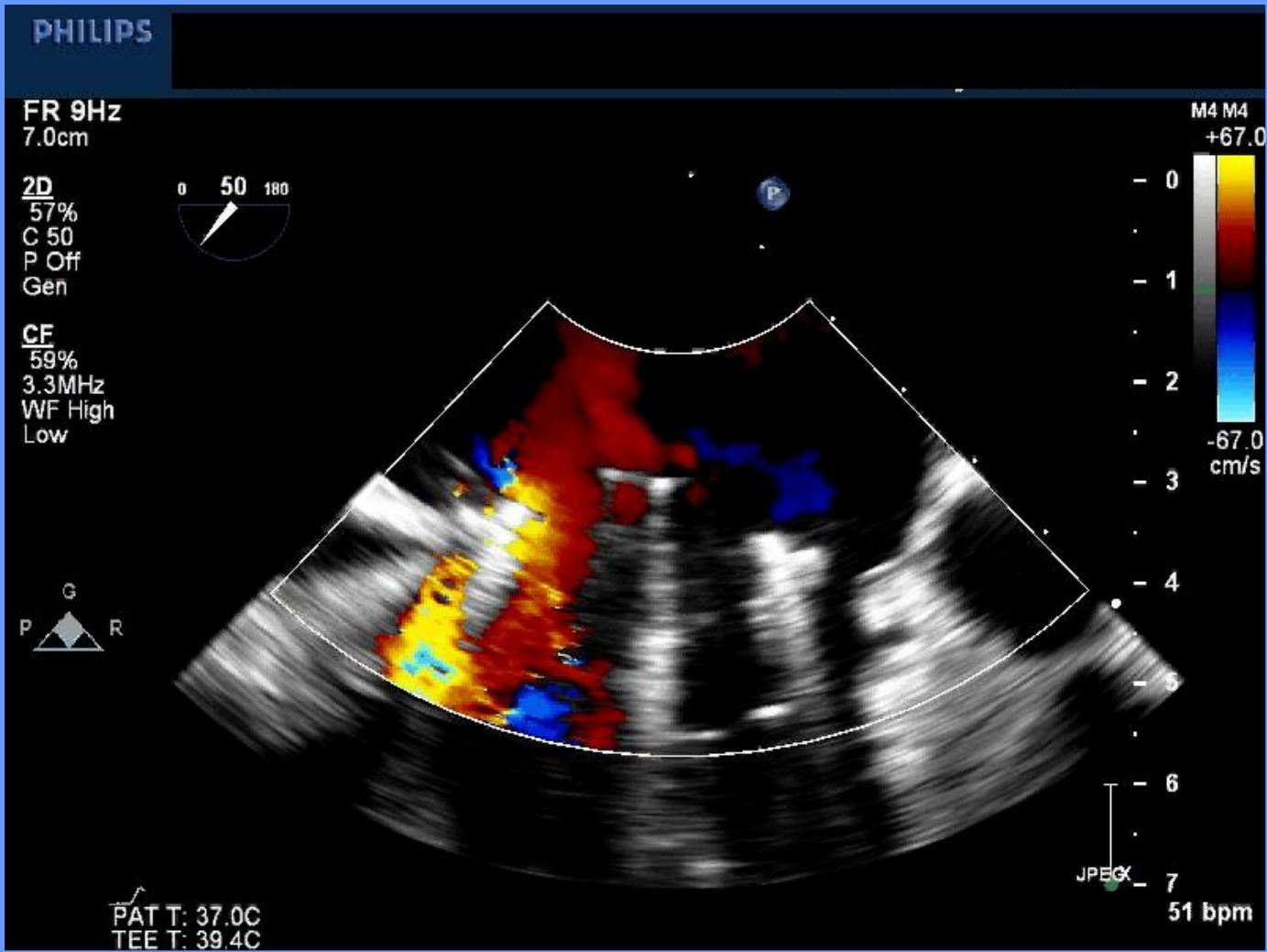


Final Result: Mild MR

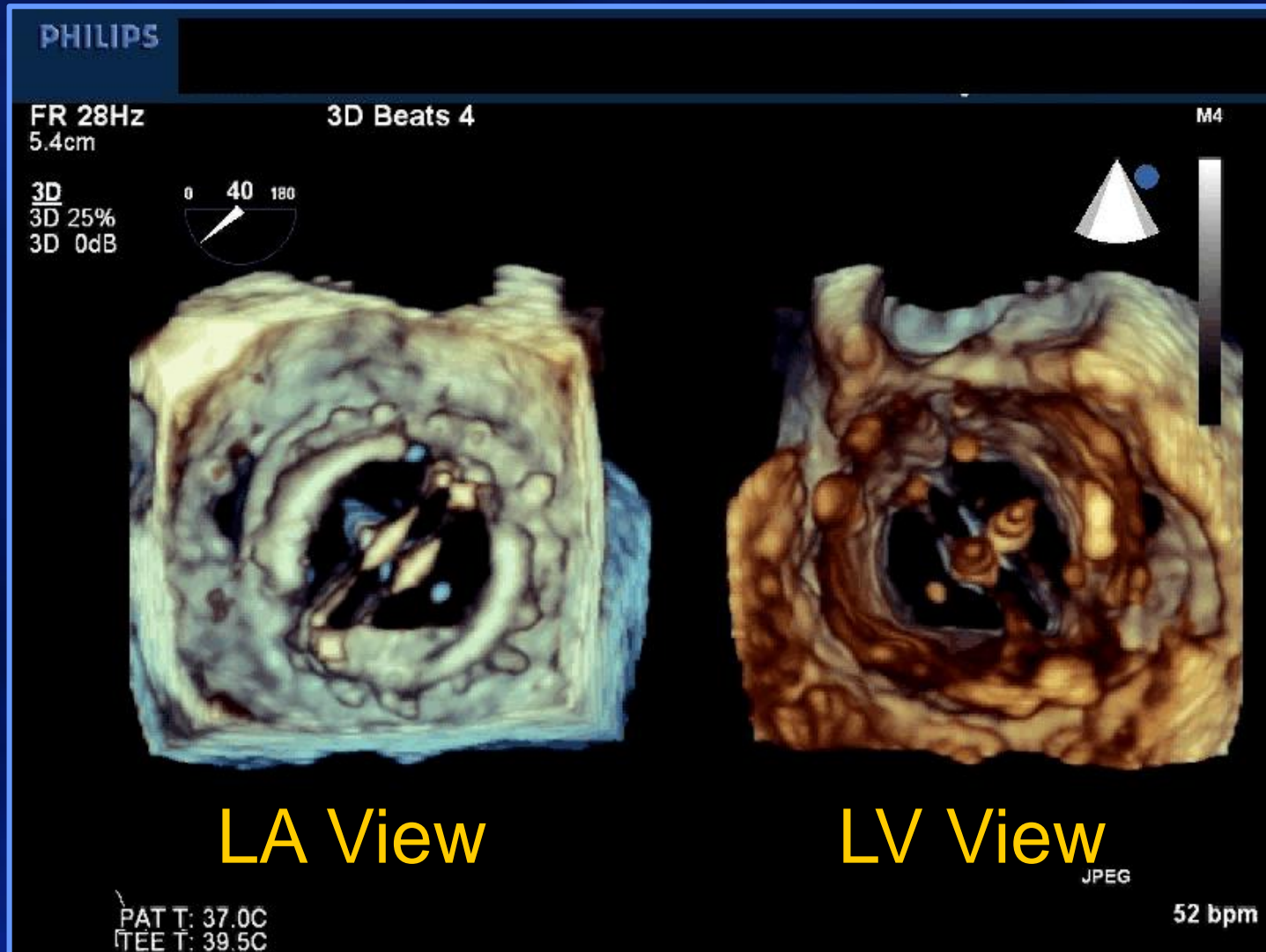


Mean Gradient 5 at HR 77 BPM

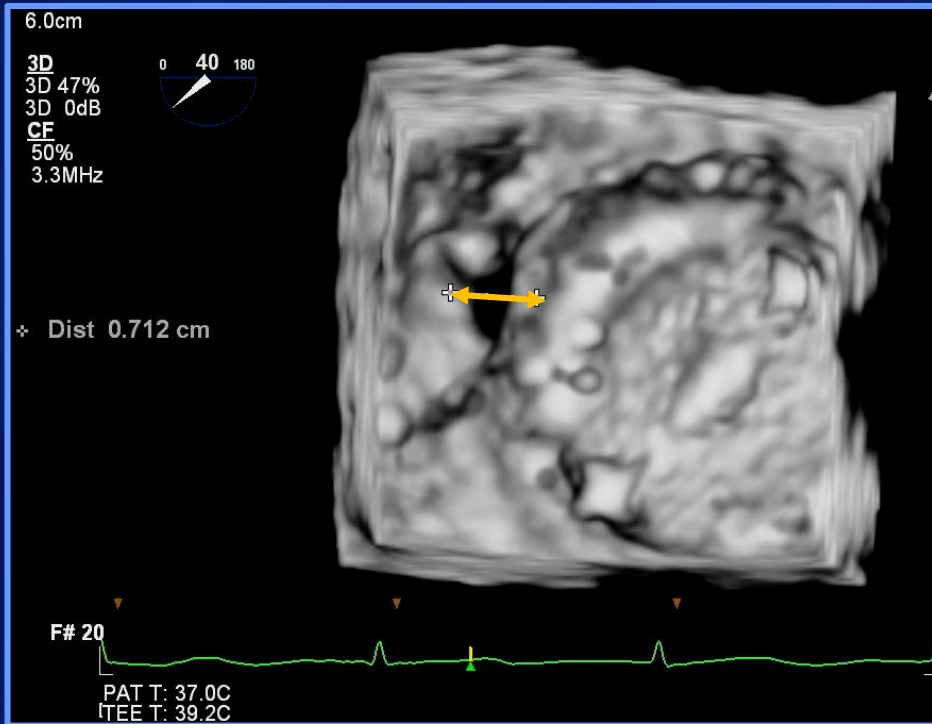
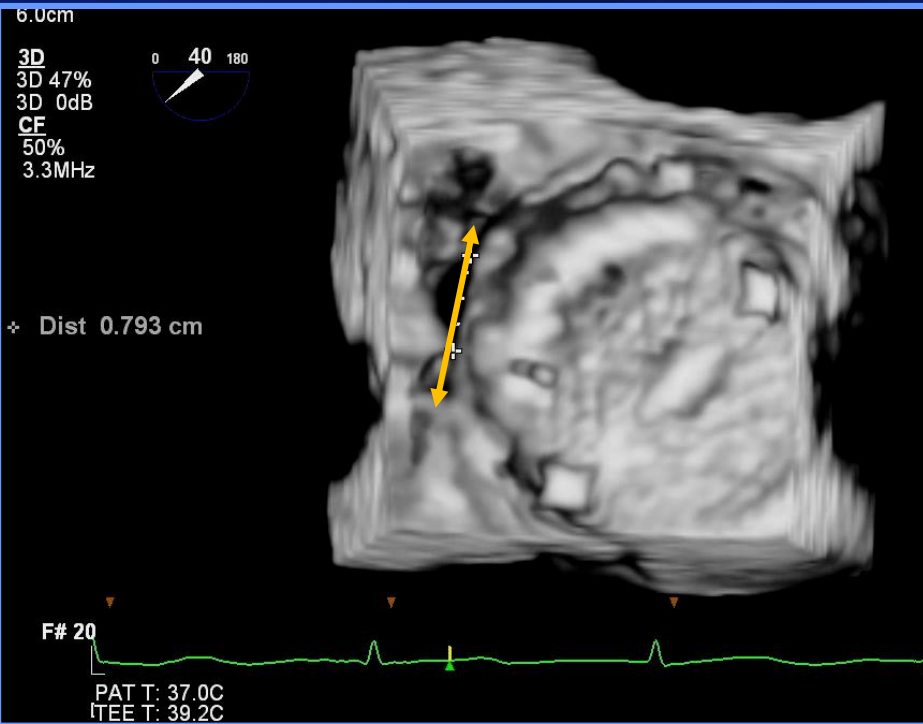
Paravalvular Leak Closure



Procedural 3D TEE: Dual View

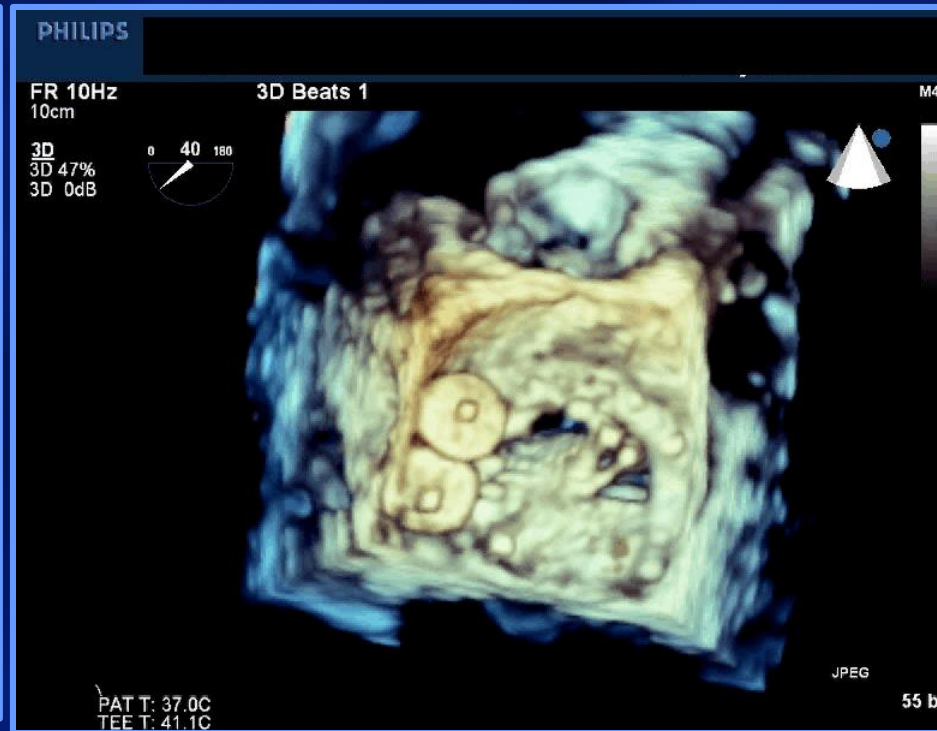
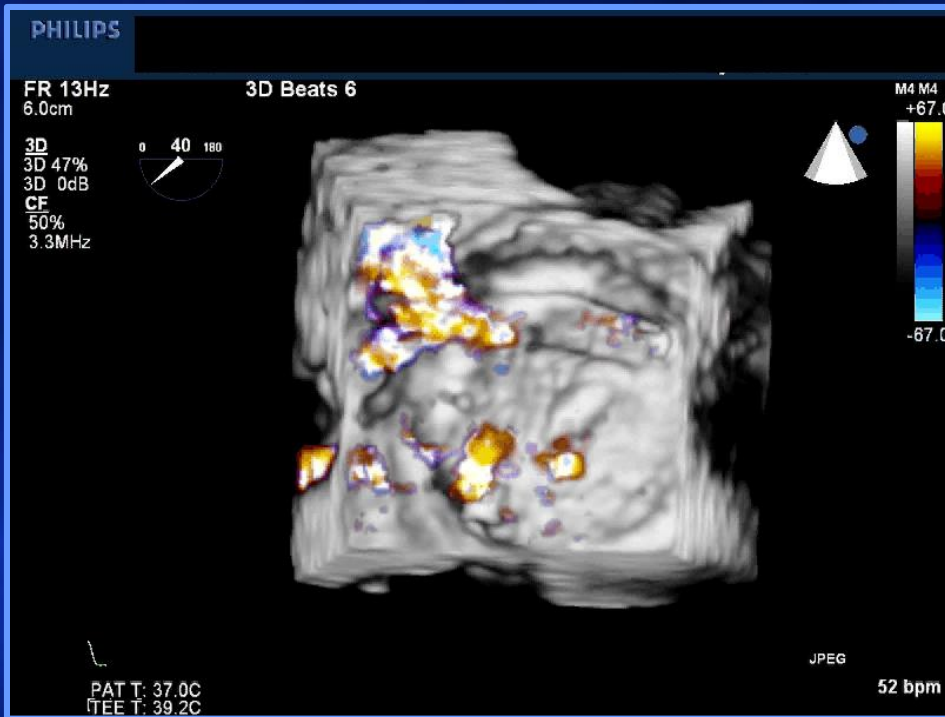


Measurements

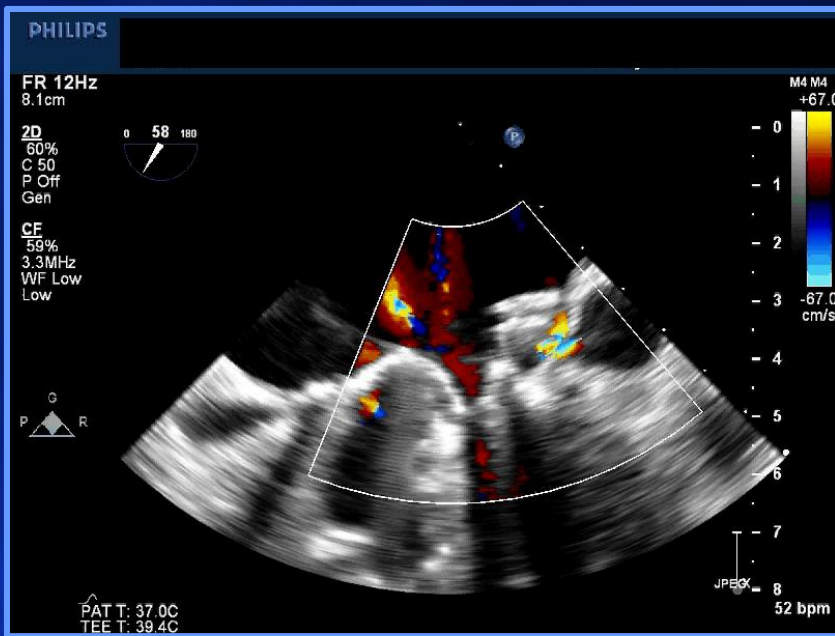


3D Color: Shape of Defect

View from the LA



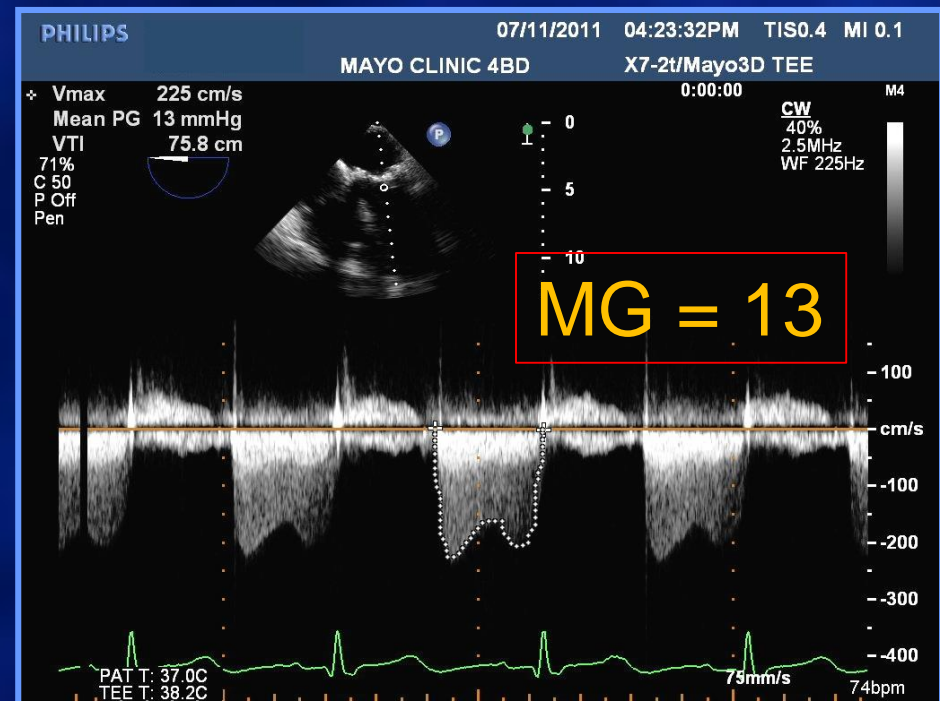
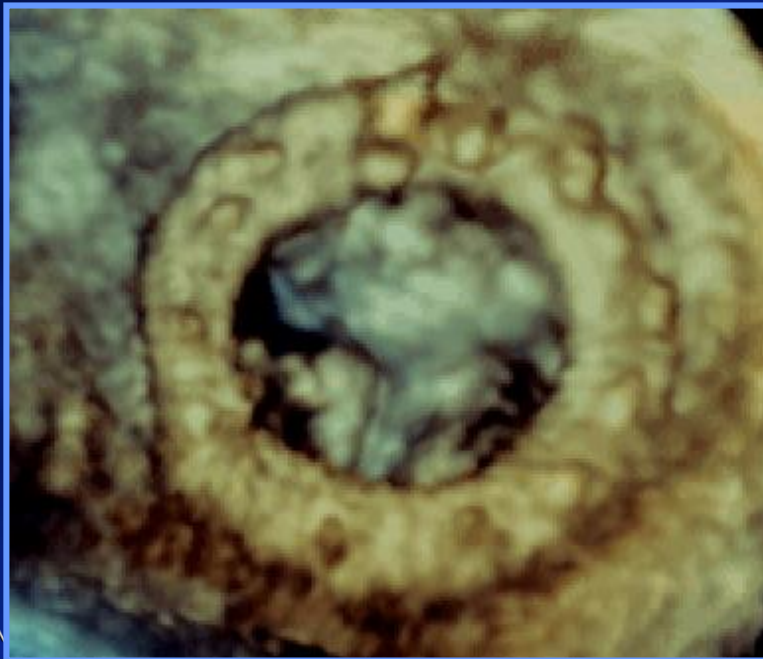
Final Result: Trivial Paravalvular MR



6 Beat Color Acquisition
View from LA

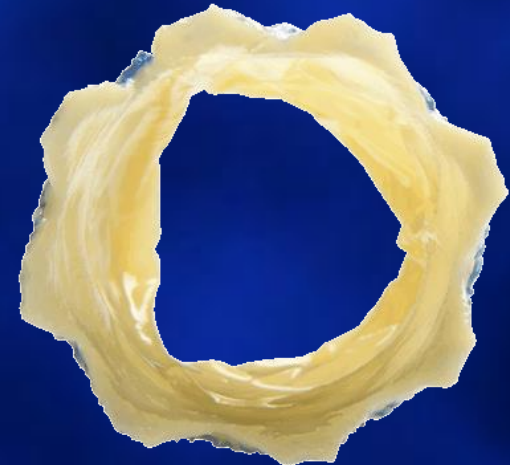
Case

- 86 y/o with class IV CHF
- S/P AVR→Core-Valve (Germany)
- S/P MVR with a CE valve (2000)
- Severe mitral prosthesis stenosis

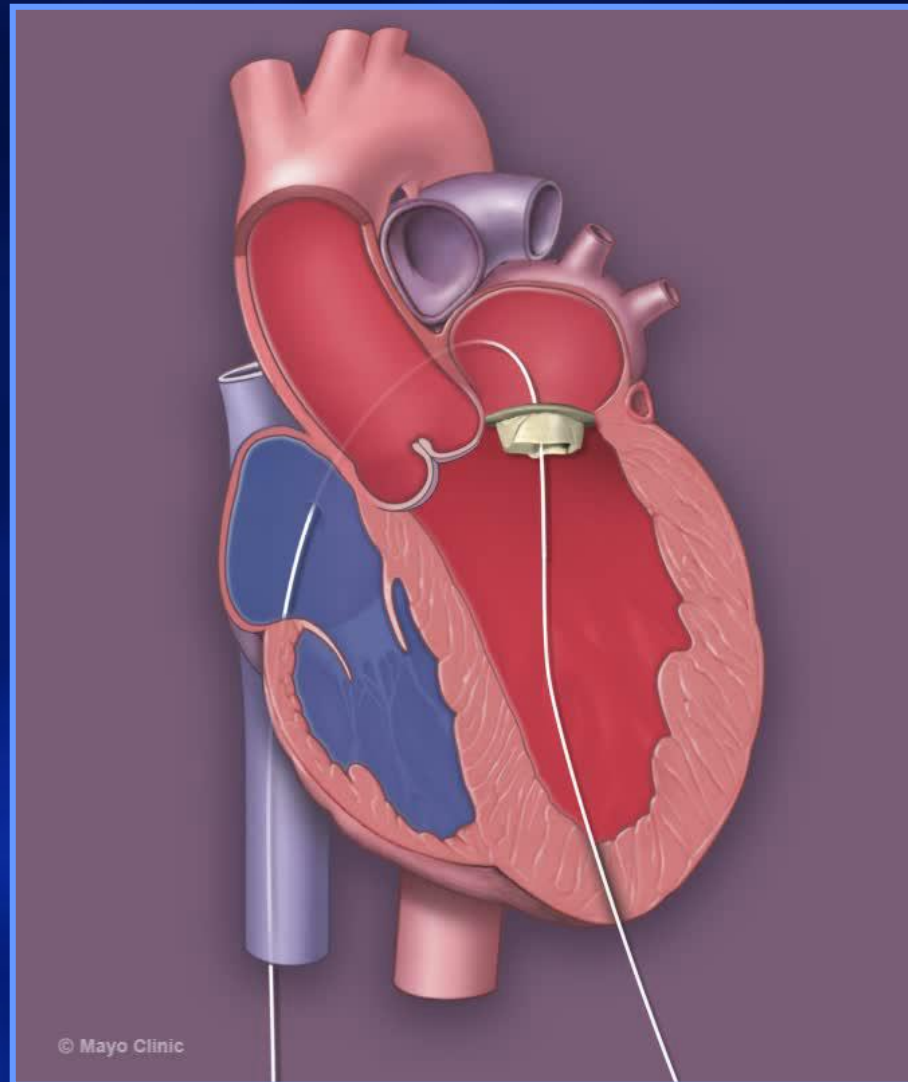


Melody Valve

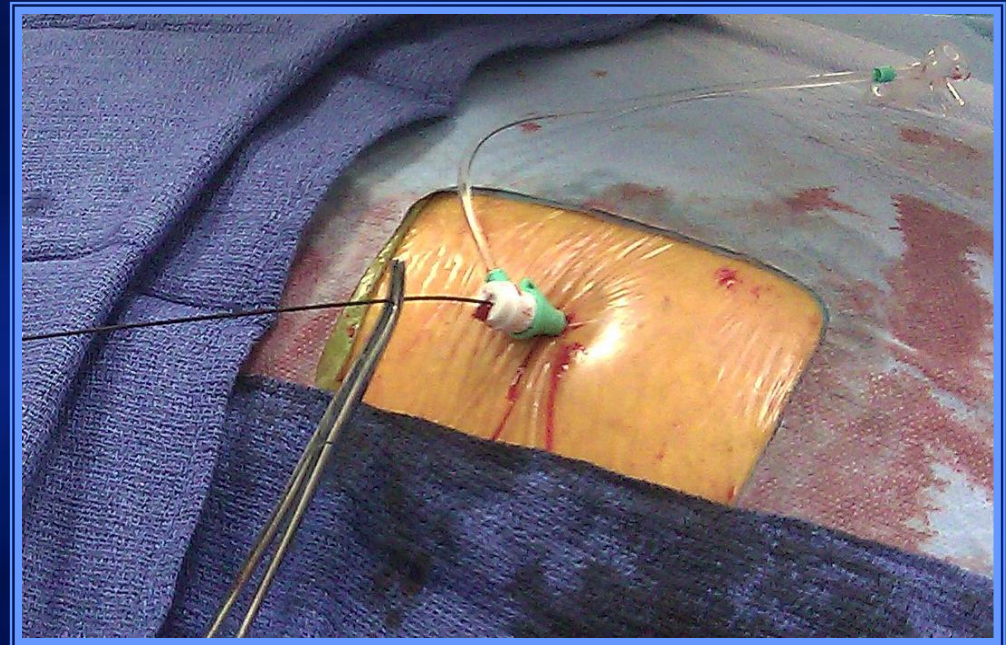
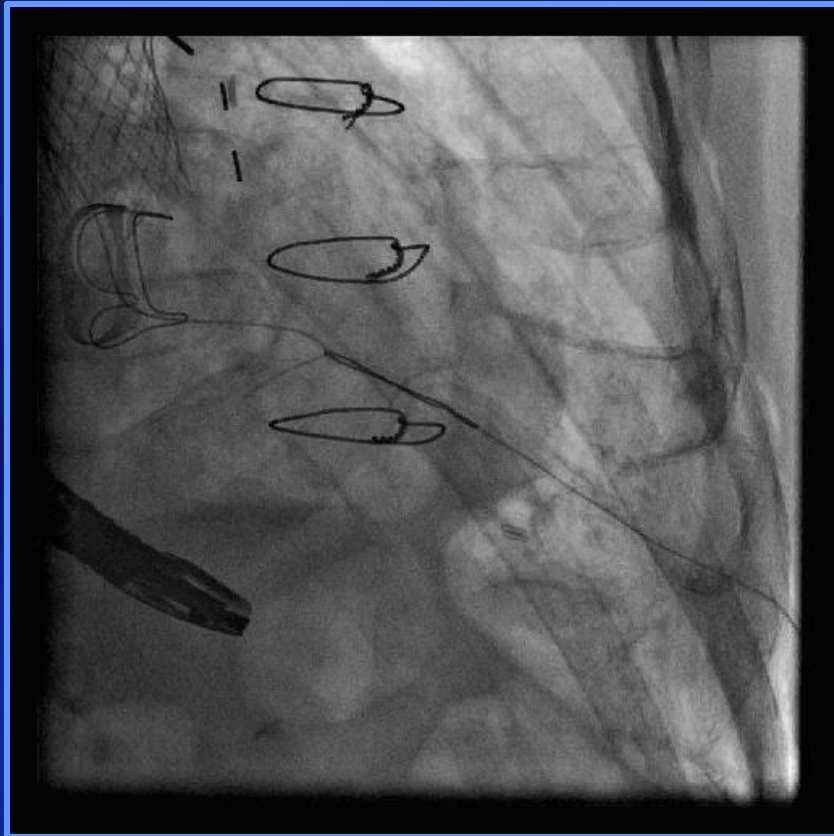
- Bovine jugular venous valve segment
- Platinum-Iridium stent



Mitral Valve-in-Valve Therapy



Transapical Approach

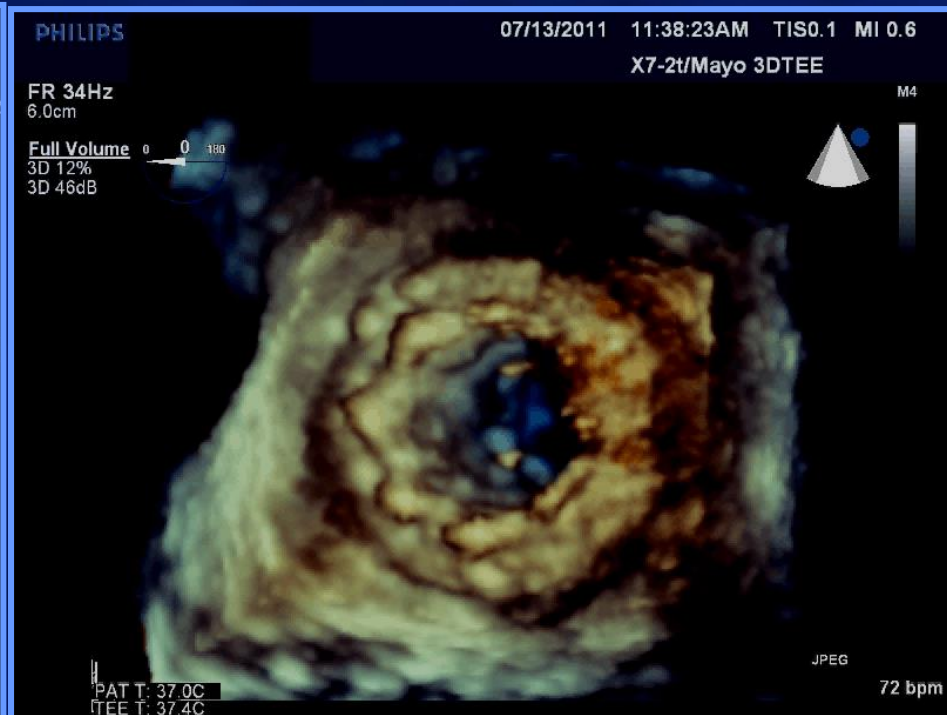


3D Echo During Deployment



Courtesy of Joe Maaoluf

Melody in Mitral Valve-in-Valve



Conclusions: 3D Echo

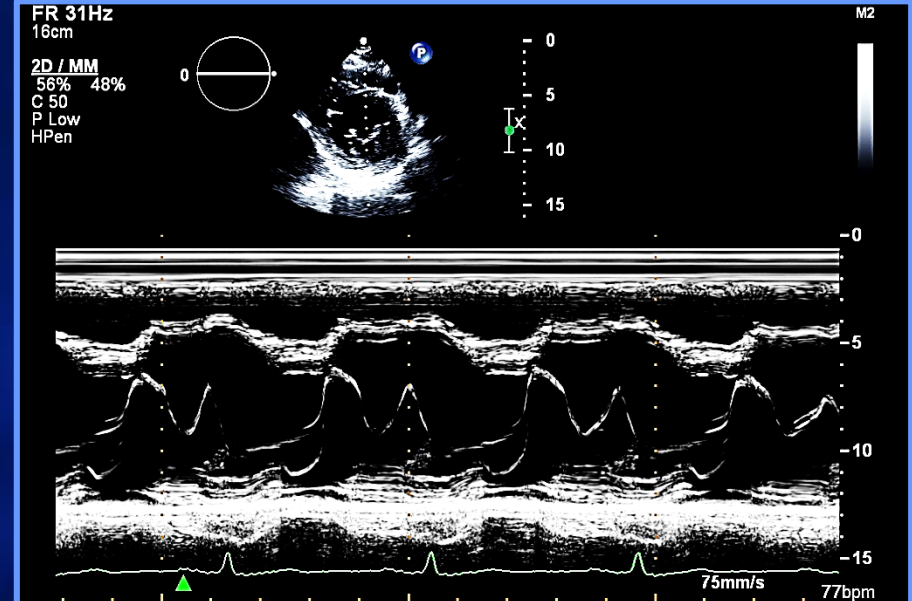
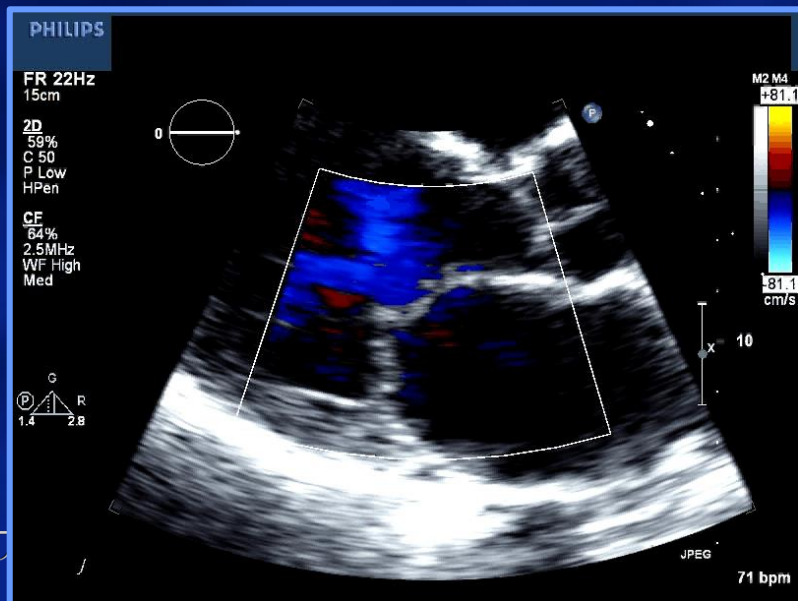
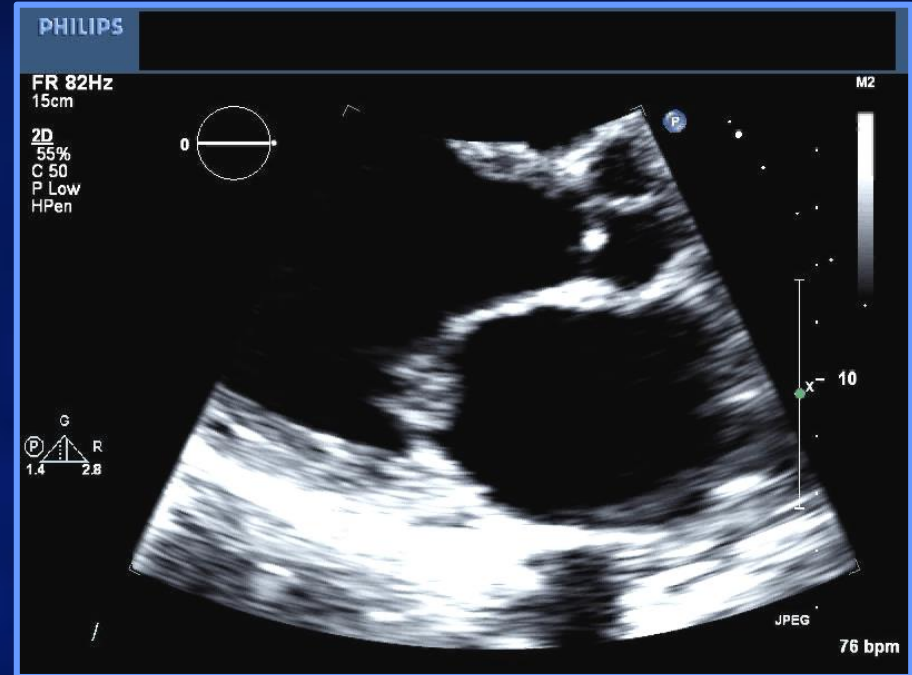
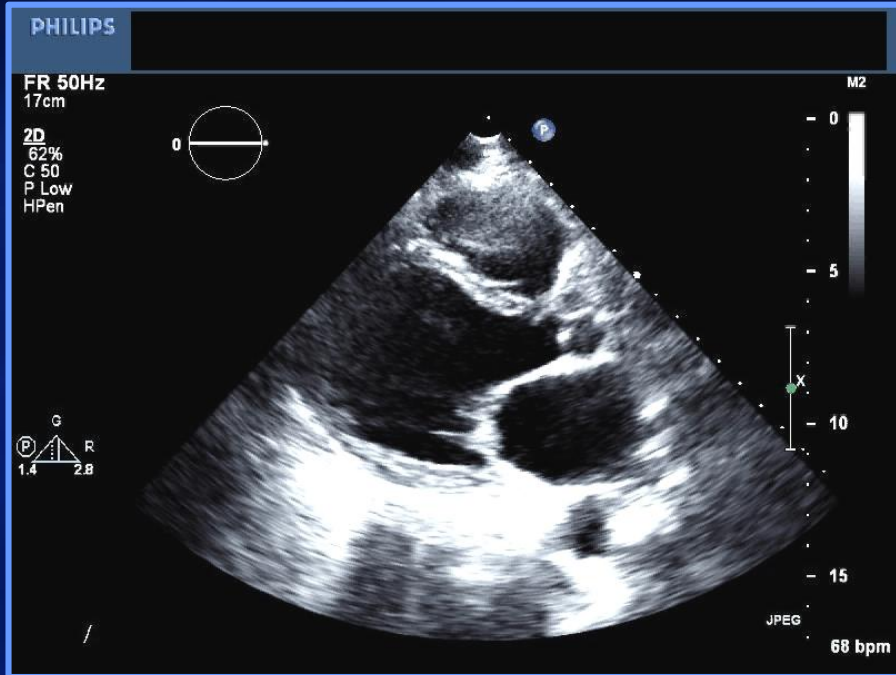
- Still in evolution and at a phase of early adaptation with respect to its clinical application
- More accurate and reproducible assessment of LV ejection fraction
 - Better guide medical management and device decisions
- Unique perspective of valvular structures
- Compliment current echo techniques
 - Better understanding of the topographical aspects of pathology
 - Refined definition of the spatial relationships of intra-cardiac structures
 - Provides new indices not described by 2D echo and makes the existing ones more accurate
 - Better quantify and guide procedures

Post Test Question

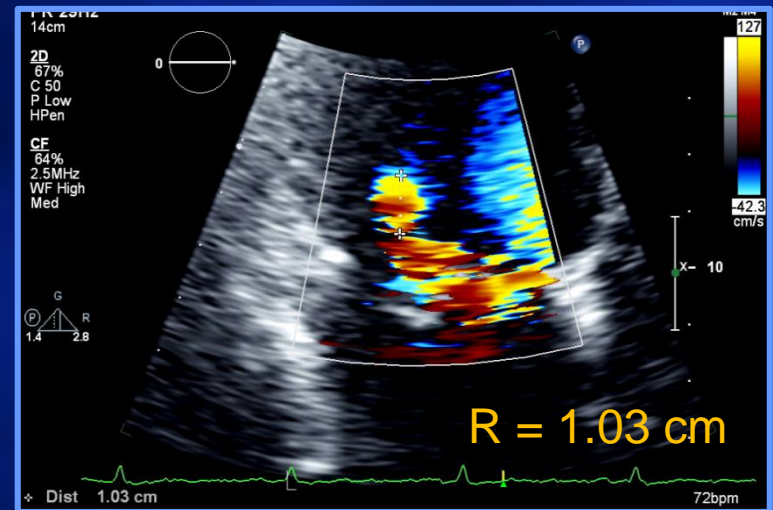
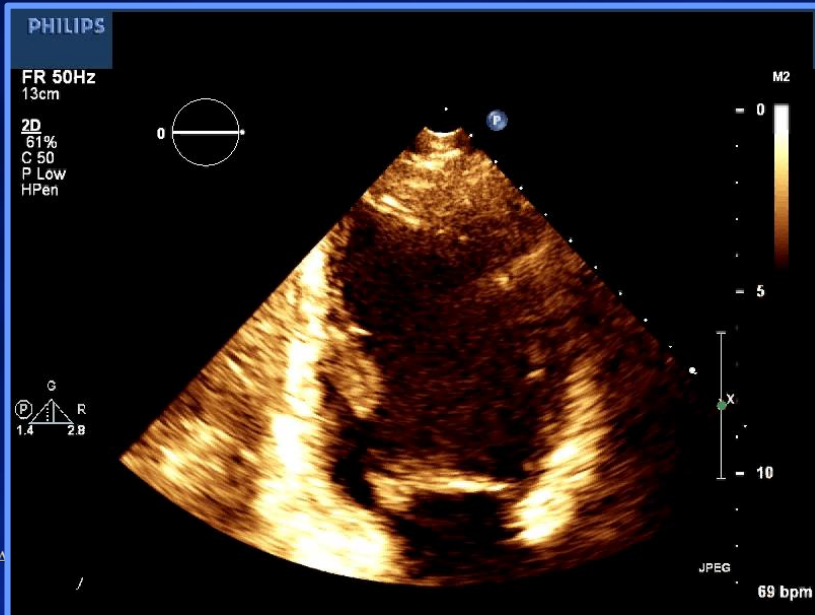
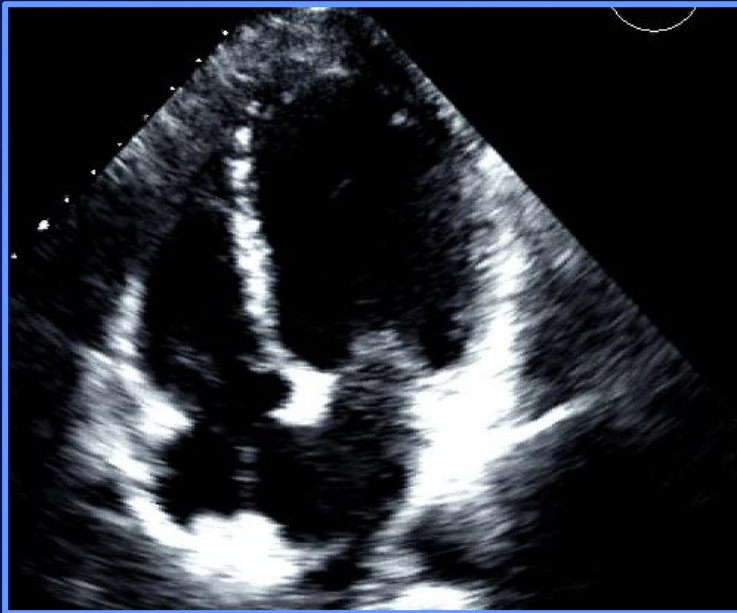
Question

- What is the specific mitral abnormality shown?
 1. Flail/prolapse middle scallop of posterior leaflet (P2)
 2. Flail/prolapse middle scallop of anterior leaflet (A2)
 3. Mitral valve vegetation
 4. Flail/prolapse medial scallop of posterior leaflet (P3)
 5. Flail/prolapse medial scallop of anterior leaflet (A3)

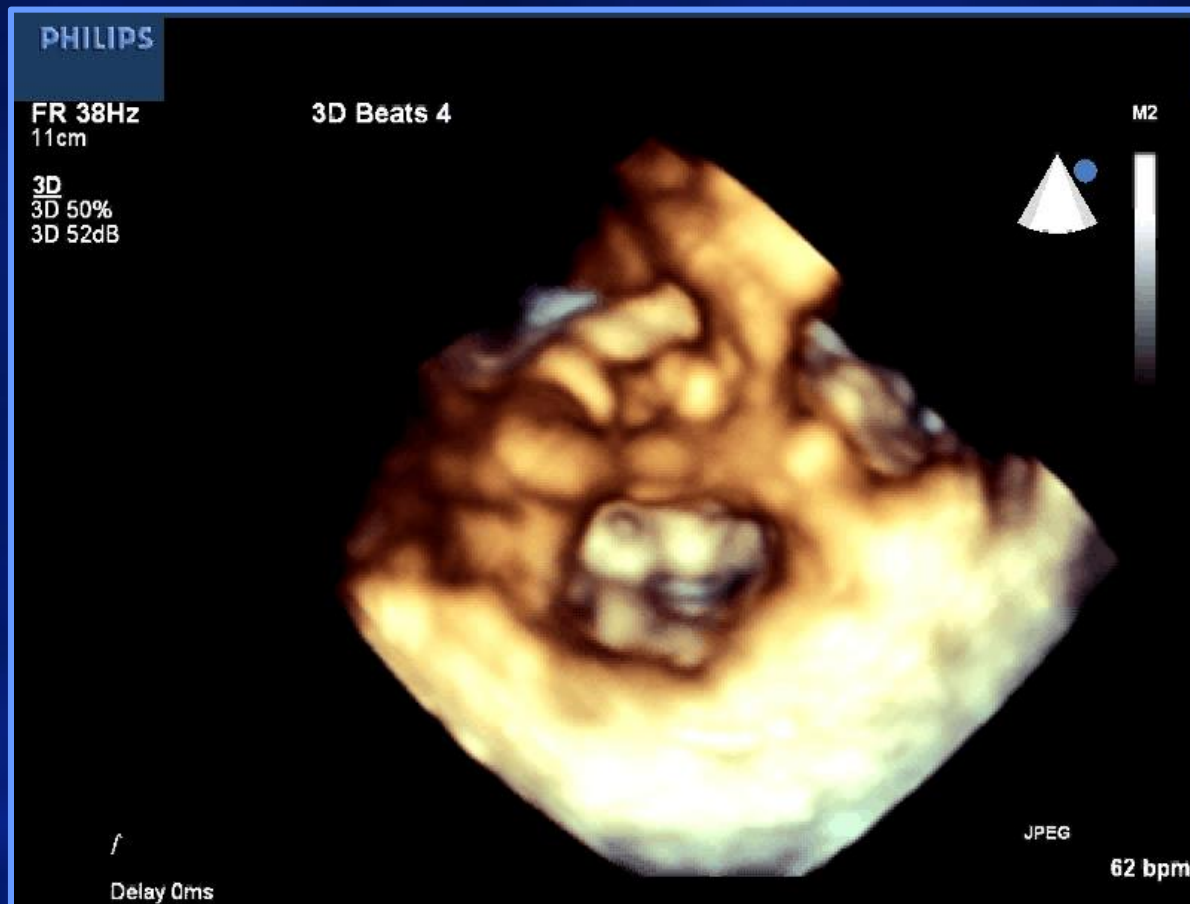
Parasternal Views



Apical Views



3D Echocardiography: View from the Left Atrium (Surgeon's View)



Question

- What is the specific mitral abnormality shown?
 1. Flail/prolapse middle scallop of posterior leaflet (P2)
 2. Flail/prolapse middle scallop of anterior leaflet (A2)
 3. Mitral valve vegetation
 4. Flail/prolapse medial scallop of posterior leaflet (P3)
 5. Flail/prolapse medial scallop of anterior leaflet (A3)



Thank You!
mankad.sunil@mayo.edu

