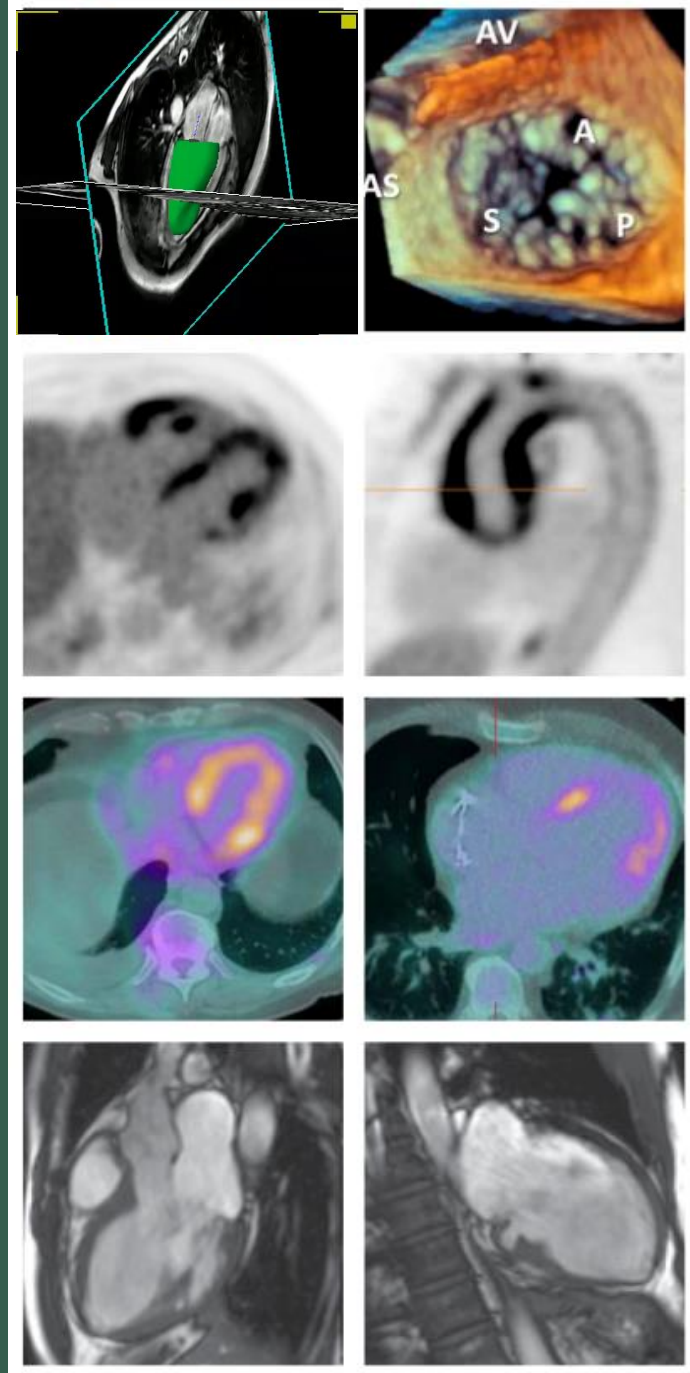


12th ANNUAL

MULTIMODALITY CARDIOVASCULAR IMAGING FOR THE CLINICIAN

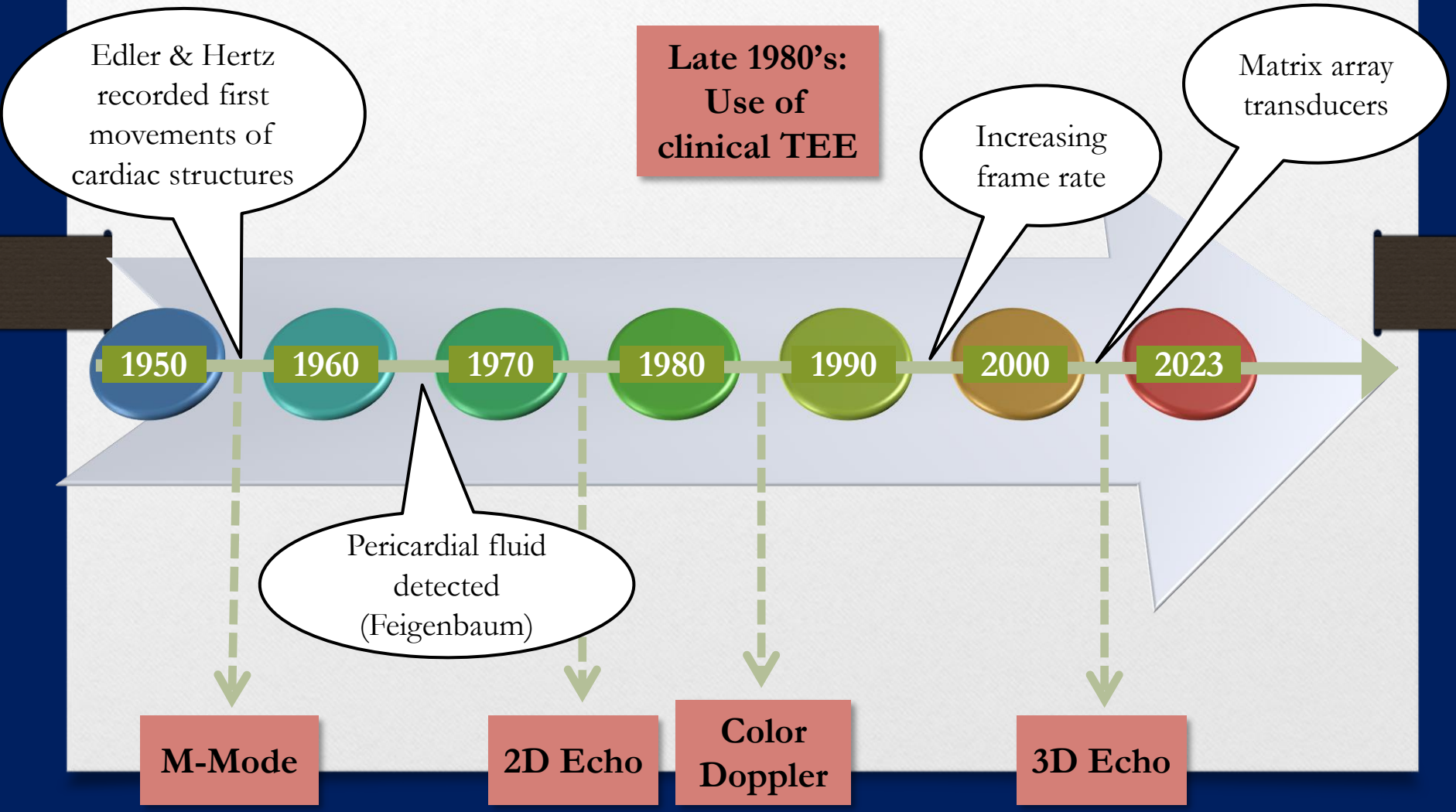
OCT. 20-22, 2023

3D Echocardiography: Latest Advances and Applications

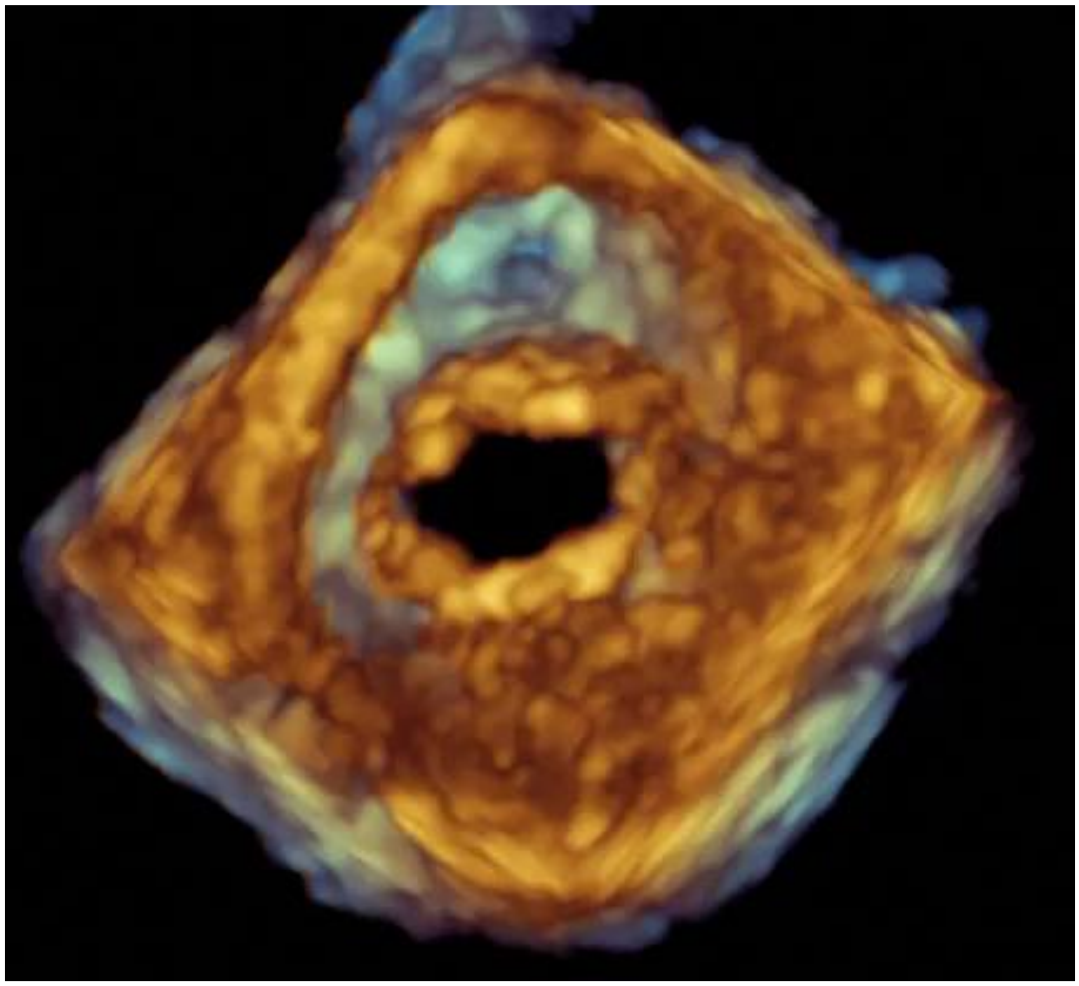
Karima Addetia M.D.

University of Chicago, Chicago, IL

The Echocardiography timeline

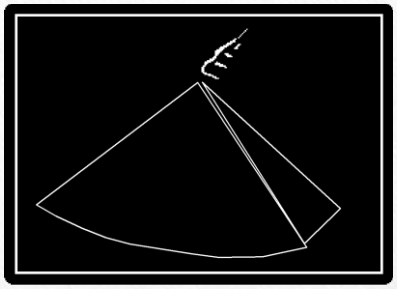


Matrix array TEE Probe: 2007



Sugeng L, Shernan SK, Salgo IS, Weinert L, Shook D, Raman J, Jeevanandam V, DuPont F, Settlemier S, Savord B, Fox J, Mor-Avi V, Lang RM. *J Am Coll Cardiol* 2008 August 5;52(6):446-449.

2D Image optimization



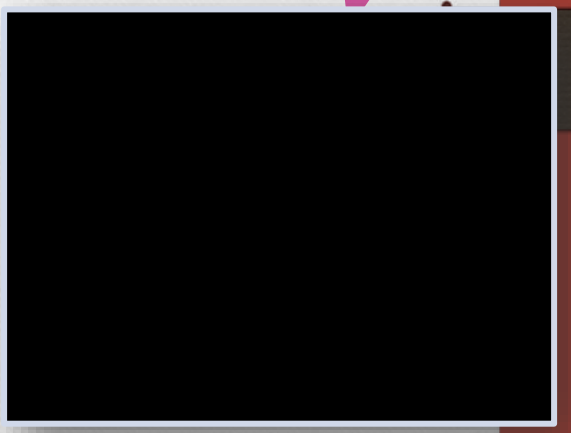
Acquisition modes

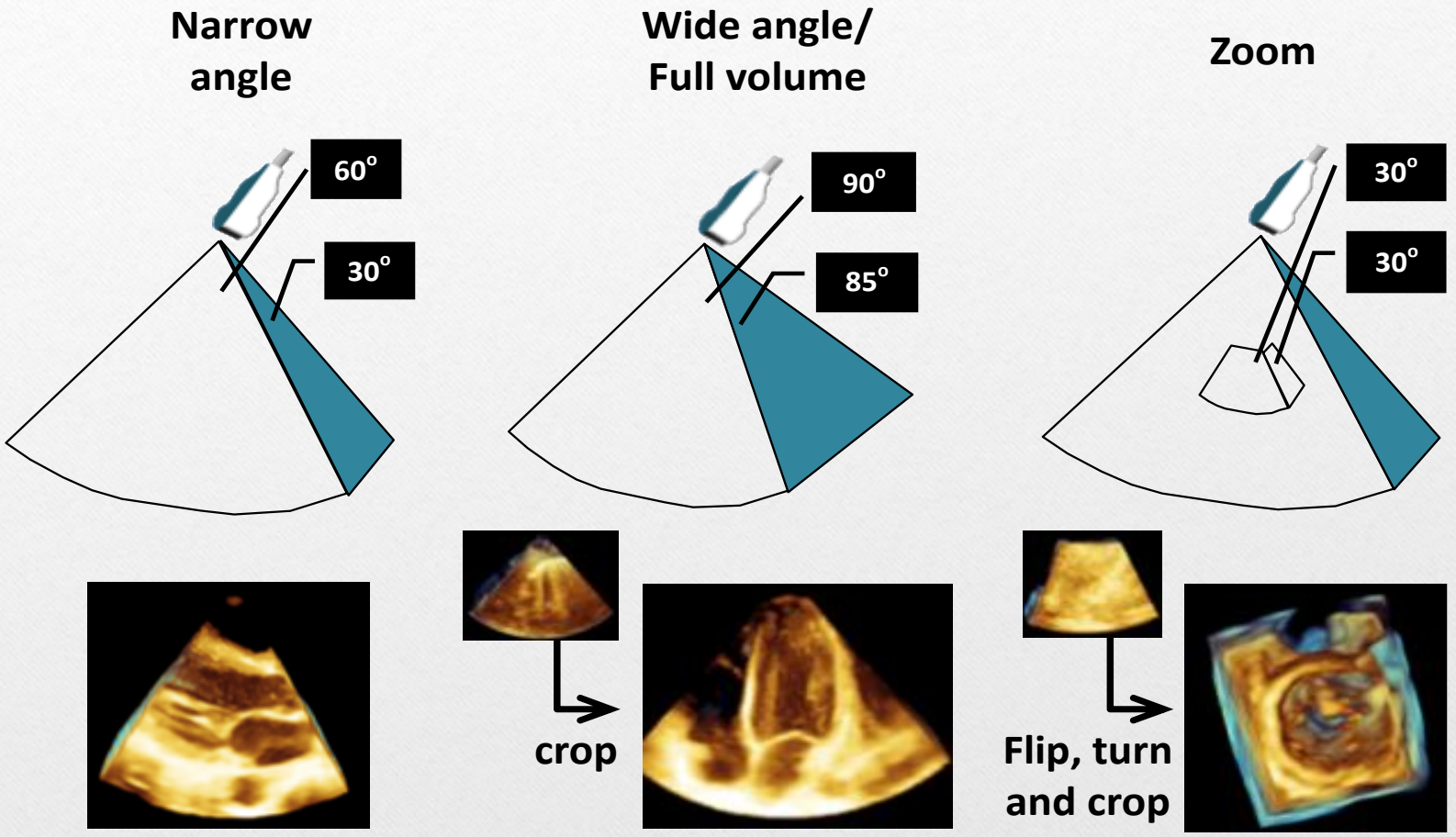
- Narrow angle
- Wide angle
- Zoom
- Color Doppler

Rendering

- Cropping
- Thresholds

Final image display

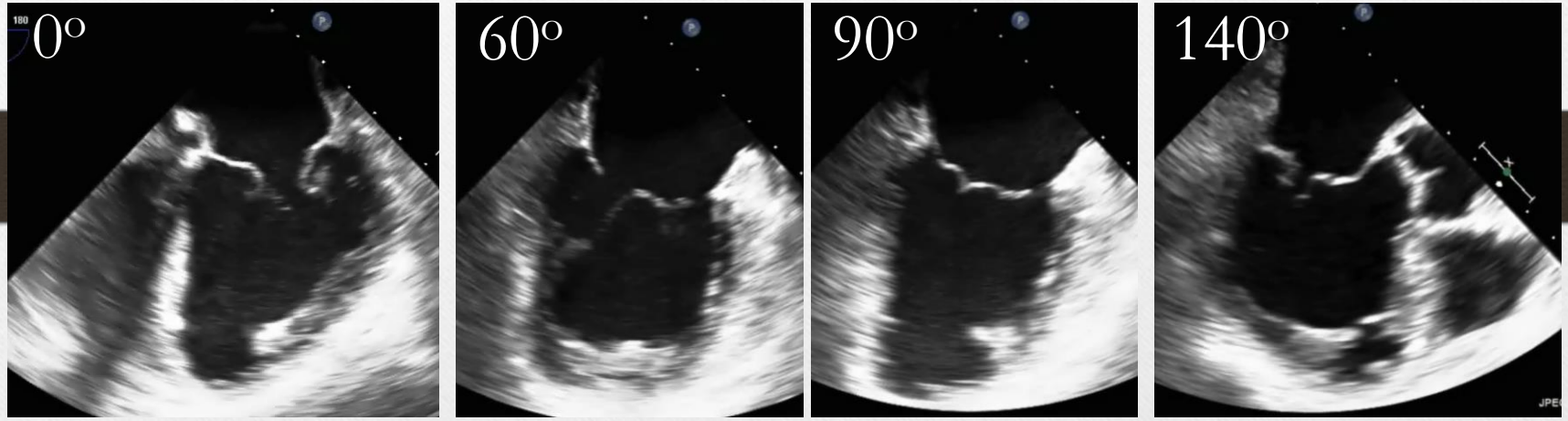



Narrow angle
60°
30°
Wide angle/ Full volume
90°
85°
Zoom
30°
30°
crop
Flip, turn and crop

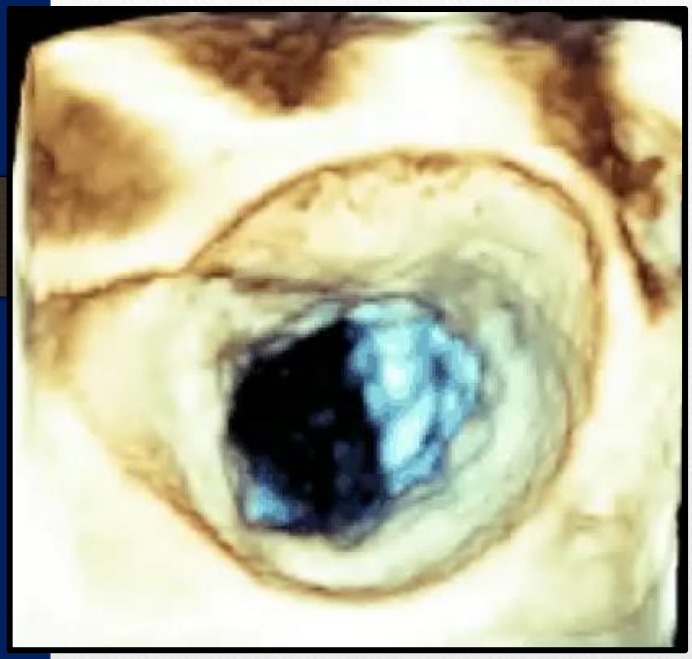
3D = OR

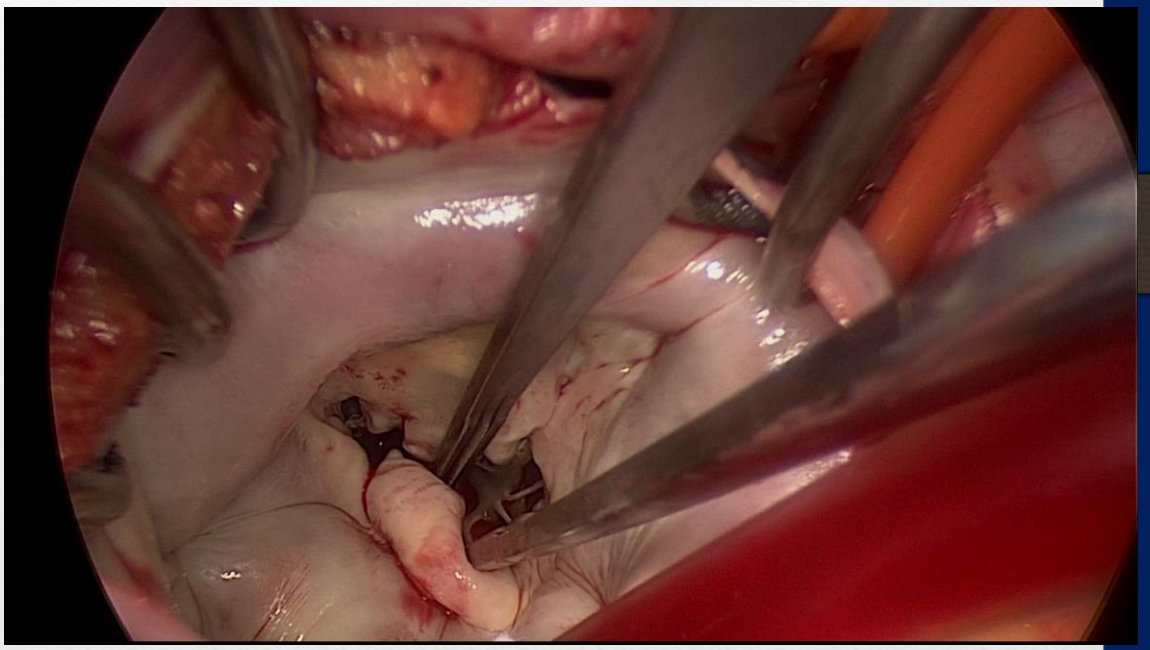
3D images correlate directly with intra-op findings!

Case 1: Degenerative Mitral Valve Disease and Severe Mitral Regurgitation

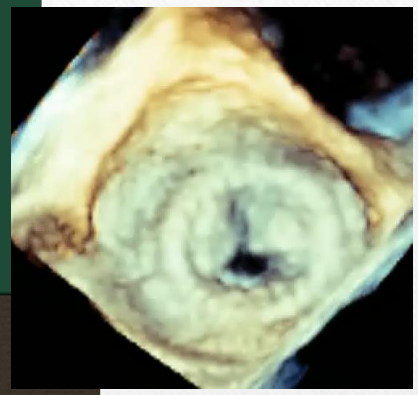


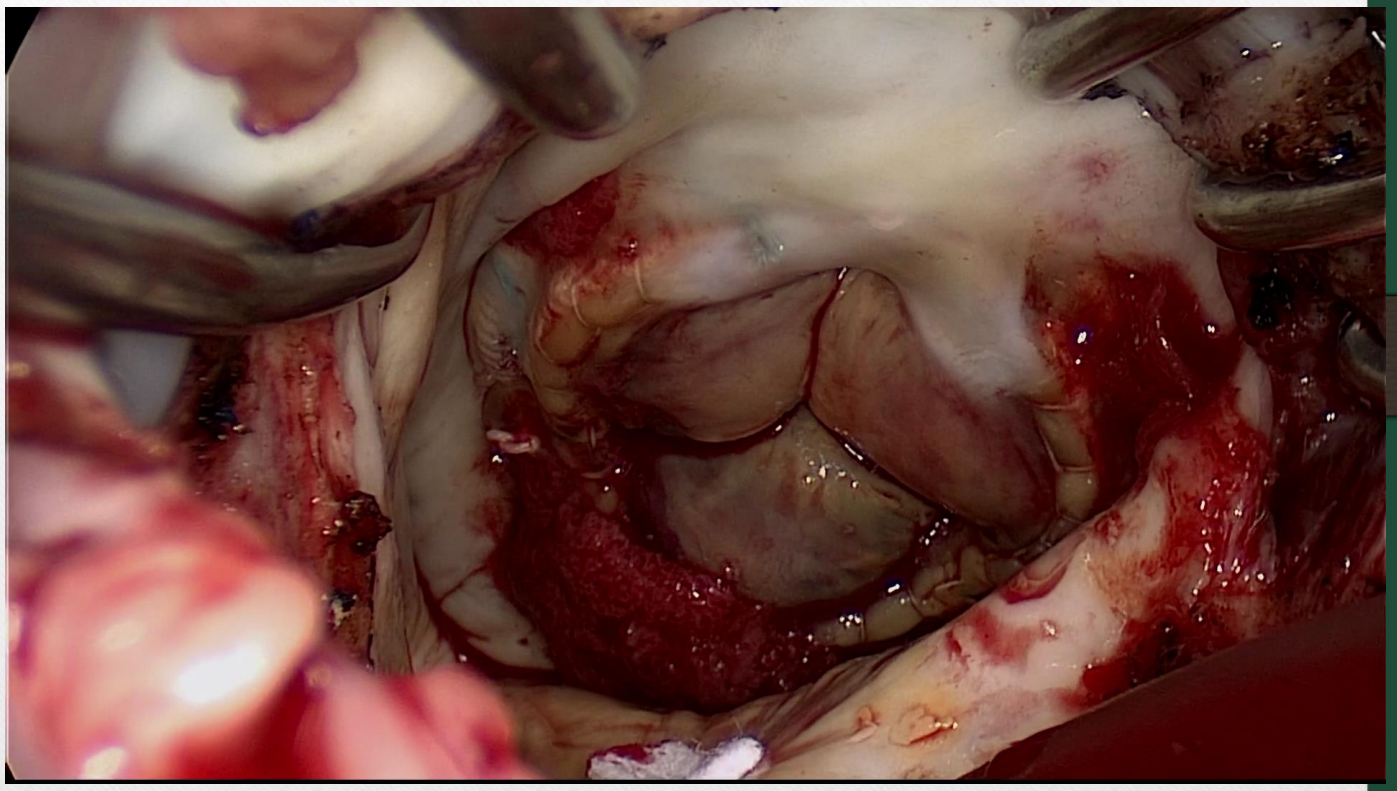
Case 1: Degenerative Mitral Valve Disease and Severe Mitral Regurgitation



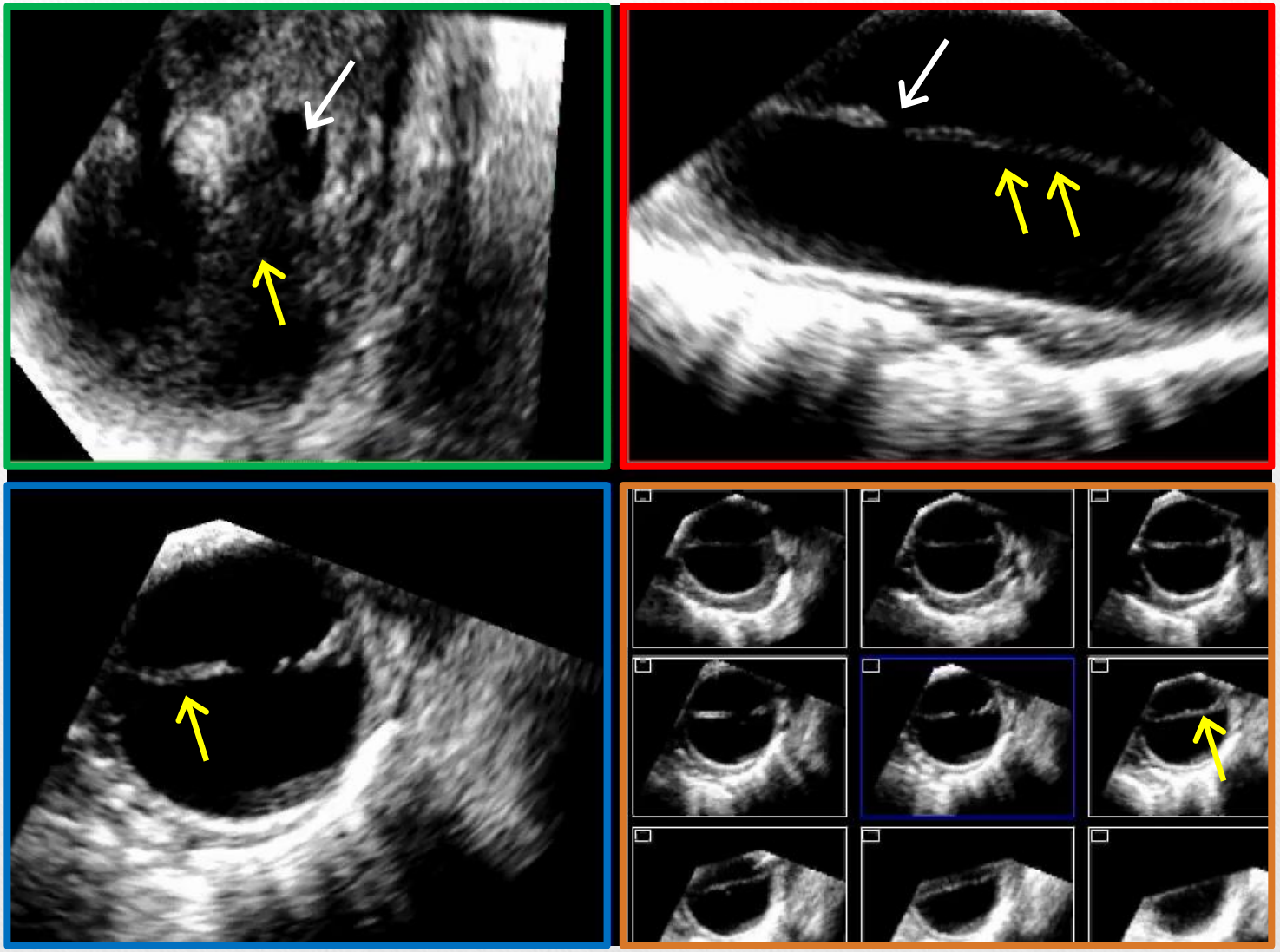


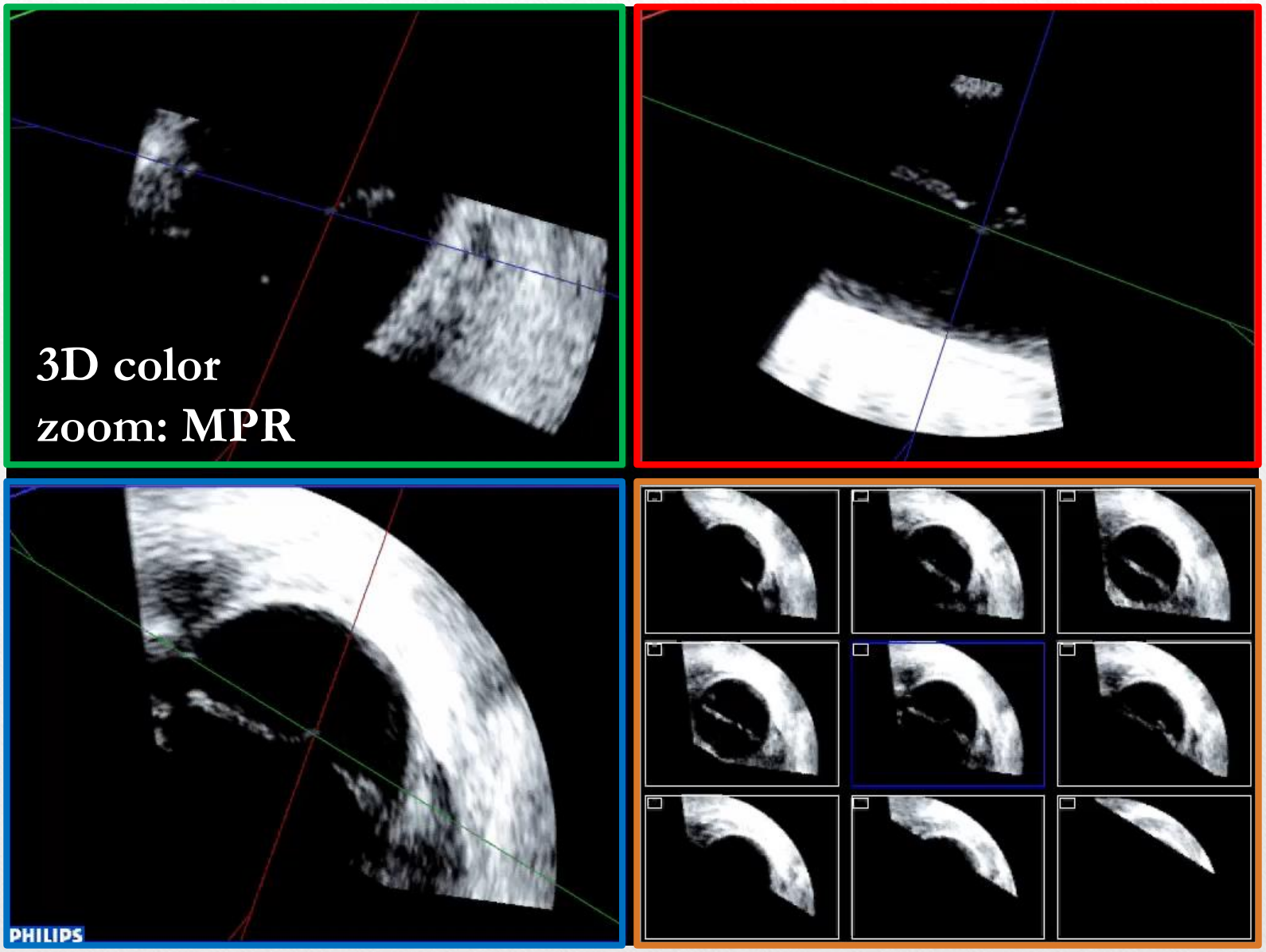
Case 2: Elevated gradient across a bioprosthetic mitral valve of 12 mmHg





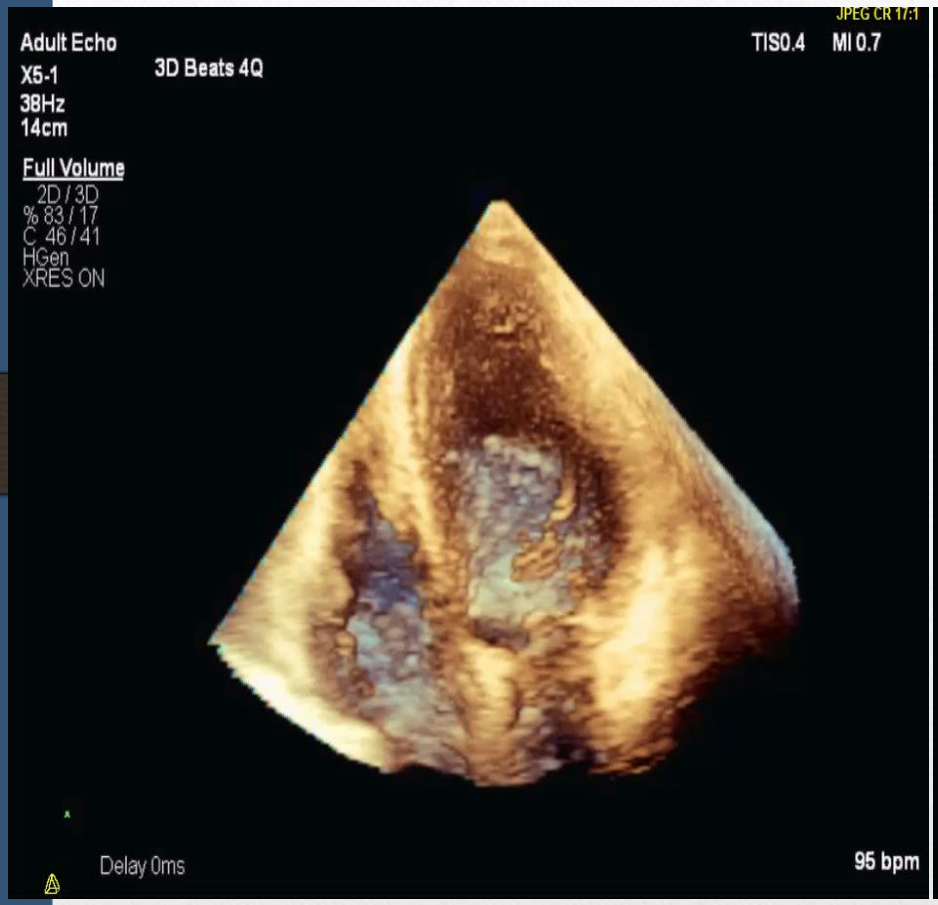
53 yo man with a Type B dissection of the descending thoracic aorta




3D color
zoom: MPR
PHILIPS

3D Rendering

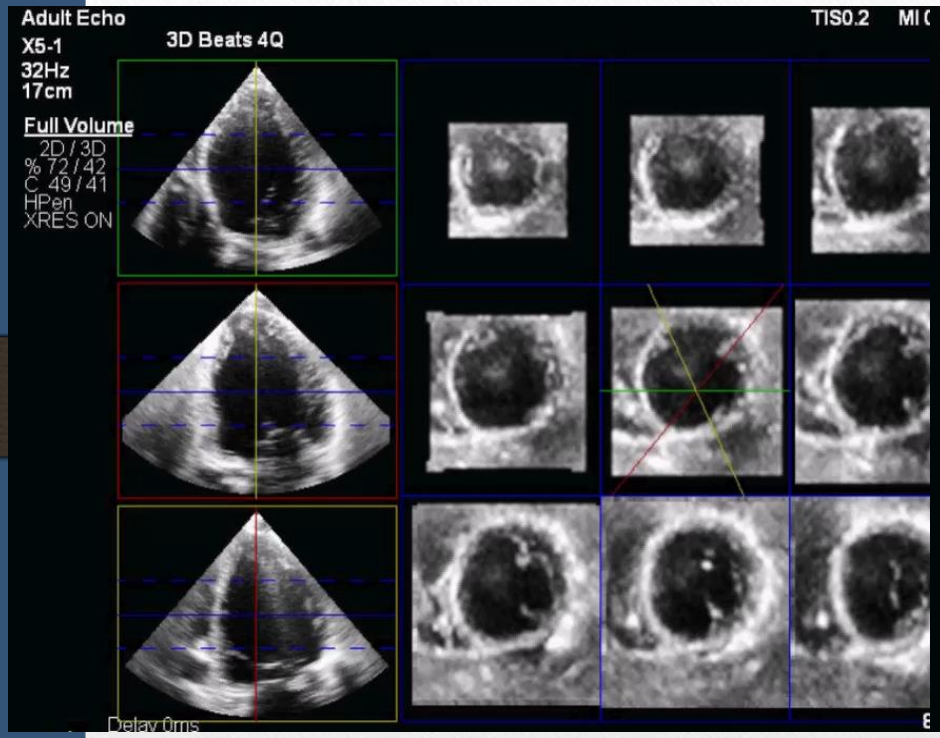
OLD

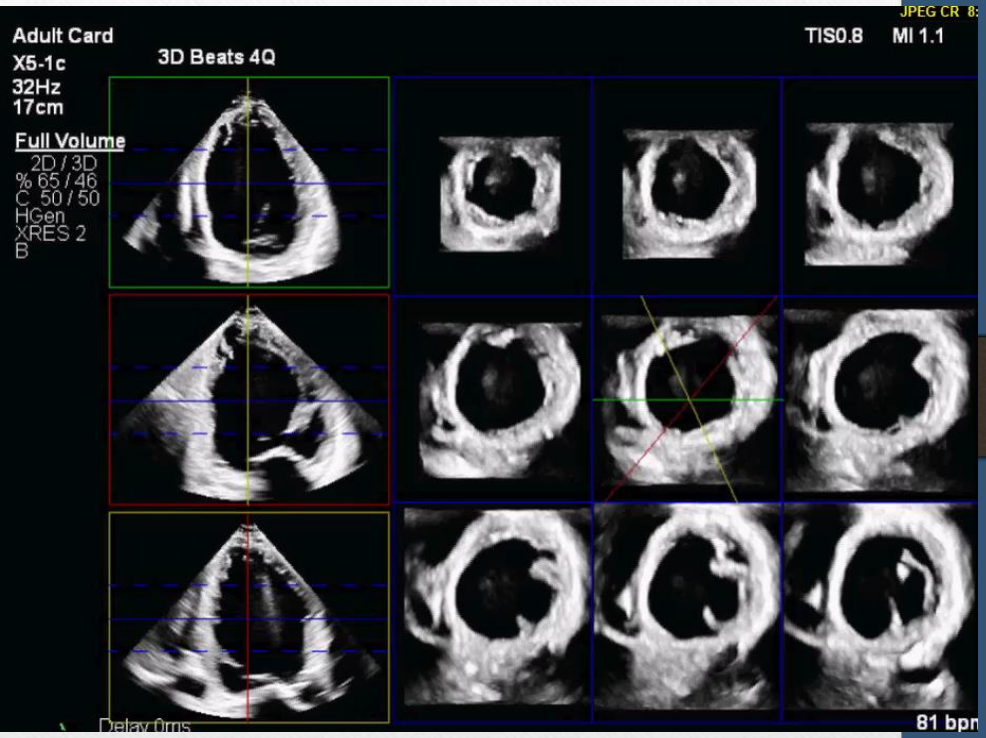

JPEG CR 17:1
Adult Echo
X5-1
38Hz
14cm
3D Beats 4Q
TIS0.4 MI 0.7
Full Volume
2D / 3D
% 83 / 17
C 46 / 41
HGen
XRES ON
Delay 0ms
95 bpm

NEW


JPEG CR 14:1
Adult Card
X5-1c
38Hz
14cm
3D Beats 4Q
TIS0.8 MI 1.0
Full Volume
2D / 3D
% 73 / 50
C 46 / 50
HGen
XRES 2
B
Delay 0ms
95 bpm

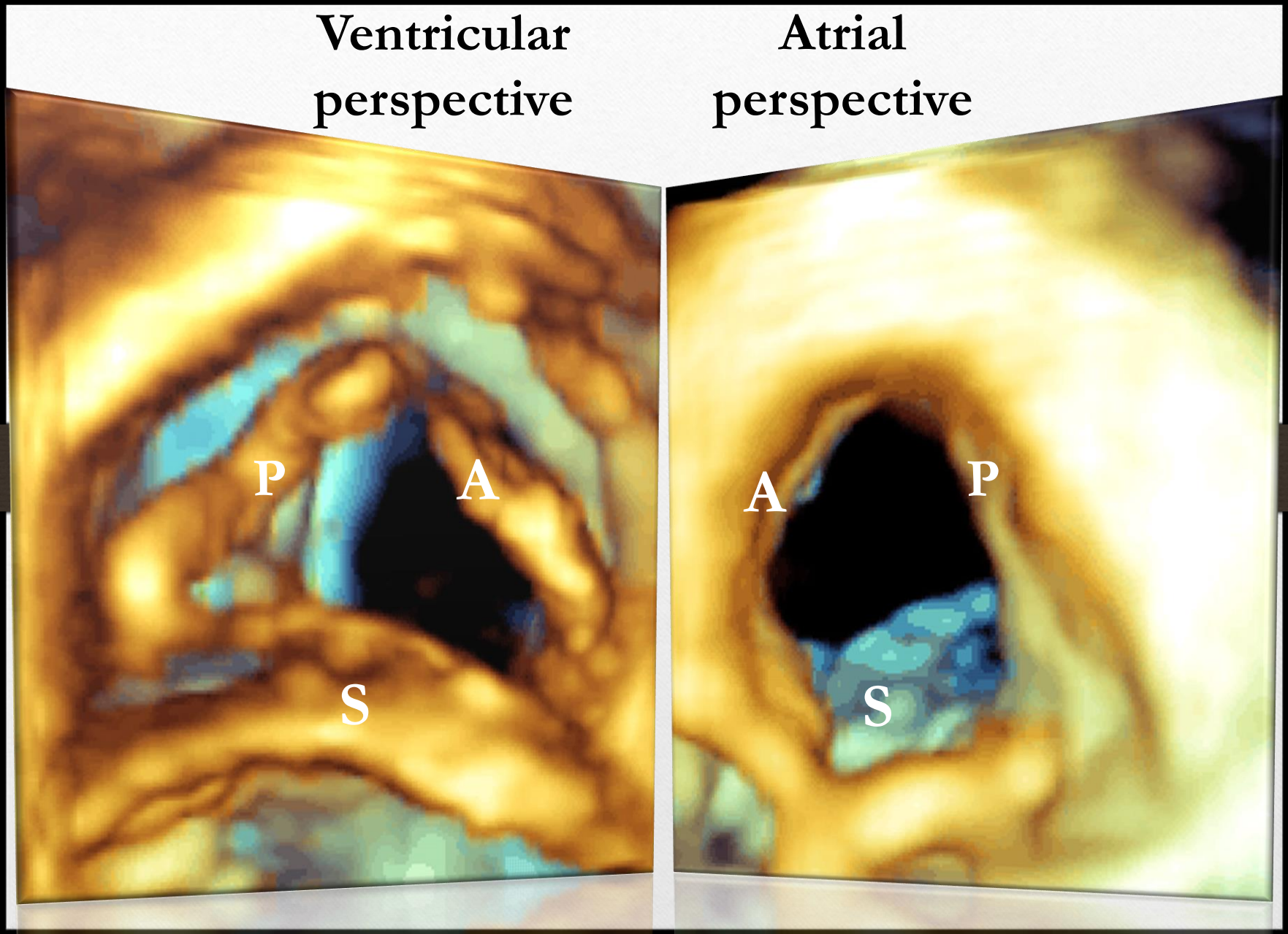
MULTI-SLICE





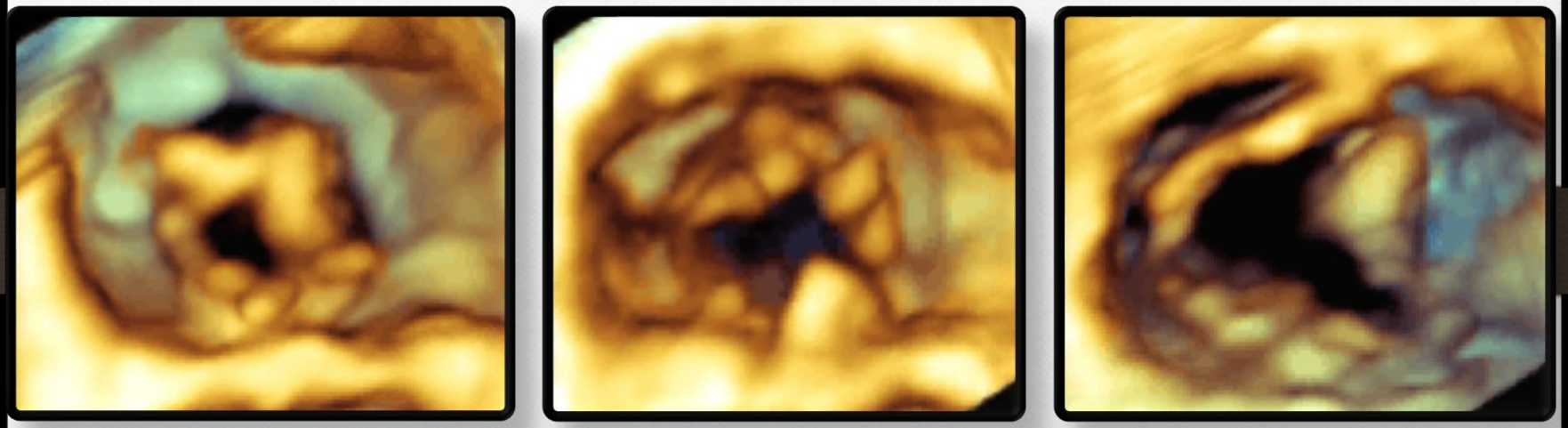
OLD

NEW

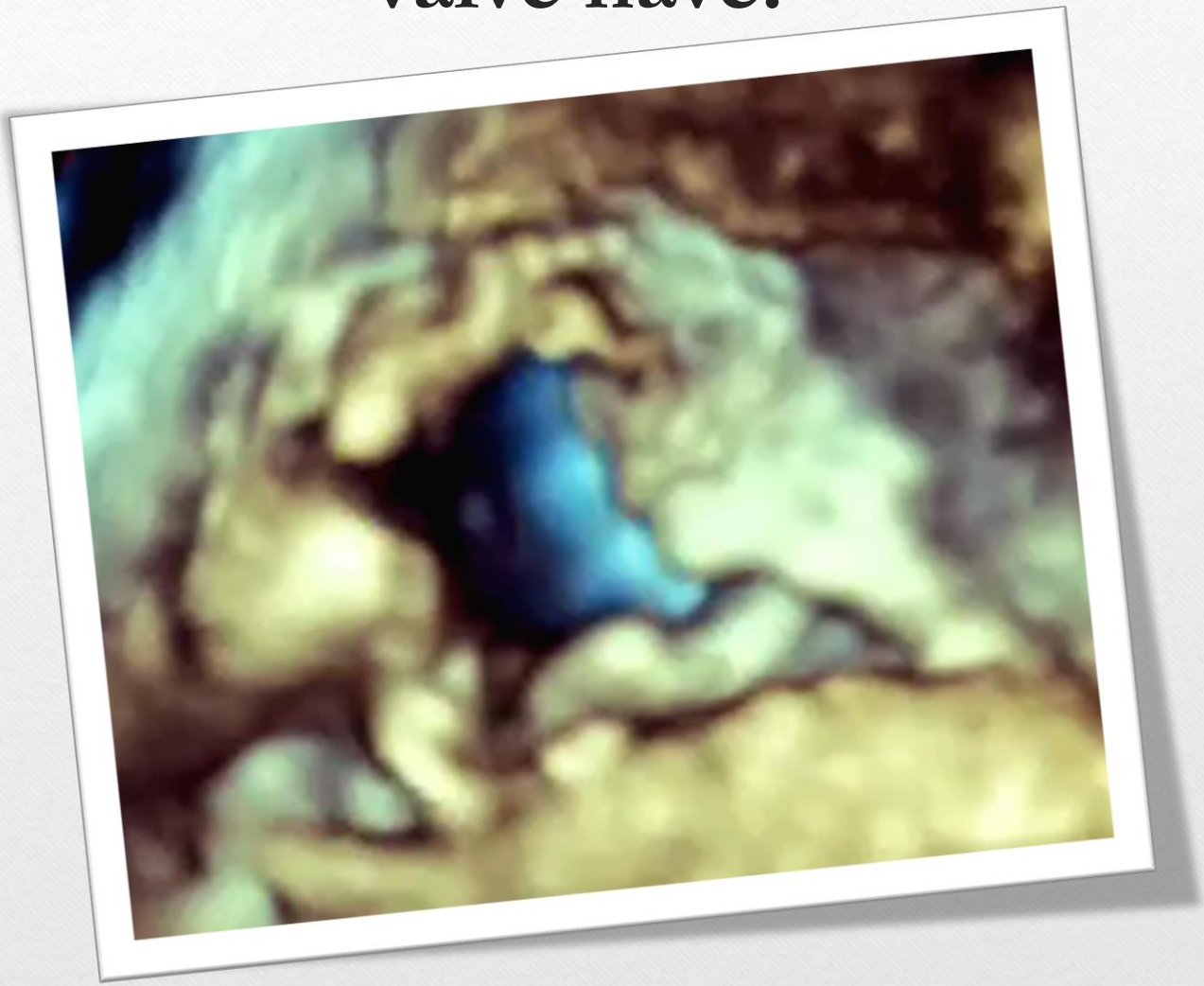


Yamat M, Addetia K, Lang RM ASE 2013 Clinical case competition finalist

Tricuspid valve malcoaptation

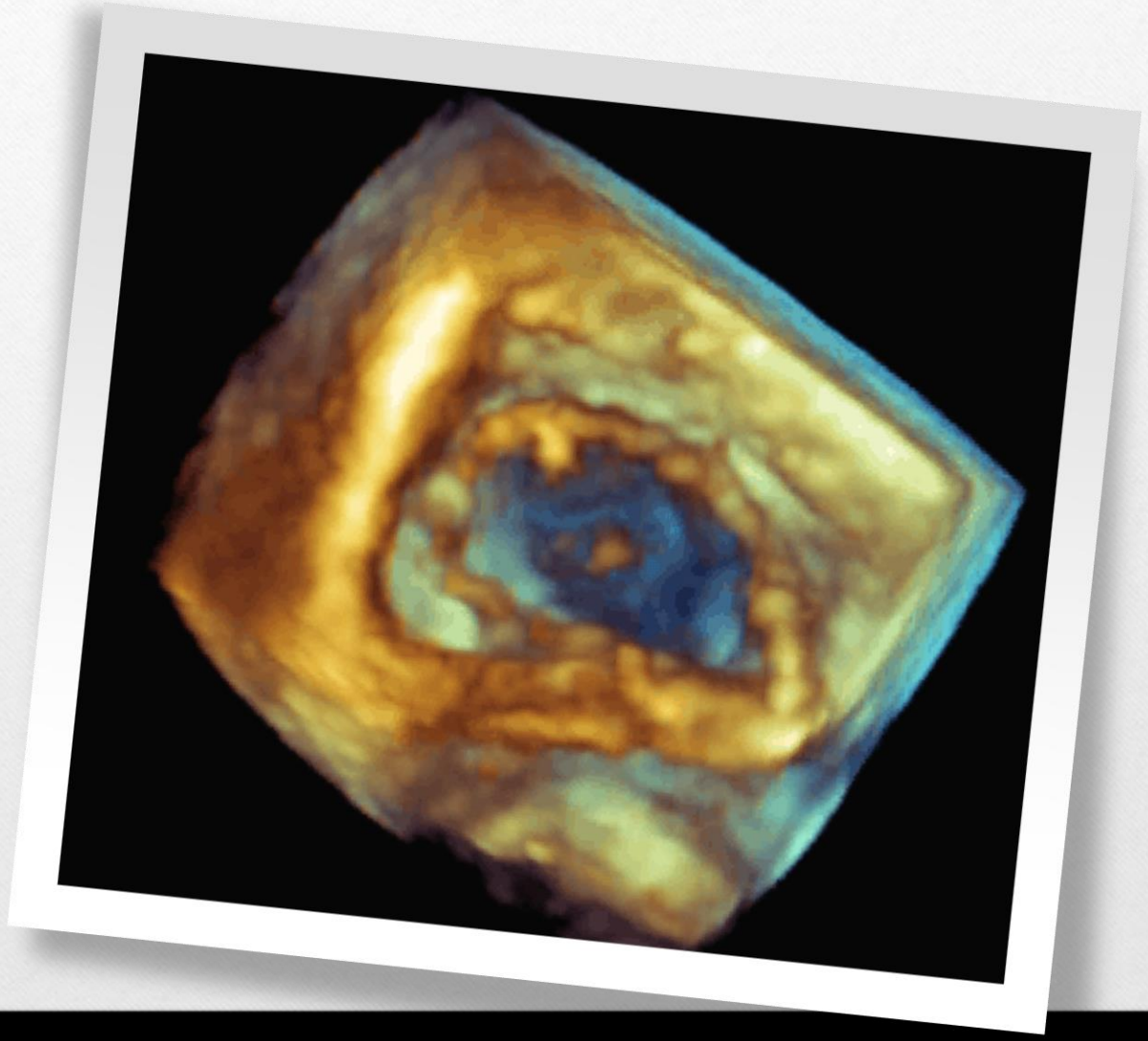


How many leaflets does the tricuspid valve have?



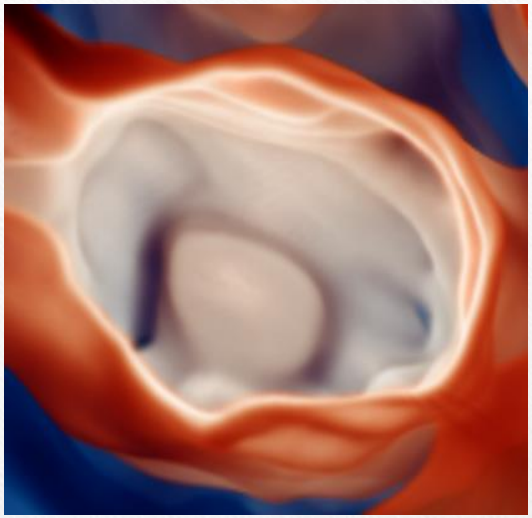
4?

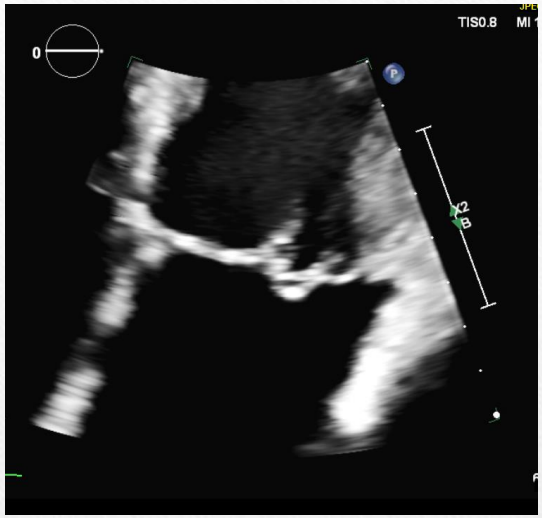
How many leaflets does the tricuspid valve have?

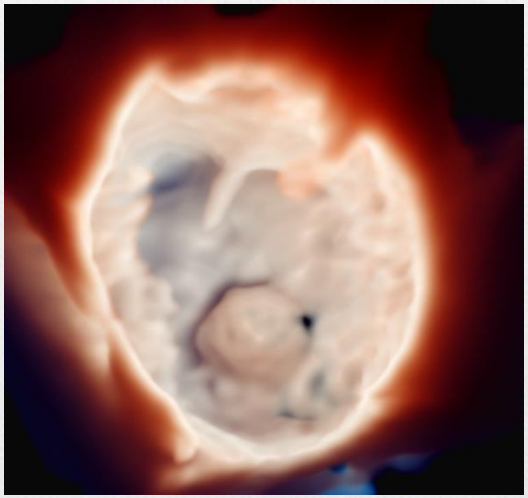


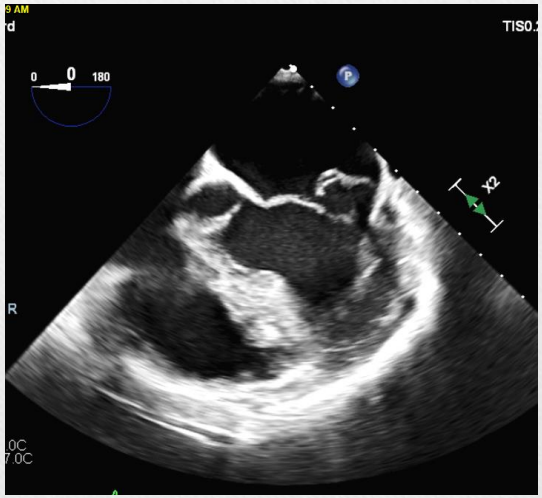
2?

Transthoracic Echocardiography





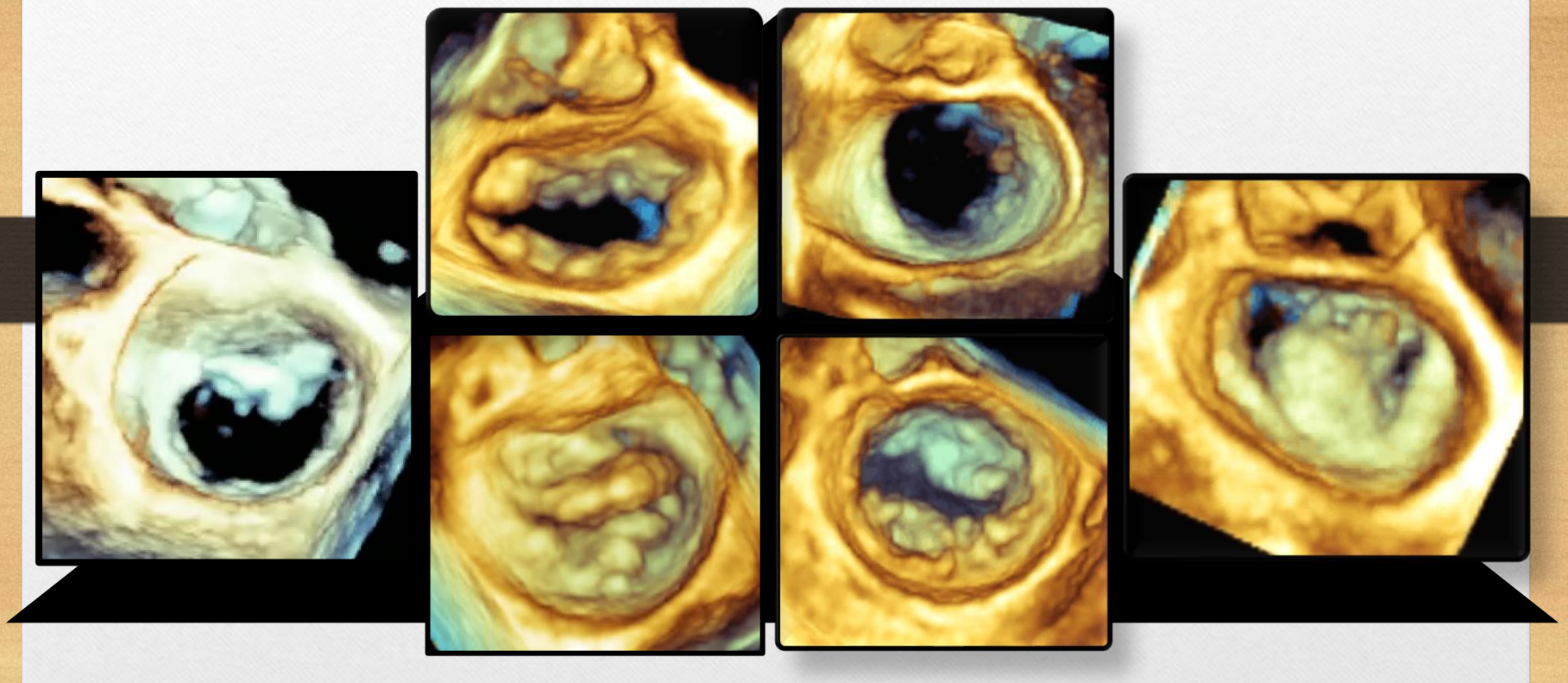


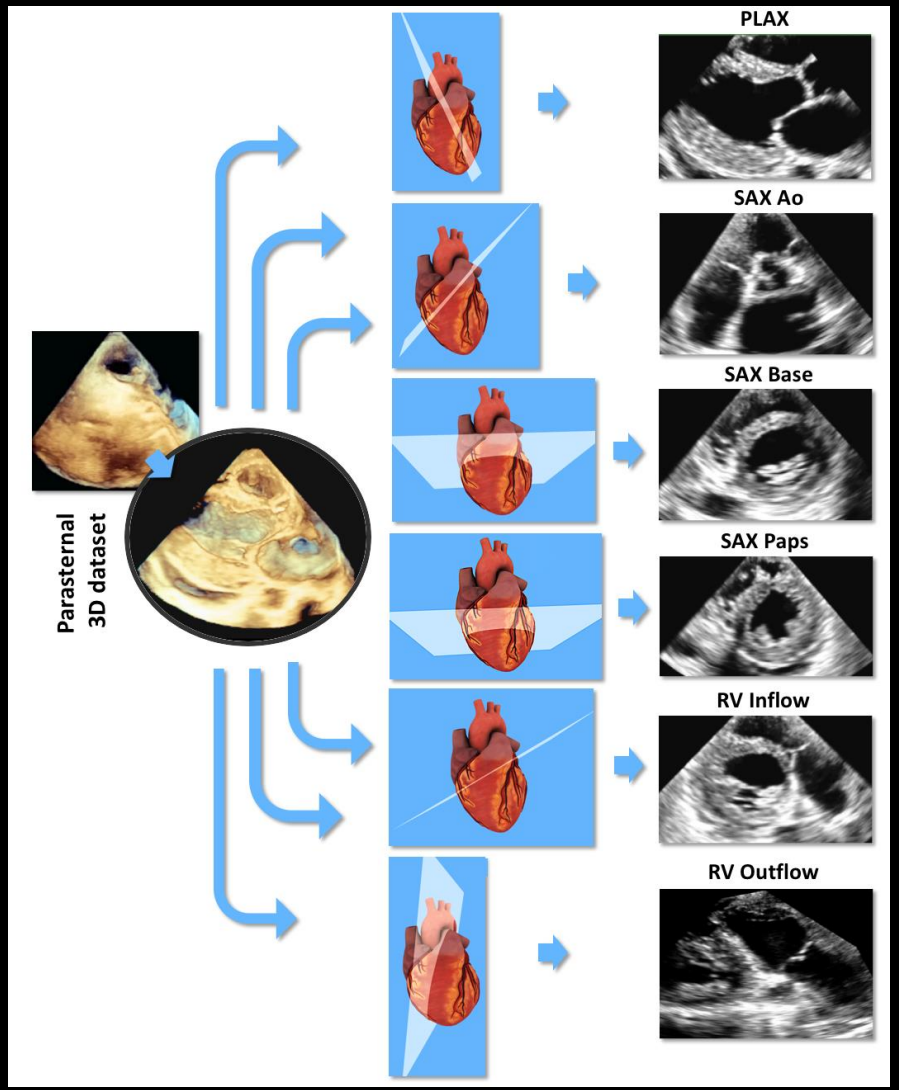


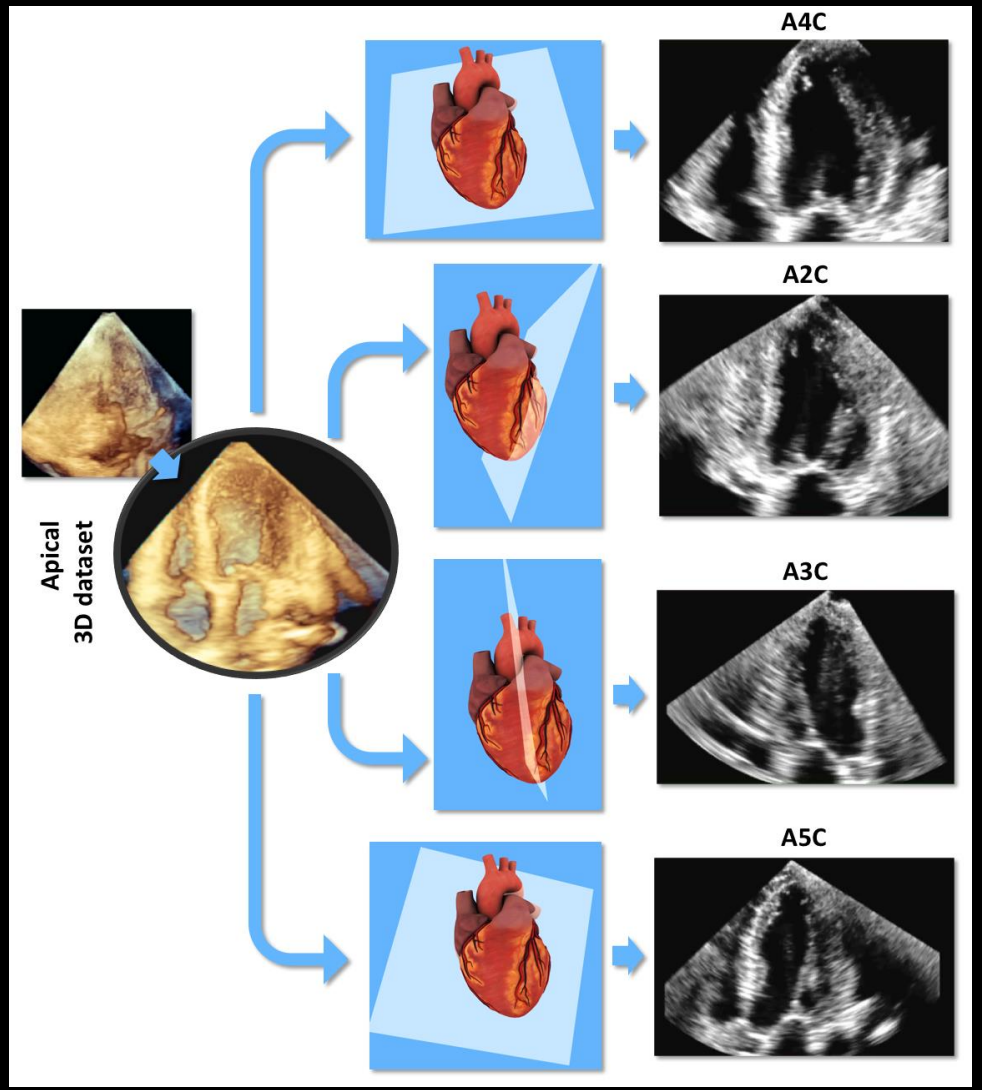
Transesophageal Echocardiography

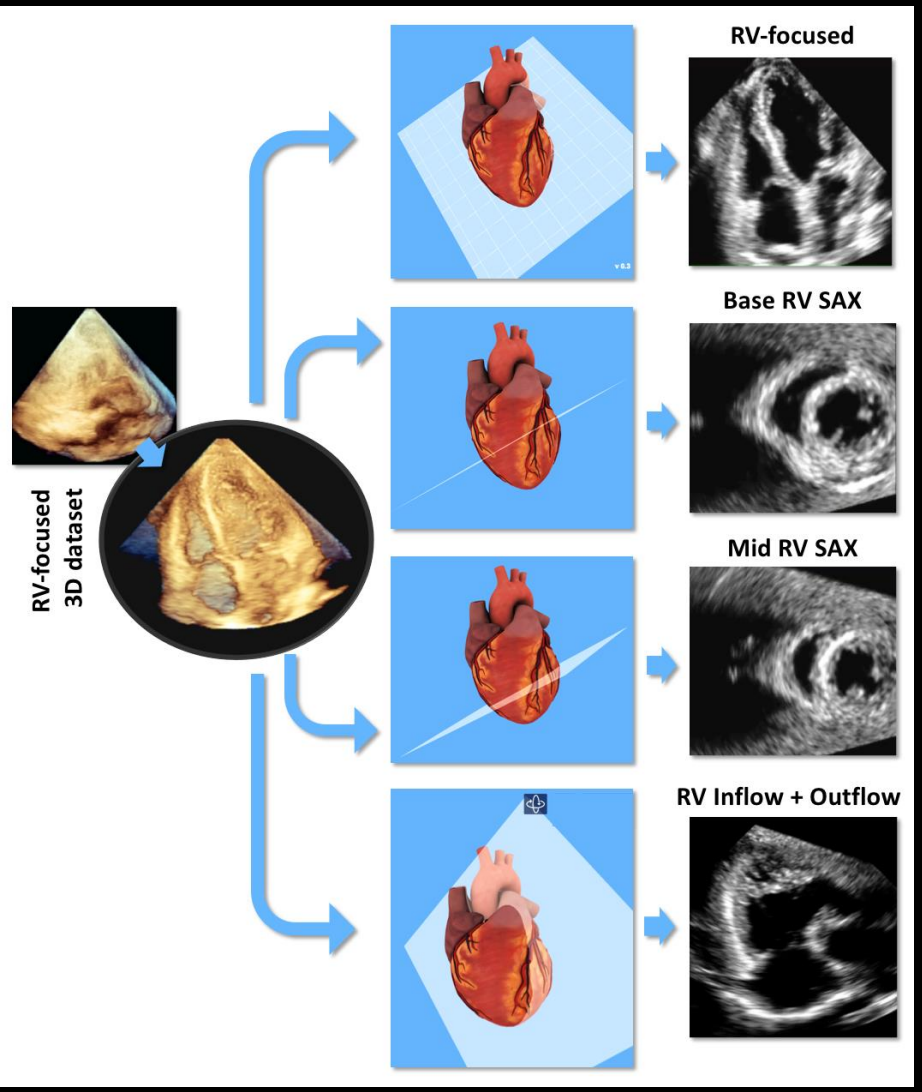
Displaying the 3D Mitral Valve

Different faces of degenerative mitral valve disease




Parasternal
3D dataset
PLAX
SAX Ao
SAX Base
SAX Paps
RV Inflow
RV Outflow


Apical
3D dataset
A4C
A2C
A3C
A5C



		3D score			
		1	2	3	Total
2DE score	1	1012 (85.3%)	70 (5.7%)	19 (1.6%)	1101
	2	55 (4.46%)	17 (1.6%)	5 (0.4%)	77
	3	4 (0.33%)	1 (0.08%)	5 (0.4%)	10
	Total	1071	88	29	1188

				Bland-Altman Analysis			Linear Regression	
	Standard 2DE	3DE-derived 2D	p	Bias	LOA	Relative Bias (%)	r	p
LV IDd (cm)	5.2 ± 1.4	5.3 ± 1.2	0.03	0.16	-0.67 to 0.99	3.0	0.96	<0.001
LV IDs (cm)	4.3 ± 1.7	4.4 ± 1.6	0.07	0.18	-0.97 to 1.28	4.0	0.94	<0.001
LV ISD (cm)	1.1 ± 0.2	1.1 ± 0.3	0.67	0.01	-0.17 to 0.48	1.0	0.79	<0.001
LVPW (cm)	1.1 ± 0.2	1.1 ± 0.1	0.09	-0.06	-0.26 to 0.58	-5.7	0.46	0.004
LV EDV (ml)	148 ± 105	155 ± 95	0.20	7.5	-68 to 68	4.8	0.95	<0.001
LV ESV (ml)	103 ± 100	102 ± 95	0.68	-1.7	-48 to 49	-1.6	0.97	<0.001
LV EF (%)	40 ± 19	42 ± 18	0.03	1.8	-9.3 to 9.7	4.3	0.97	<0.001
LAV (ml)	96 ± 33	94 ± 32	0.98	-1.4	-42.2 to 42.5	-1.5	0.79	<0.001
RV BDd (cm)	4.0 ± 0.8	4.3 ± 0.8	0.0007	0.25	-0.67 to 0.99	5.9	0.88	<0.001

2DE score = 3DE score
PLAX
SAX Ao
SAX Base
SAX Paps
RV Inflow

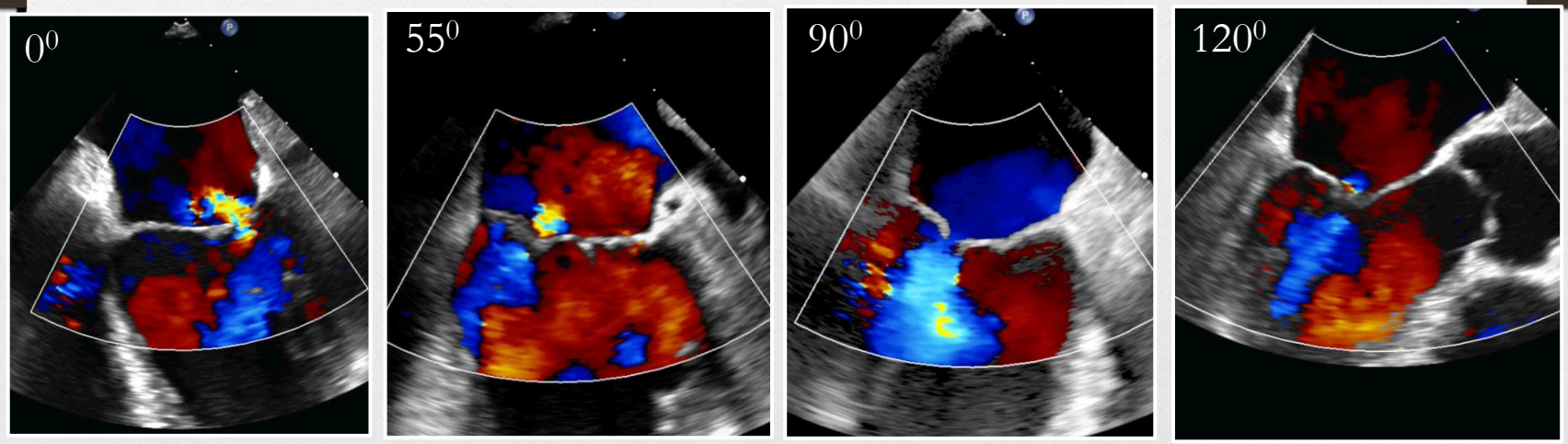
2DE score = 3DE score
A4C
A2C
A3C
RV-focused

2DE score < 3DE score
A4C
A2C
A3C
PLAX

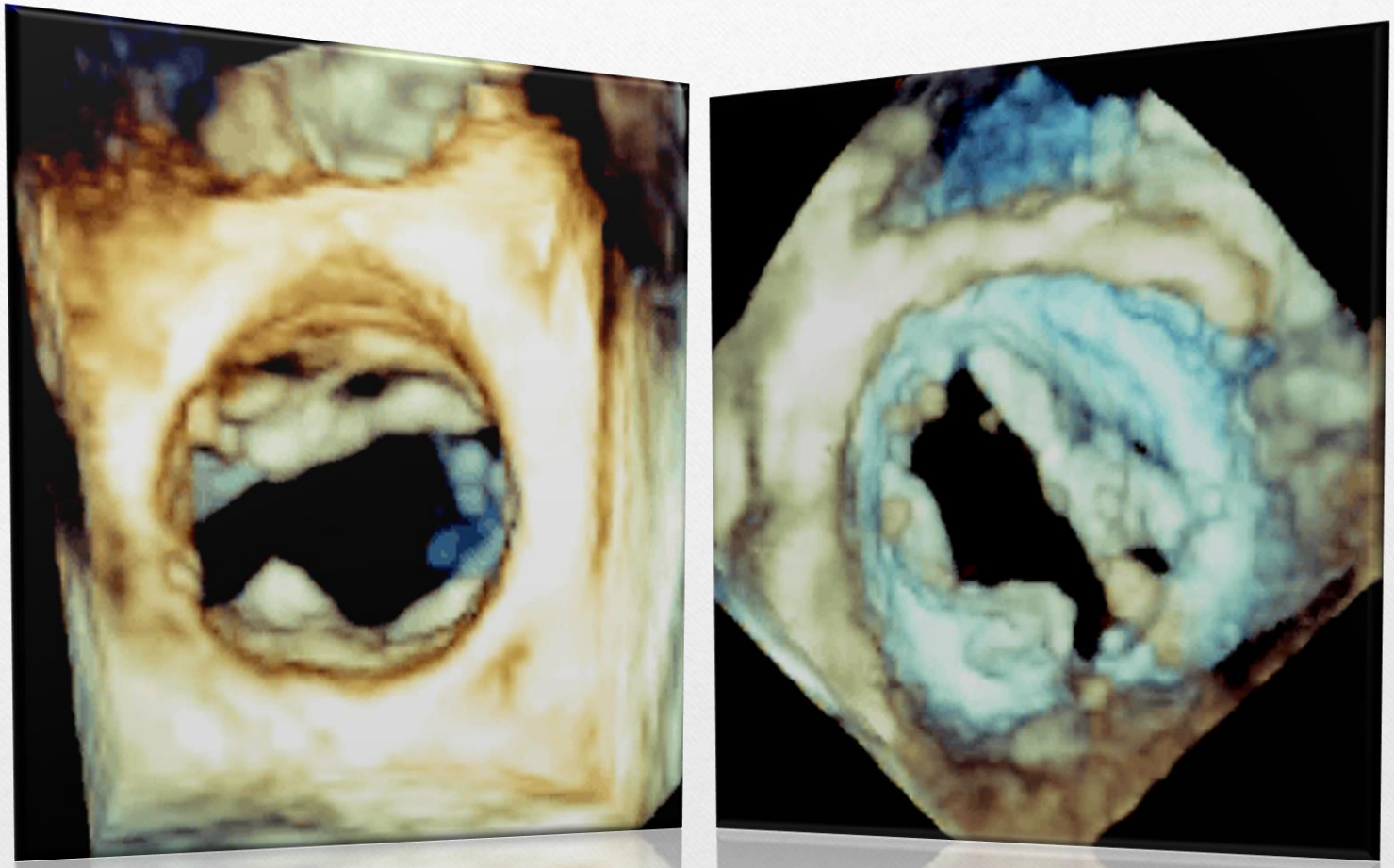
3D Color Doppler

Surprise Mechanism of MR on 3D

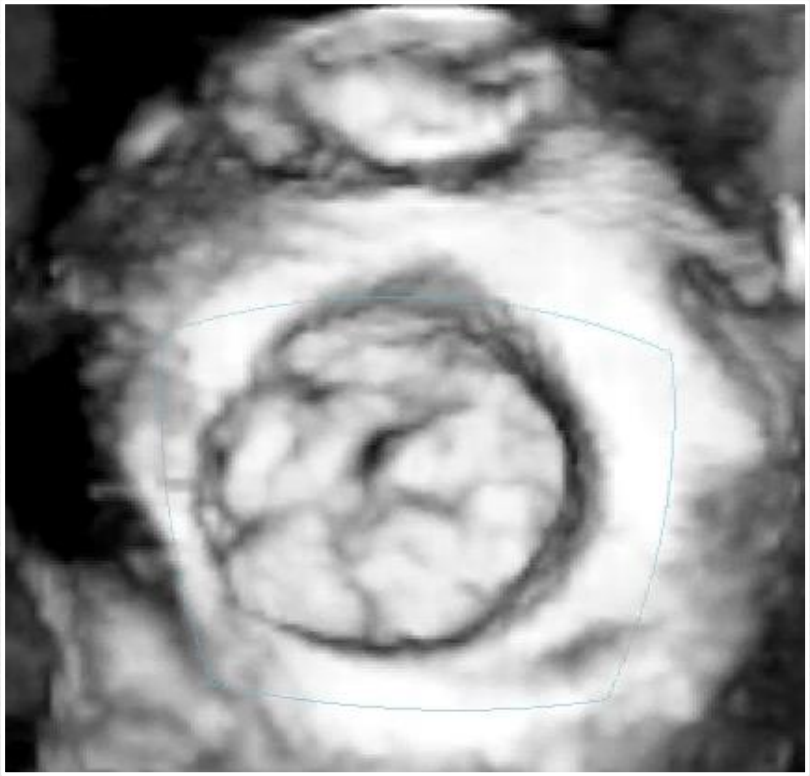
An 85-year-old man with DOE and new heart failure was diagnosed with mitral regurgitation on TTE. He is now in the echo lab for TEE and mitral clip evaluation

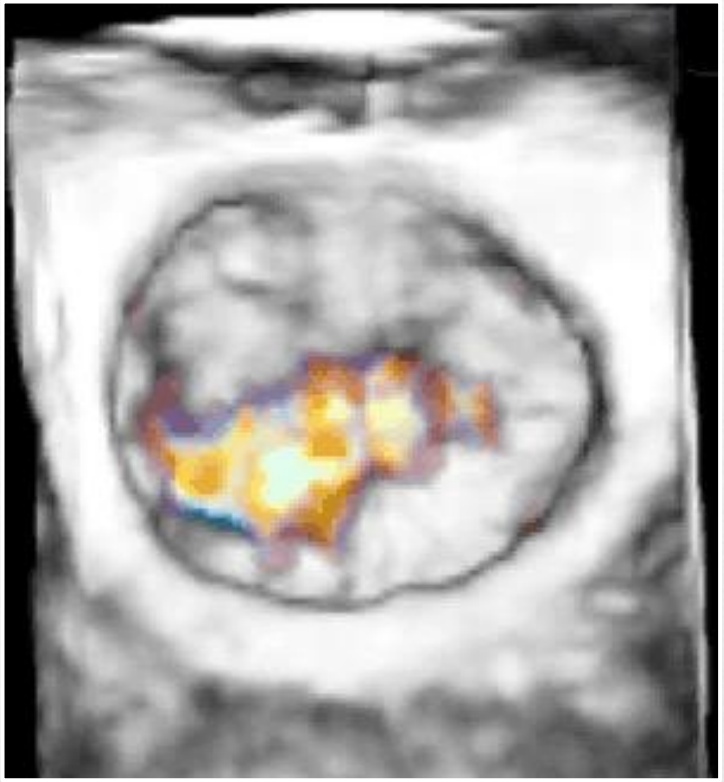


Displaying the 3D Mitral Valve

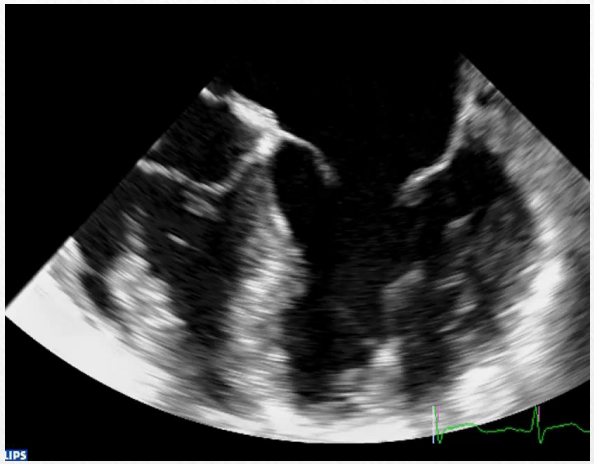


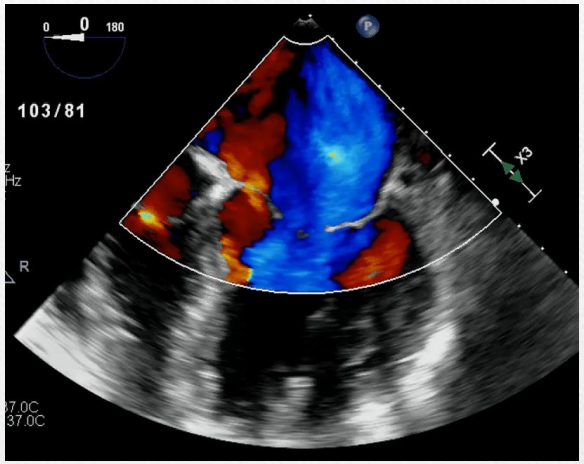
Displaying the 3D Mitral Valve

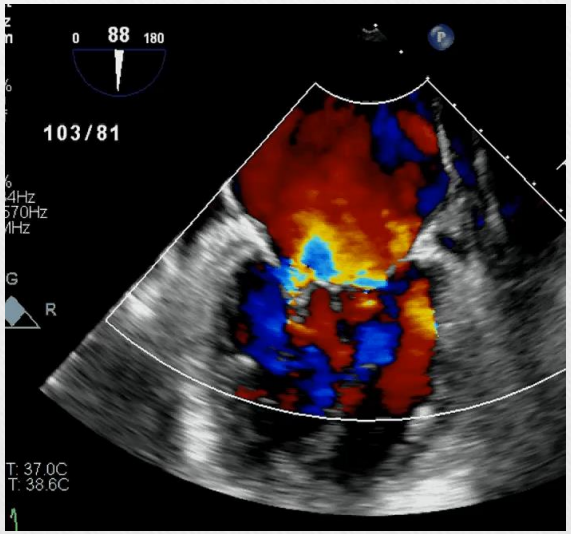


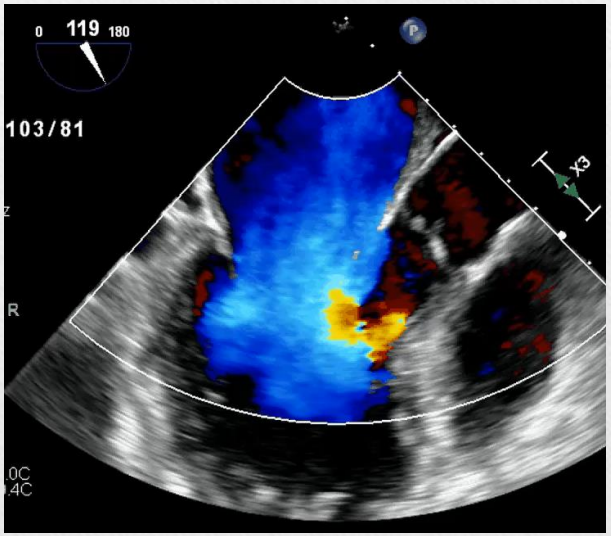


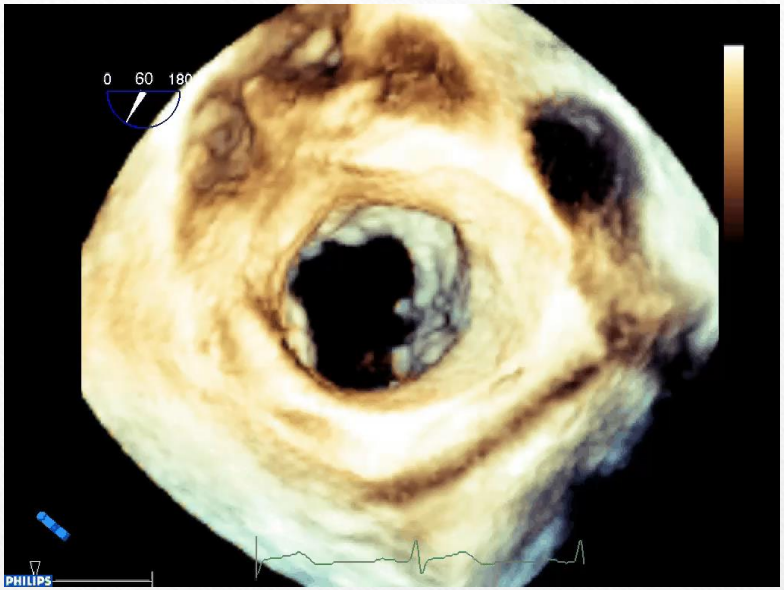
38 year-old female recently post partum with a history of repaired "hole in the heart" presents to the Echo lab for assessment of severe mitral regurgitation noted on TTE

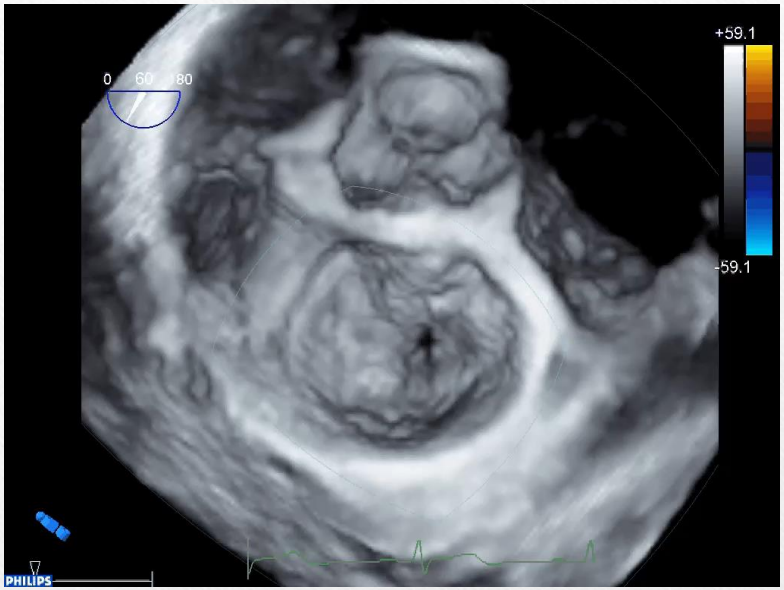


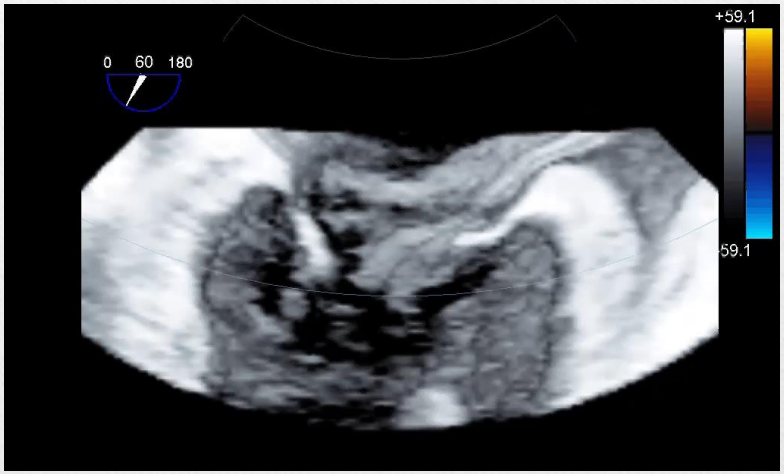







0 60 180
PHILIPS

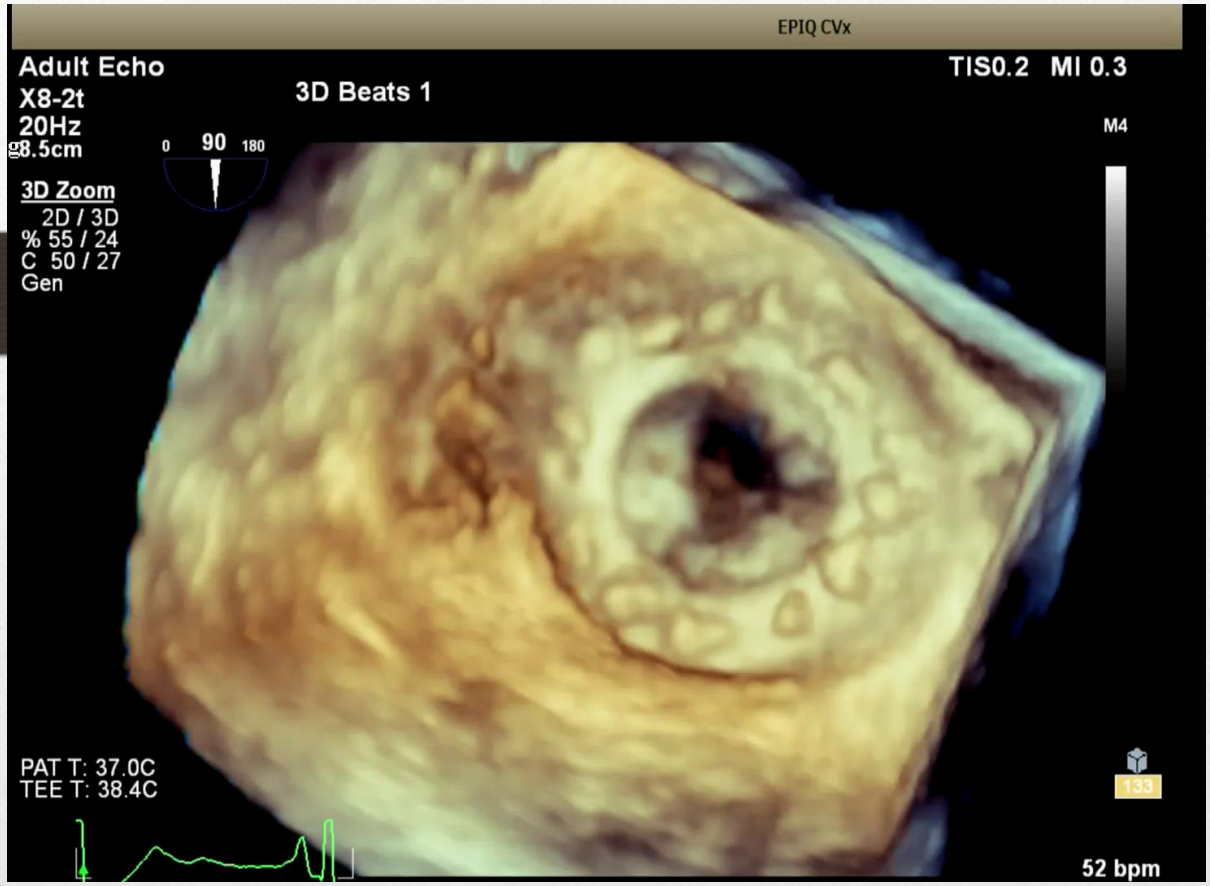

0 60 180
+59.1
-59.1
PHILIPS


0 60 180
+59.1
-59.1


Adult Echo
X8-2t
29Hz
9.5cm
3D Beats 6
TIS0.6 MI 0.2
0 60 180
3D Zoom
2D / 3D
% 65 / 80
C 50 / 30
Gen
103 / 81
CF
% 48 / 50
6818Hz
WF 681Hz
4.4MHz
M4M4
+59.1
-59.1

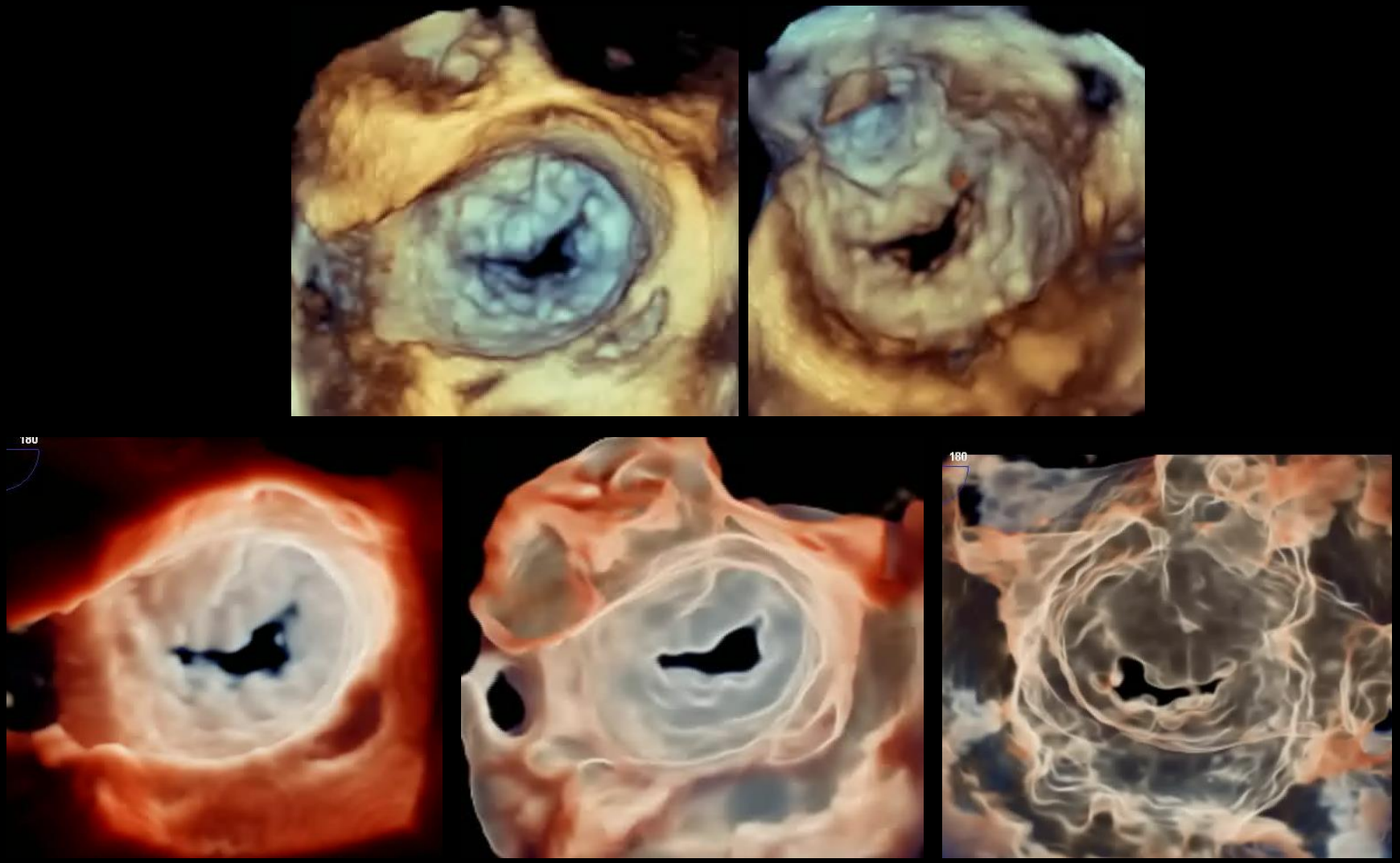
First Clinical Experience With 3-Dimensional Echocardiographic Transillumination Rendering

Davide Genovese, MD,[a,b] Karima Addetia, MD,[a] Kalie Kebed, MD,[a] Eric Kruse, RDCS,[a] Megan Yamat, RDCS,[a] Akhil Narang, MD,[a] Amit R. Patel, MD,[a] Luigi P. Badano, MD, PhD,[b] Denisa Muraru, MD, PhD,[b] Alexandra Gonçalves, MD, PhD,[c] Victor Mor-Avi, PhD,[a] Roberto M. Lang, MD[a]

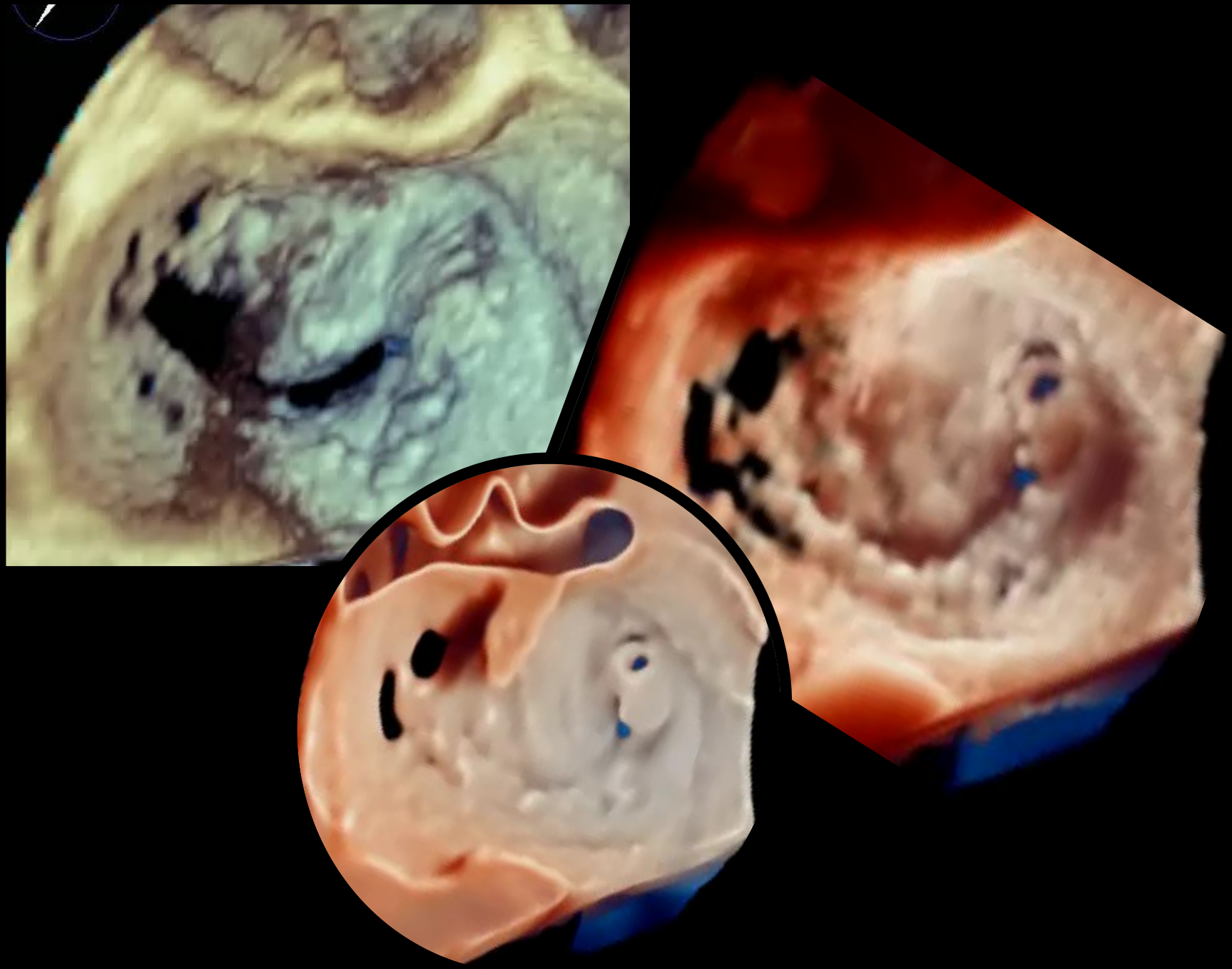


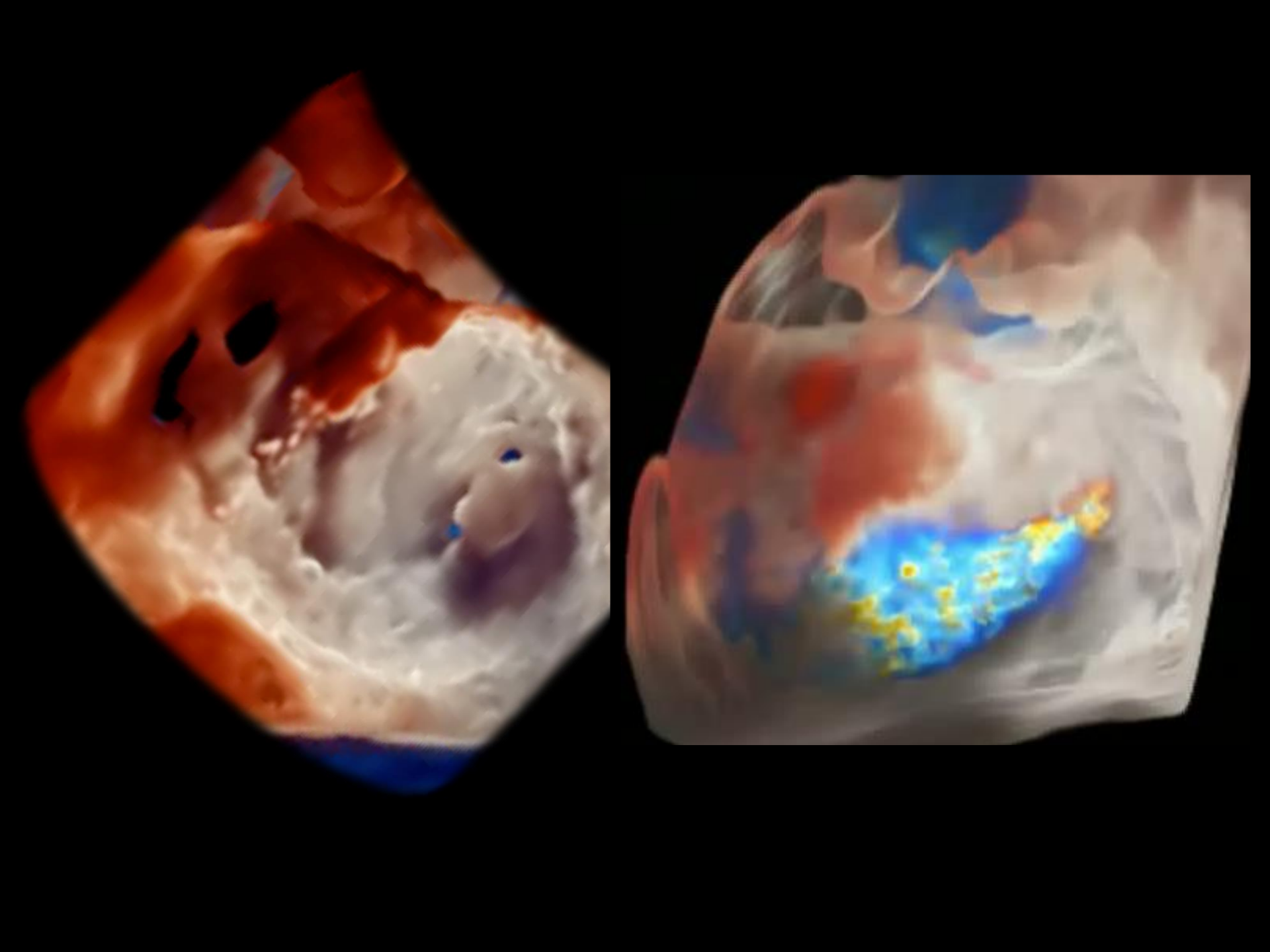
Absorption of light increases with the intensity of the ultrasound signal.

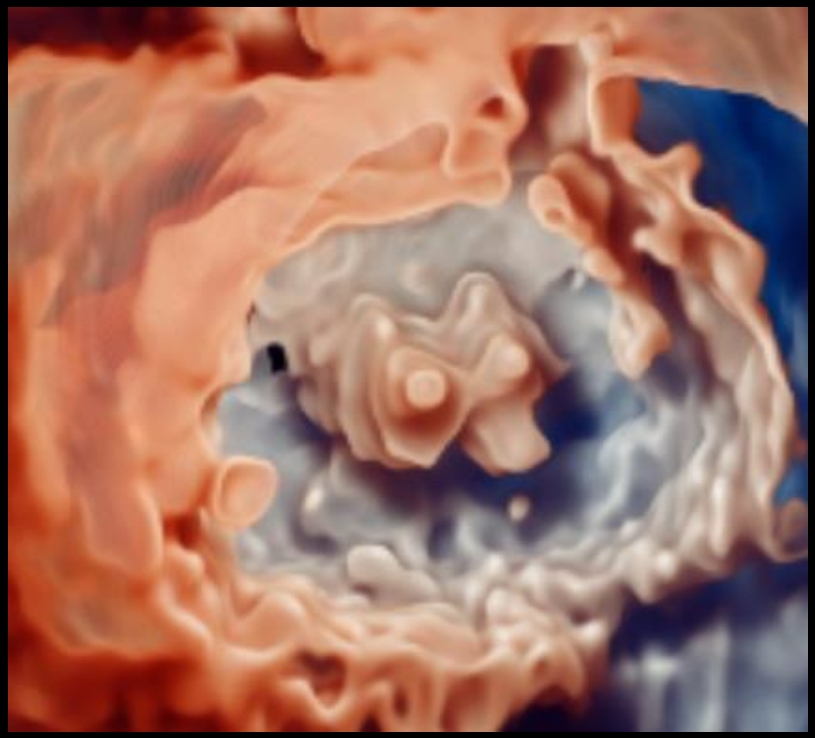
Most of the light incident on the tissue scatters back to the viewer and the tissue appears opaque.

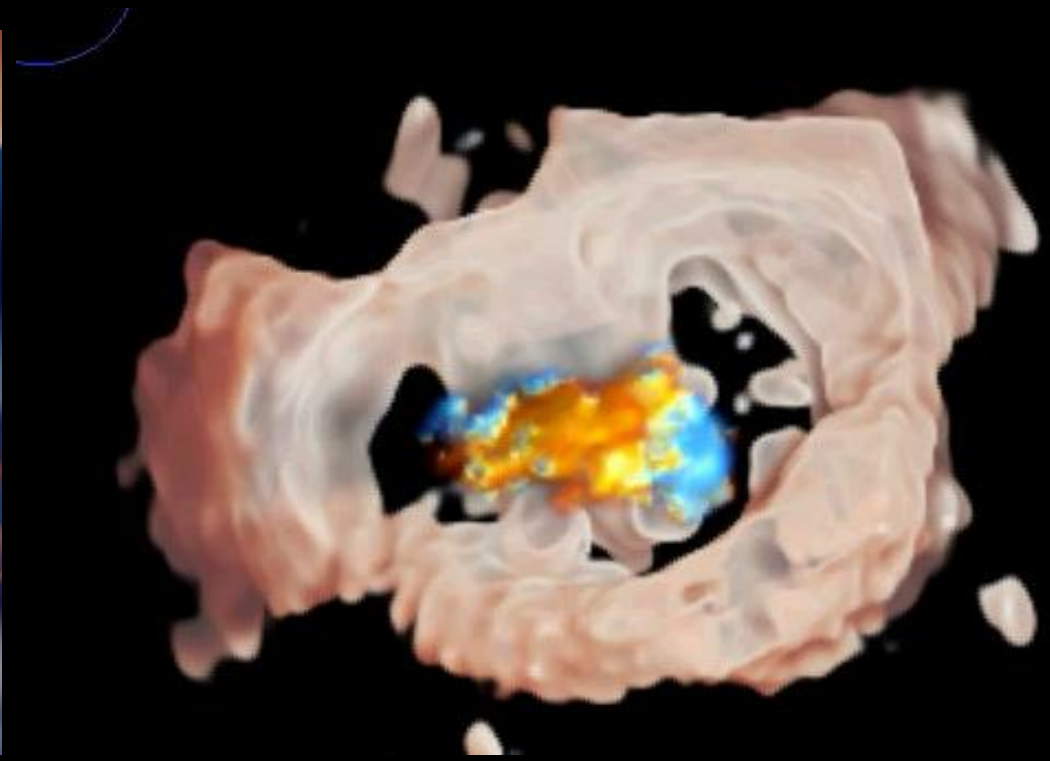


3D narrow-angle acquisition with use of transillumination and tissue transparency techniques



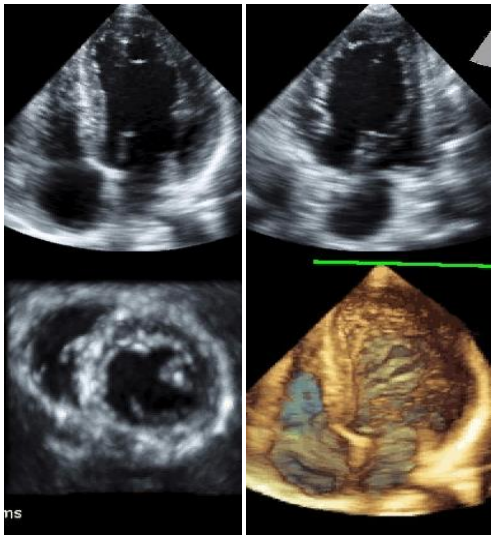




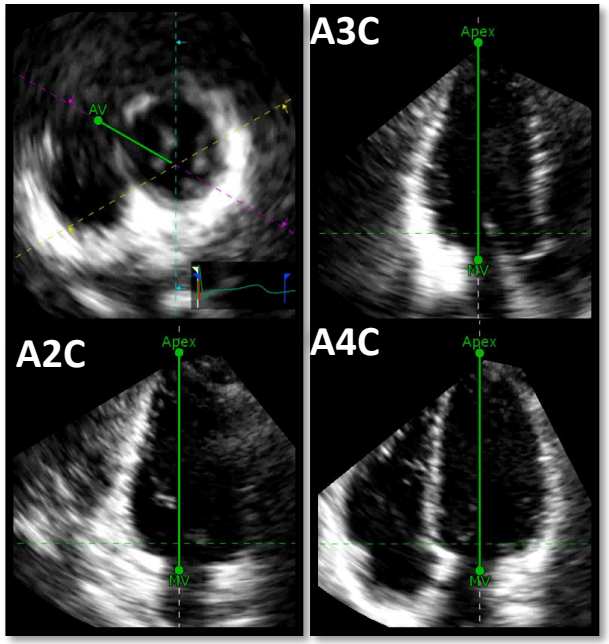


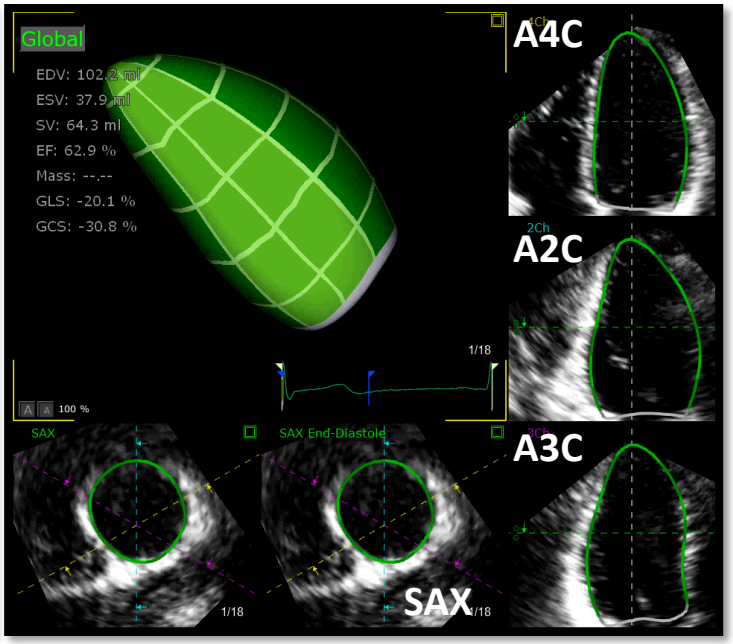
3D Surface Rendering

Surface Rendering: The Left Ventricle



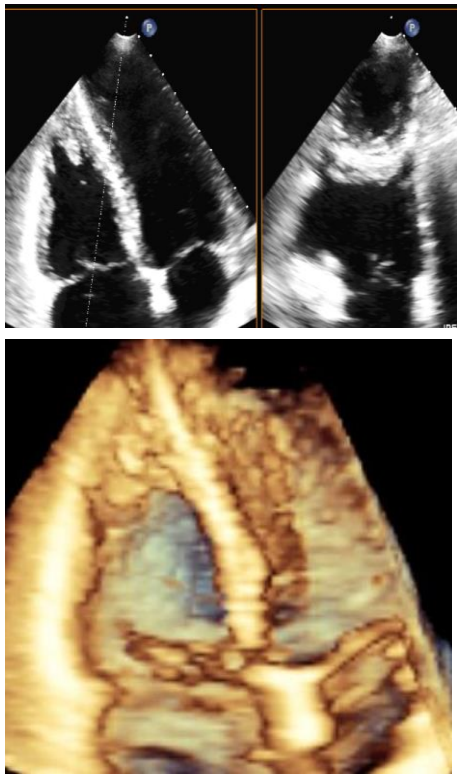
A good LV 3D full volume dataset

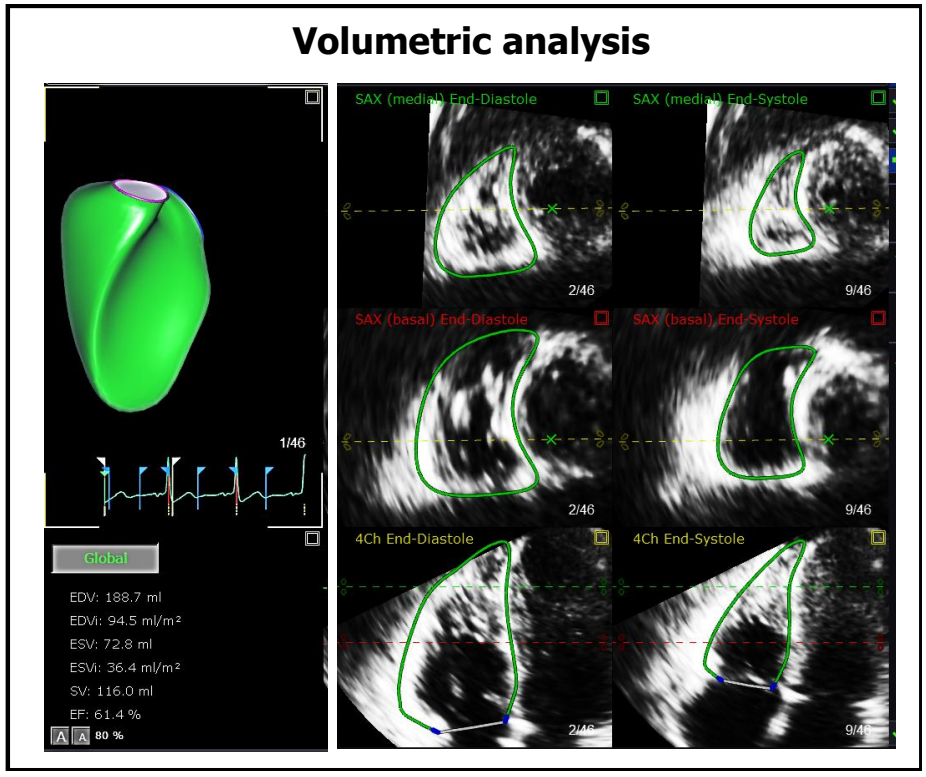


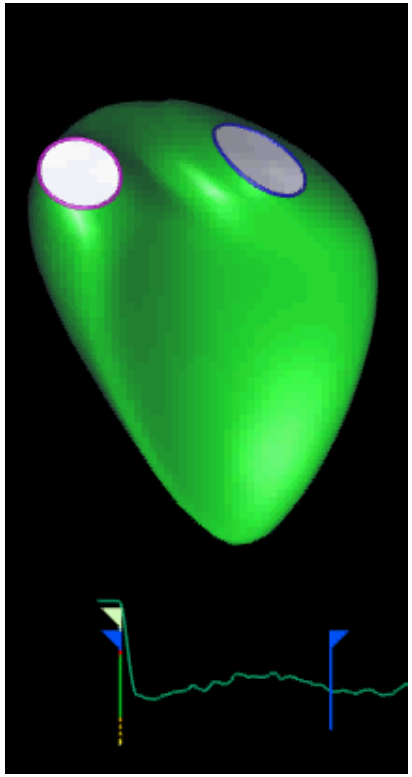


Mor-Avi V, Lang RM et al., Circulation 2004

Surface Rendering: The Right Ventricle

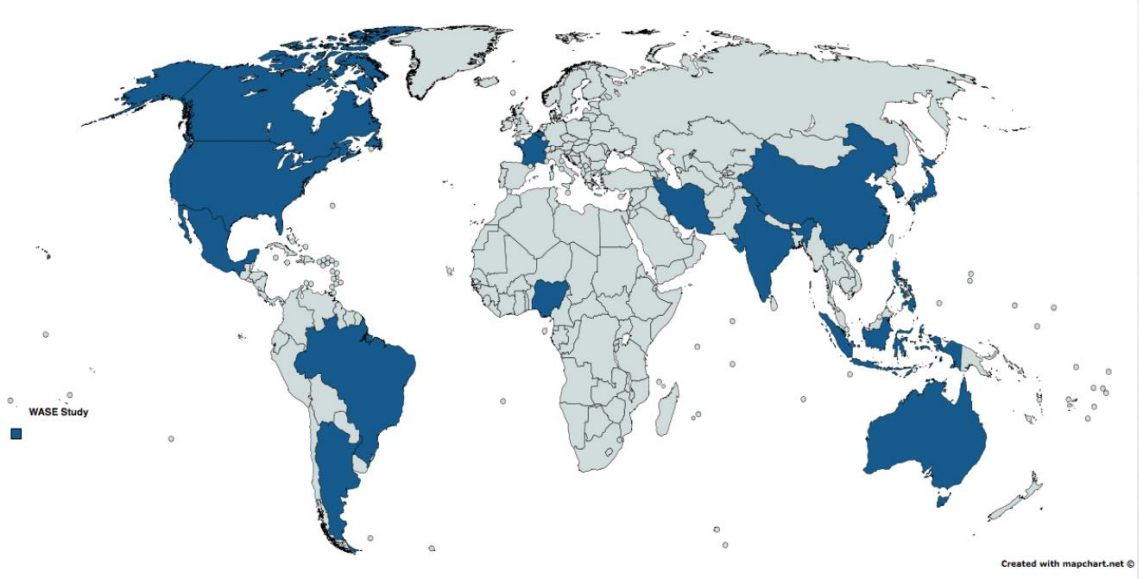






Addetia K et. al. Oh Manual

ASE Foundation



WASE
World Alliance Societies of Echocardiography
ASE A Foundation Research Initiative

Asch FM, Banchs J, Price R, Rigolin V, Thomas JD, Weissman NJ, Lang RM.
Need for a Global Definition of Normative Echo Values-Rationale and Design of the World Alliance of Societies of Echocardiography Normal Values Study (WASE). Am Soc Echocardiogr 2019 Jan;32(1):157-162.e2.

ESTABLISHING NORMAL ECHOCARDIOGRAPHIC VALUES

Editorial Comment

Need for a Global Definition of Normative Echo Values—Rationale and Design of the World Alliance of Societies of Echocardiography Normal Values Study (WASE)

. Asch, FASE, Jose Banchs, FASE, Rhonda Price, Vera Rigolin, FASE, James D. Thomas, FASE, Neil J. Weissman, FASE, nd Roberto M. Lang, FASE, *Washington, DC; Houston, Texas; Durham, North Carolina; and Chicago, Illinois*

NORMAL IN ECHOCARDIOGRAPHY: CURRENT ES AND LIMITATIONS

all studies were conducted in the United States or Europe, further limiting the diversity of the populations assessed. These limitations are particularly important in view of recent publications from

NORMAL VALUES FOR MEASUREMENTS OF THE RIGHT ATRIUM

Normal Values of Right Atrial Size and Function According to Age, Sex, and Ethnicity: Results of the World Alliance Societies of Echocardiography Study

Laurie Soulat-Dufour, MD, Karima Addetia, MD, Tatsuya Miyoshi, MD, Rodolfo Citro, MD, Masao Daimon, MD, PhD, Pedro Gutierrez Fajardo, MD, FASE, Ravi R. Kasliwal, MD, FASE, James N. Kirkpatrick, MD, FASE, Mark J. Monaghan, PhD, Denisa Muraru, MD, FASE, Kofo O. Ogunyankin, MD, FASE, Seung Woo Park, MD, Ricardo E. Ronderos, MD, FASE, Anita Sadeghpour, MD, FASE, Gregory M. Scalia, MD, FASE, Masaaki Takeuchi, MD, PhD, FASE, Wendy Tsang, MD, Edwin S. Tucay, MD, FASE, Ana Clara Tude Rodrigues, MD, Amuthan Vivekanandan, MI DM, FASE, Yun Zhang, MD, FASE, Markus Diehl, MS, Marcus Schreckenberg, MS, Victor Mor-Avi, PhD, FASI Federico M. Asch, MD, FASE, and Roberto M. Lang, MD, FASE, on Behalf of the WASE Investigators, *Chicag Illinois; Washington, District of Columbia; Salerno, Italy; Tokyo and Kitakyushu, Japan; Guadalajara, Mexico; Gurgaon and Madurai, India; Seattle, Washington; London, United Kingdom; Milan, Italy; Lagos, Nigeria; Seou Korea; Buenos Aires, Argentina; Tehran, Iran; Brisbane, Australia; Toronto, Ontario, Canada; Quezon City, Philippines; São Paulo, Brazil; Jinan, China; and Unterschleissheim, Germany*

ARTICLE IN PRESS

Two-Dimensional Echocardiographic Right Ventricular Size and Systolic Function Measurements Stratified by Sex, Age, and Ethnicity: Results of the World Alliance of Societies of Echocardiography Study

Karima Addetia, MD, FASE, Tatsuya Miyoshi, MD, Rodolfo Citro, MD, Masao Daimon, MD, PhD, Pedro Gutierrez Fajardo, MD, FASE, Ravi R. Kasliwal, MD, FASE, James N. Kirkpatrick, MD, FASE, Mark J. Monaghan, PhD, Denisa Muraru, MD, FASE, Kofo O. Ogunyankin, MD, FASE, Seung Woo Park, MD, Ricardo E. Ronderos, MD, FASE, Anita Sadeghpour, MD, FASE, Gregory M. Scalia, MD, FASE, Masaaki Takeuchi, MD, PhD, FASE, Wendy Tsang, MD, Edwin S. Tucay, MD, FASE, Ana Clara Tude Rodrigues, MD, Amuthan Vivekanandan, MD, DM, FASE, Yun Zhang, MD, FASE, Marcus Schreckenberg, MS, Victor Mor-Avi, PhD, FASE, Federico M. Asch, MD, FASE, and Roberto M. Lang, MD, FASE, on Behalf of the WASE Investigators, *Chicago, Illinois; Washington, District of Columbia; Salerno and Milan, Italy; Tokyo and Kitakyushu, Japan; Jalisco, Mexico; Gurgoan and Madurai, India; Seattle, Washington; London, United Kingdom; Lagos, Nigeria; Seoul, Korea; Buenos Aires, Argentina; Tehran, Iran; Brisbane, Australia; Toronto, Ontario, Canada; Quezon City, Philippines; São Paulo, Brazil; Jinan, China; and Unterschleissheim, Germany*

Normal Values of Left Atrial Size and Function and the Impact of Age: Results of the World Alliance Societies of Echocardiography Study

Amita Singh, MD, Cristiane Carvalho Singulane, MD, Tatsuya Miyoshi, MD, Aldo D. Prado, MD, ma Addetia, MD, Michele Bellino, MD, Masao Daimon, MD, PhD, Pedro Gutierrez Fajardo, MD, FASE, Ravi R. Kasliwal, MD, FASE, James N. Kirkpatrick, MD, FASE, Mark J. Monaghan, PhD, Denisa Muraru, MD, FASE, Kofo O. Ogunyankin, MD, FASE, Seung Woo Park, MD, Ricardo E. Ronderos, MD, FASE, Anita Sadeghpour, MD, FASE, Gregory M. Scalia, MD, FASE, Masaaki Takeuchi, MD, PhD, FASE, Wendy Tsang, MD, Edwin S. Tucay, MD, FASE, Ana Clara Tude Rodrigues, MD, Amuthan Vivekanandan, MD, DM, FASE, Yun Zhang, MD, FASE, Marcus Schreckenberg, MS, Michael Blankenhagen, MS, Markus Degel, MS, Niklas Hitschrich, BA, or Mor-Avi, PhD, FASE, Federico M. Asch, MD, FASE, and Roberto M. Lang, MD, FASE, on Behalf of WASE Investigators, *Chicago, Illinois; São José do Rio Preto and São Paulo, Brazil; Washington, District of umbia; Tucumán and Buenos Aires, Argentina; Salerno, Italy; Tokyo and Kitakyushu, Japan; Guadalajara, co; Gurgaon and Madurai, India; Seattle, Washington; London, United Kingdom; Milan, Italy; Lagos, Nigeria; , Korea; Tehran, Iran; Brisbane, Australia; Toronto, Ontario, Canada; Quezon City, Philippines; Jinan, China; and Unterschleissheim, Germany*

Background: Left atrial (LA) evaluation includes volumetric and functional parameters with an abundance of diagnostic and prognostic implications. Solid normal reference ranges are compulsory for accurate interpretation in individual patients, but previous studies have yielded mixed conclusions regarding the effects of age, sex, and/or race. The present report from the World Alliance Societies of Echocardiography study focuses on two-dimensional (2D) and three-dimensional (3D) measures of LA structure and function, with subgroup analysis by age, sex, and race.

Methods: Transthoracic 2D and 3D echocardiographic images were obtained in 1,765 healthy individuals (901 men, 864 women) evenly distributed among age subgroups: 18 to 40 years ($n = 745$), 41 to 65 years ($n = 618$), and >65 years ($n = 402$); the racial distribution was 38.4% white, 39.9% Asian, and 9.7% black. Images were analyzed using dedicated LA analysis software to measure LA volumes and phasic function from 3D volume and 2D strain curves.

Results: Three-dimensional maximum and minimum LA volumes adjusted for body surface area were nearly identical for men and women, but women demonstrated higher 3D total and passive emptying fractions (EFs). Two-dimensional reservoir strain was similar for both sexes. Age was associated with an incremental rise in LA volumes alongside characteristic shifts in functional indices. Total 2D EF and reservoir and conduit strain varied inversely with age, counteracted by higher booster strain, with a greater magnitude of effect in women.

CLINICAL INVESTIGATIONS

NORMATIVE ECHOCARDIOGRAPHIC VALU

LV SIZE AND FUNCTION AROUND THE W

Similarities and Differences in L Ventricular Size and Function among Races and Nationalities: Results of the World Alliance Societies of Echocardiography Normal Values Study

Federico M. Asch, MD, FASE, Tatsuya Miyoshi, MD, Karima Addetia, MD, FASE, Rodolfo Citro, MD, Masao Daimon, MD, PhD, Sameer Desale, MS, Pedro Gutierrez Fajardo, MD, FASE, Ravi R. Kasliwal, MD, FASE, James N. Kirkpatrick, MD, FASE, Mark J. Monaghan, PhD, Denisa Muraru, MD, FASE, Kofo O. Ogunyankin, MD, FASE, Seung Woo Park, MD, Ricardo E. Ronderos, MD, FASE, Anita Sadeghpour, MD, FASE, Gregory M. Scalia, MD, FASE, Masaaki Takeuchi, MD, PhD, FASE, Wendy Tsang, MD, Edwin S. Tucay, MD, FASE, Ana Clara Tude Rodrigues, MD, Amuthan Vivekanandan, MD,

> J Am Soc Echocardiogr. 2021 May 25;S0894-7317(21)00493-4. doi: 10.1016/j.echo.2021.05.012
Online ahead of print.

Normal Values of Cardiac Output and Stroke Volume According to Measurement Technique, Age, Sex, and Ethnicity: Results of the World Alliance of Societies of Echocardiography Study

Hena N Patel [1], Tatsuya Miyoshi [2], Karima Addetia [1], Michael P Henry [1], Rodolfo Citro [3], Masao Daimon [4], Pedro Gutierrez Fajardo [5], Ravi R Kasliwal [6], James N Kirkpatrick [7], Mark J Monaghan [8], Denisa Muraru [9], Kofo O Ogunyankin [10], Seung Woo Park [11], Ricardo E Ronderos [12], Anita Sadeghpour [13], Gregory M Scalia [14], Masaaki Takeuchi [15], Wendy Tsang [16], Edwin S Tucay [17], Ana Clara Tude Rodrigues [18], Amuthan Vivekanandan [19], Yun Zhang [20], Marcus Schreckenberg [21], Michael Blankenhagen [21], Markus Degel [21], Alexander Rossmanith [21], Victor Mor-Avi [1], Federico M Asch [2], Roberto M Lang [22], WASE Investigators

Collaborators, Affiliations + expand

PMID: 34044105 DOI: 10.1016/j.echo.2021.05.012

WORLD ALLIANCE SOCIETIES OF ECHOCARDIOGRAPHY NORMAL VALUES

Left Ventricular Diastolic Function in Healthy Adult Individuals: Results of the World Alliance Societies of Echocardiography Normal Values Study

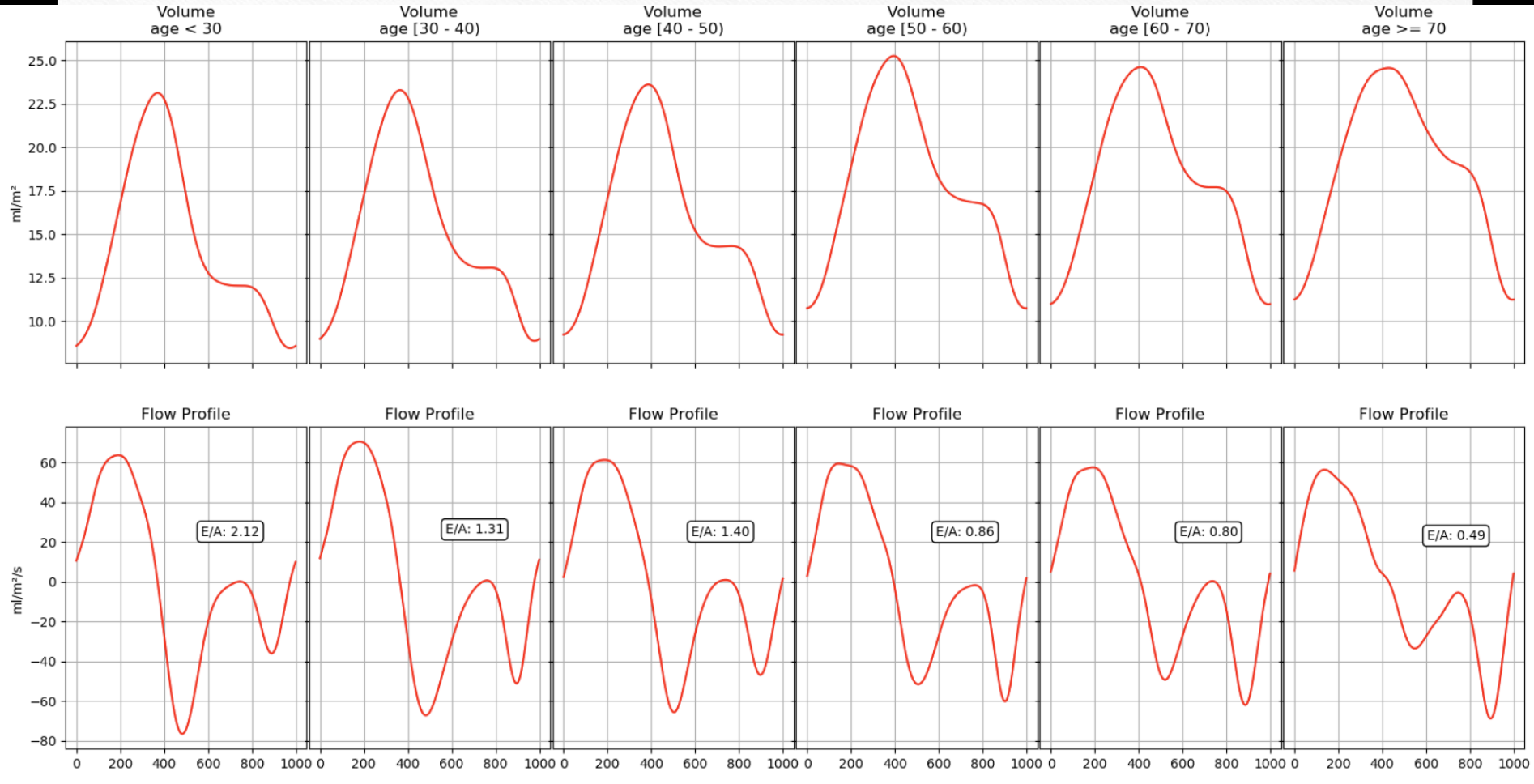
Tatsuya Miyoshi, MD, Karima Addetia, FASE, Rodolfo Citro, MD, Masao Daimon, MD, PhD, Sameer Desale, MS, Pedro Gutierrez Fajardo, FASE, Ravi R. Kasliwal, FASE, James N. Kirkpatrick, FASE, Mark J. Monaghan, PhD, Denisa Muraru, FASE, Kofo O. Ogunyankin, FASE, Seung Woo Park, MD, Ricardo E. Ronderos, FASE, Anita Sadeghpour, FASE, Gregory M. Scalia, FASE, Masaaki Takeuchi, FASE, Wendy Tsang, MD, Edwin S. Tucay, FASE, Ana Clara Tude Rodrigues, MD, Amuthan Vivekanandan, FASE, Yun Zhang, FASE, Alexandra Blitz, MD, Roberto M. Lang, FASE, and Federico M. Asch, MD, FASE, on behalf of the WASE Investigators, *Washington and D.C.; Chicago, Illinois, and Seattle, Washington; Salerno and Milan, Italy; Tokyo and Kitakyushu, Japan; Guadalajara, Jalisco, Mexico; Gurgoan, Haryana, and Madurai, India; London, United Kingdom; Lagos, Nigeria; Seoul, Republic of Korea; Buenos Aires, Argentina; Tehran, Iran; Brisbane, Australia; Toronto, Ontario, Canada; Quezon City, Philippines; São Paulo, Brazil; Jinan, Shandong, People's Republic of China; and Unterschleissheim, Germany*

Background: The World Alliance Societies of Echocardiography (WASE) study was conducted to describe echocardiographic normal values in adults ar and measurement protocol. This report focu

Methods: WASE is an international, cross-sec

World Alliance Societies of Echocardiography

ASE A Foundation Research Initiative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10.0
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Flow Profile
Flow Profile
Flow Profile
E/A: 2.12
E/A: 1.31
E/A: 1.40
E/A: 0.86
E/A: 0.80
E/A: 0.49
ml/m²/s
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−80
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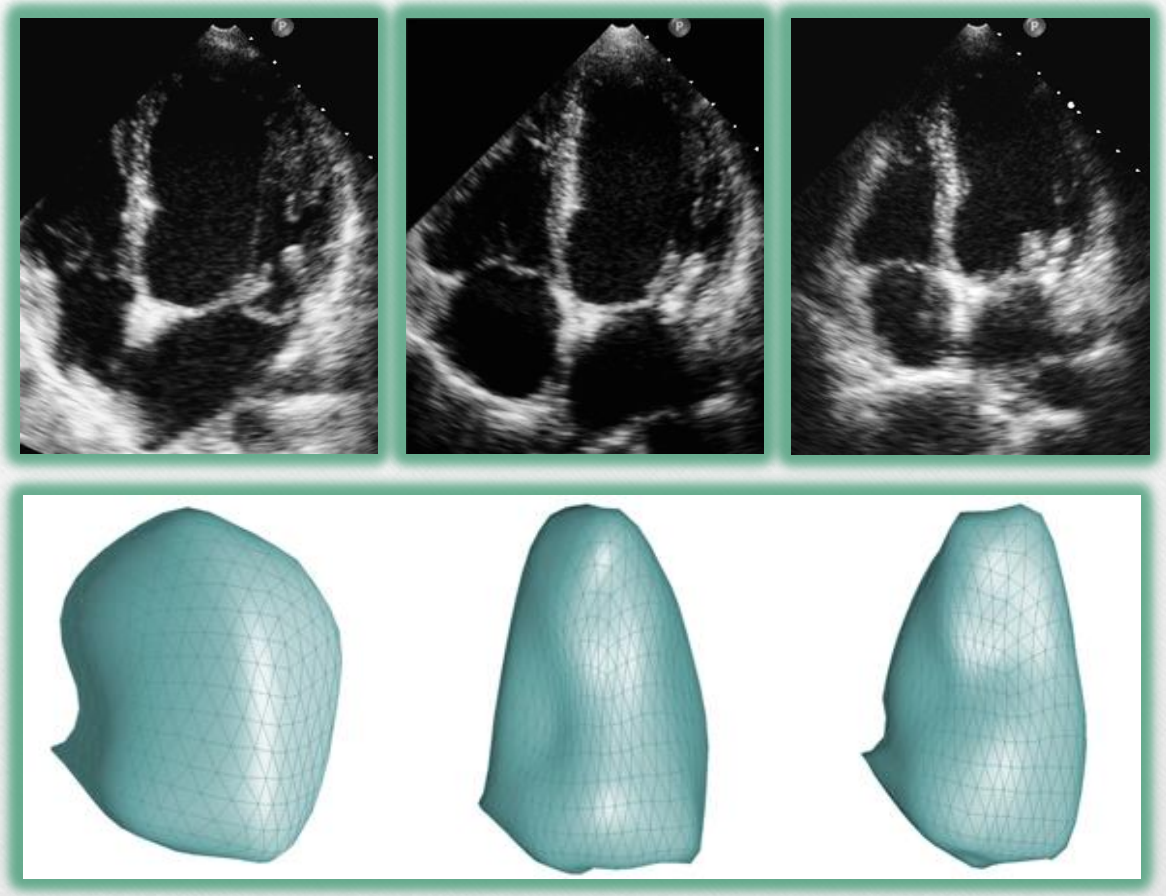
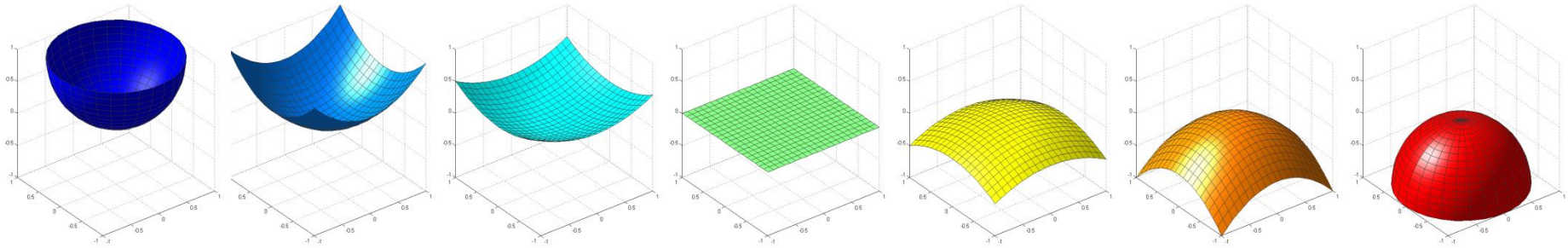
400
600
800
1000

Pre-Operative	6 Months	12 Months



Maffessanti F, Caiani EG, Tamborini G, Muratori M, Sugeng L, Weinert L, Alamanni F, Zanobini M, Mor-Avi V, Lang RM, Pepi M. *Am J Cardiol* 2010 September 15;106(6):836-842.

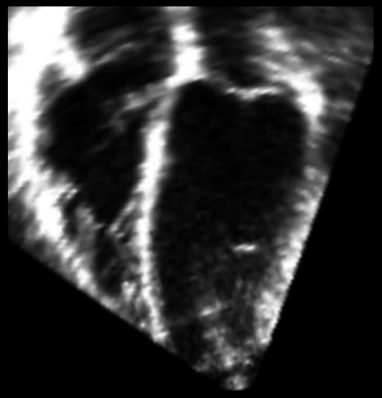
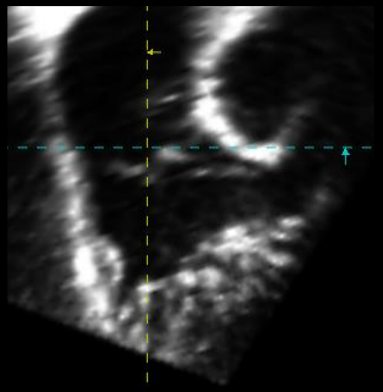
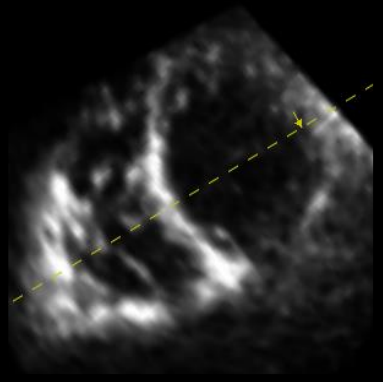
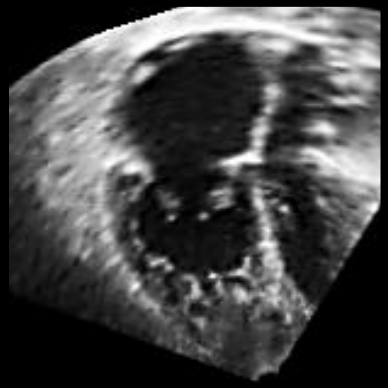
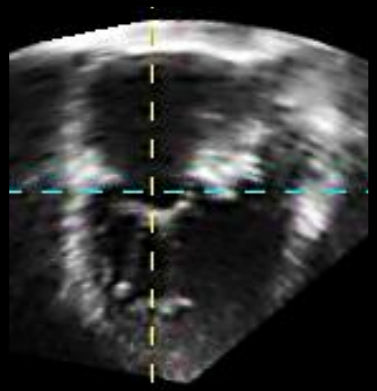
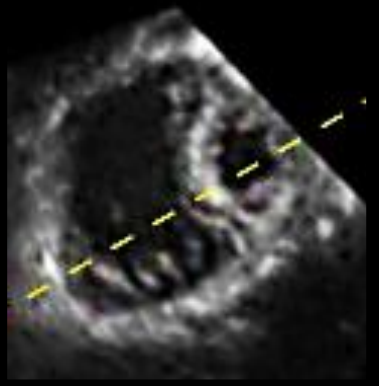
Can we depict RV shape using 3D Echocardiography



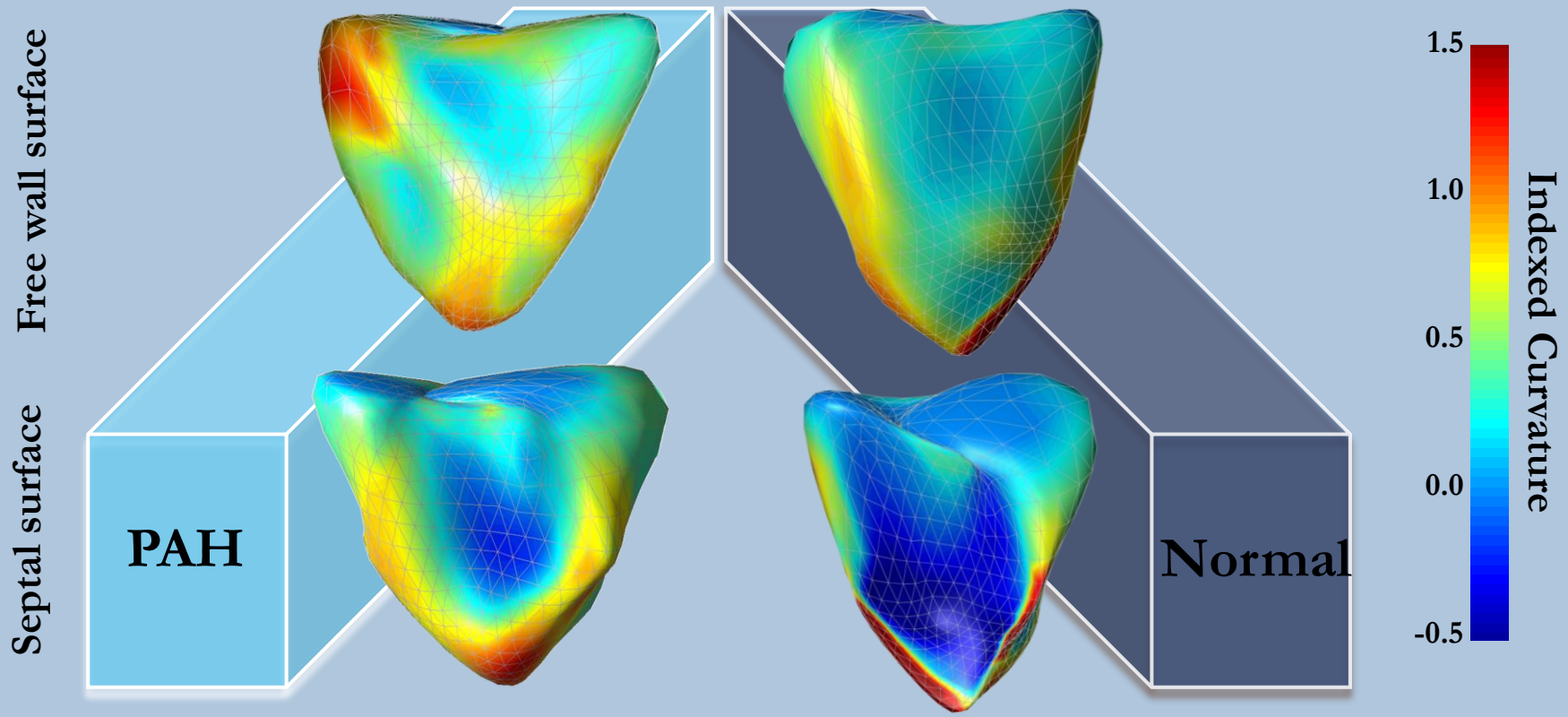
Curvature: the amount by which a surface deviates from being flat

Addetia K, Maffessanti F. …Singh A, Mor-Avi V, Lang RM European Heart Journal Cardiovascular Imaging 2016

Can we depict RV shape using 3D Echocardiography

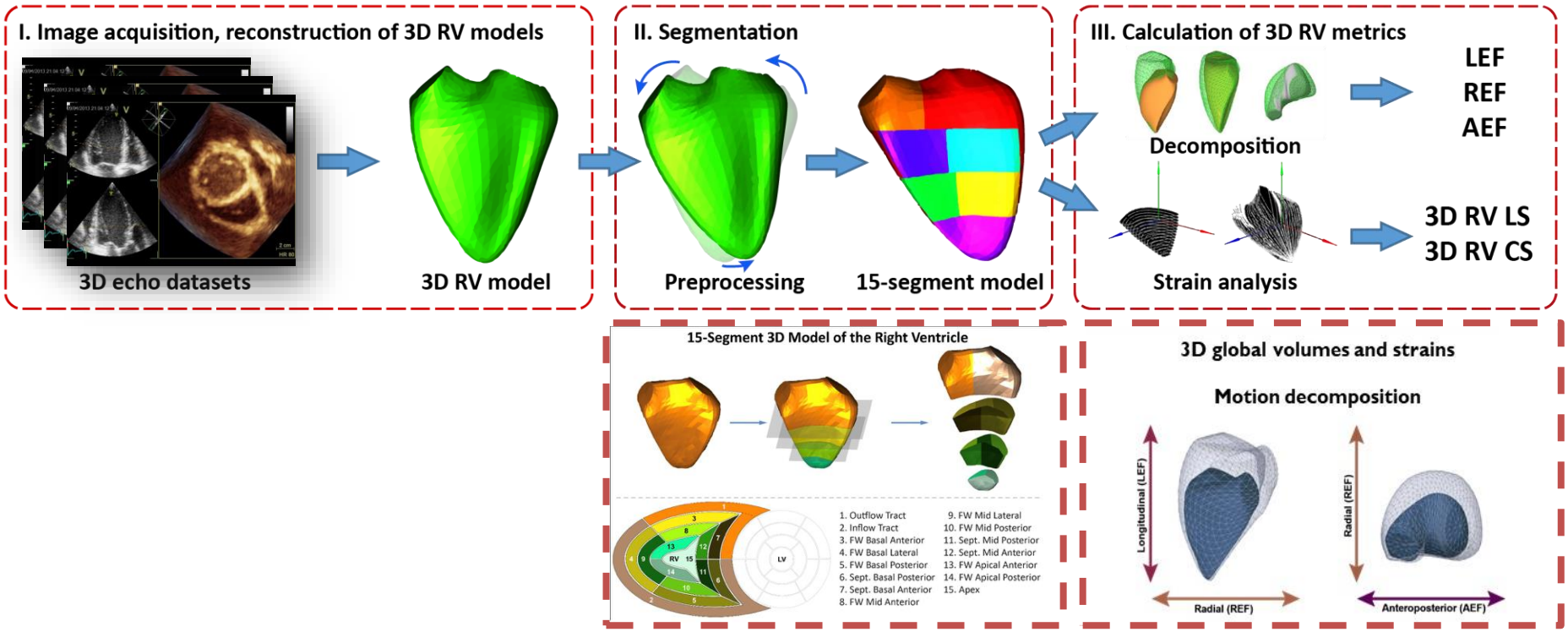
	4-chamber	Coronal	Sagittal
Normal subject			
Pulmonary arterial hypertension			

RV shape: normal and Pulmonary arterial hypertension



Addetia K et. al. EHJ Cardiovascular Imaging 2016

Workflow



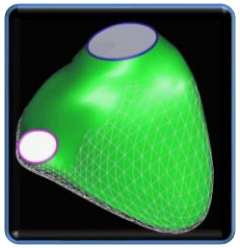
LEF – Longitudinal Ejection Fraction, REF – Radial Ejection Fraction, AEF – Antero-posterior Ejection Fraction
LS – Longitudinal Strain, CS – Circumferential Strain

REVISION SOFTWARE

The Problem with 3D Imaging

3D Acquisition

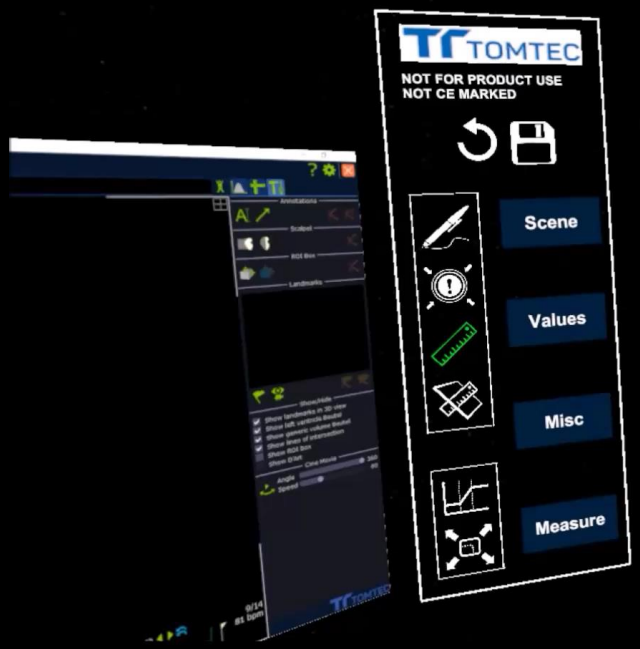
3D Analysis



2D Display

3D Display

What is the Future of 3D Echocardiography?



Virtual reality?

What is the Future of Echocardiography?

Fenster A et. al. Phys. Med. Biol. 46 (2001)

Augmented reality?

Thank you

Questions?