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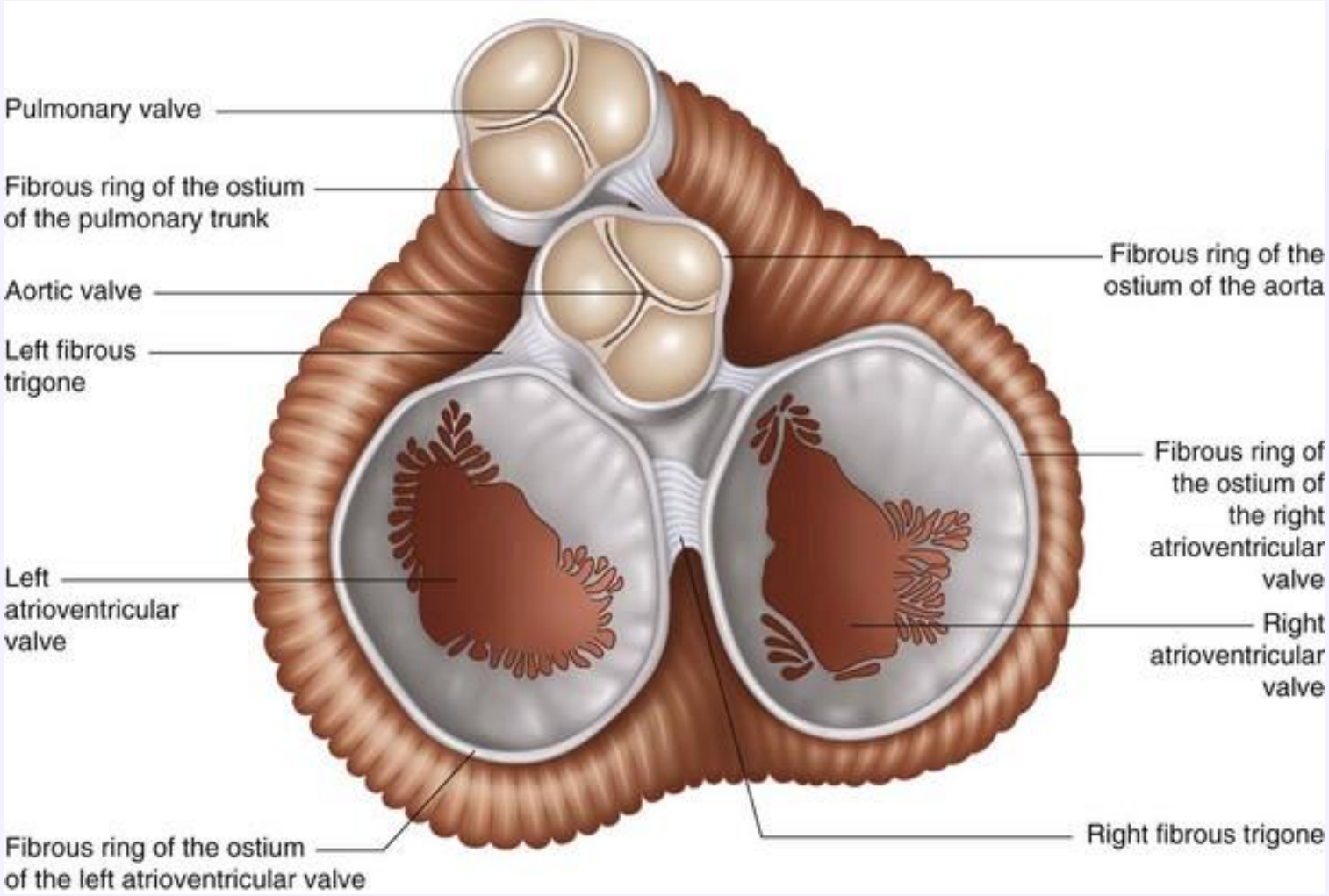
Tricuspid and Pulmonic Valves: Anatomy, Imaging, and Pathology

Aug 7, 2019
Department of Anesthesia and Pain Management- TGH, Toronto



Fibrous skeleton of the heart (cardiac skeleton)

Tricuspid Valve: The Forgotten Valve

Distribution of Valvular Heart Diseases in the Euro Heart Survey

5001 patients

- **Native Valve Disease** 72%
  - AS 34%
  - AR 10%
  - MS 10%
  - MR 25%
  - Multiple 20%
  - Right 1%
- **Previous Valvular Intervention** 28%
  - Valve Repair 18%
  - Valve Replacement 82%

Iung et al. *Eur Heart J* 2003;24:1244-53

European Heart Journal 2012 - doi:10.1093/eurheartj/ehs109 & European Journal of Cardio-Thoracic Surgery 2012 - doi:10.1093/ejcts/ezs455).

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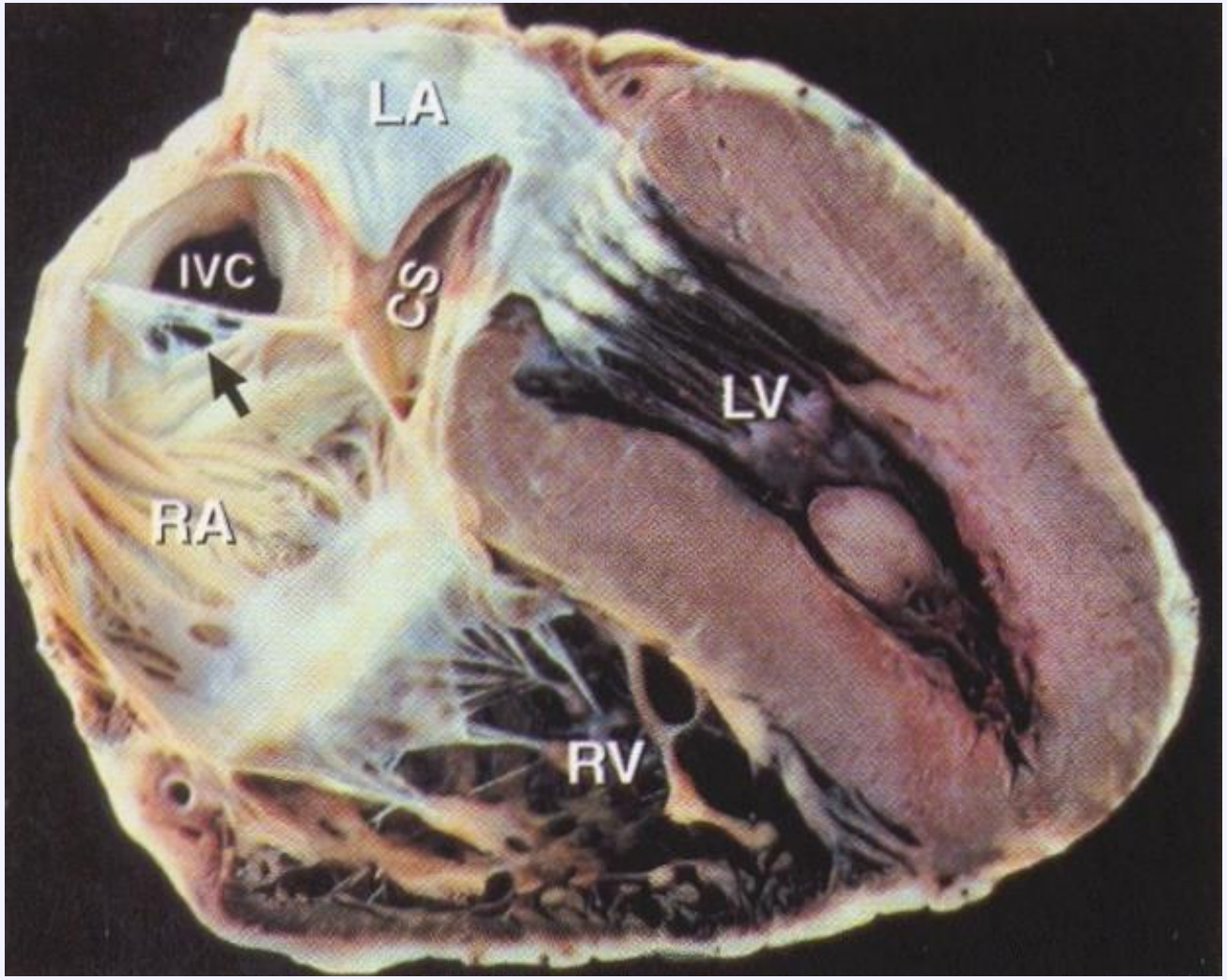
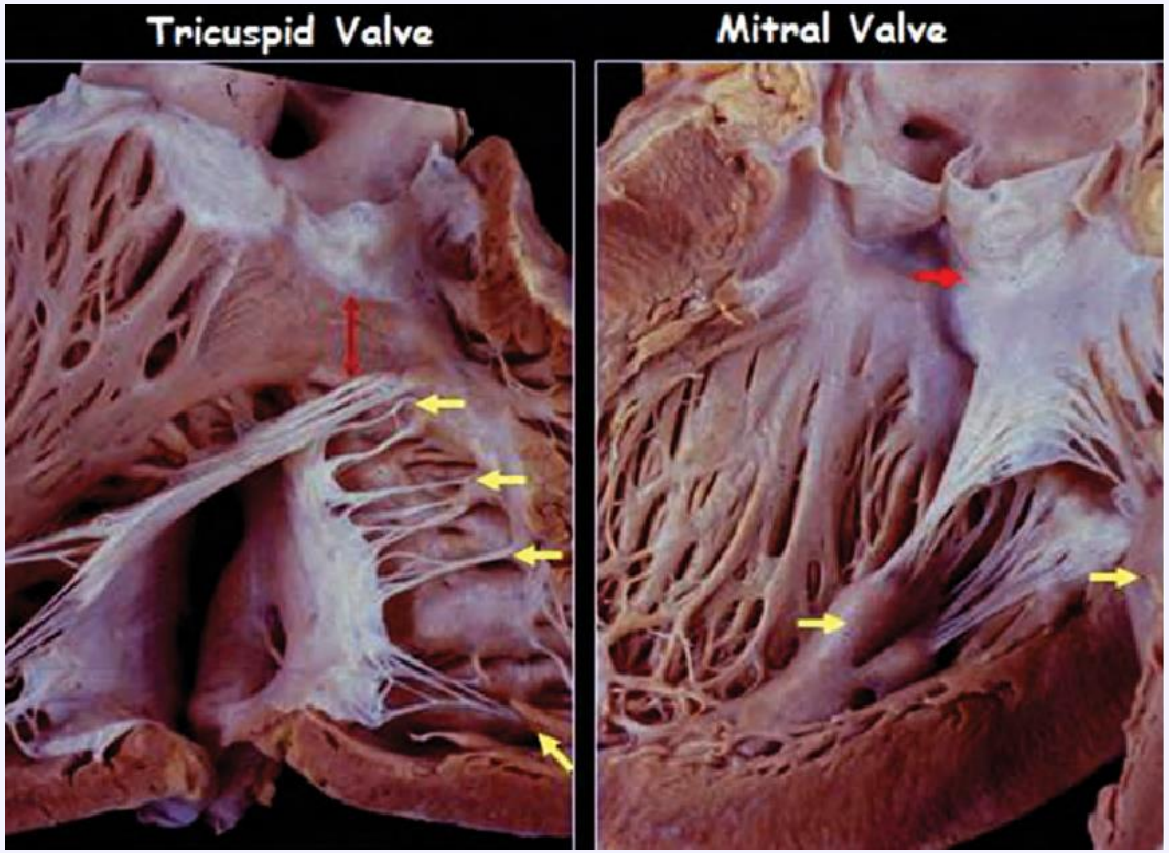


Anatomy of TV and RV



Comparison between anatomy of the MV and TV. MV is in continuity with AoV while TV is not in continuity with PV. Both papillary muscles are attached to both MV leaflets while in right side, each TV leaflet can be attached to a single papillary muscle or two of them.

STATE-OF-THE-ART PAPER

Anatomy and Physiology of the Tricuspid Valve

Abdellaziz Dahou, MD, PhD,[a,b] Dmitry Levin, BA,[c] Mark Reisman, MD,[c] Rebecca T. Hahn, MD[a,b]

JACC Imaging, March 2019

EDITORIAL COMMENT

The Forgotten Valve Finally Gets Some Respect*

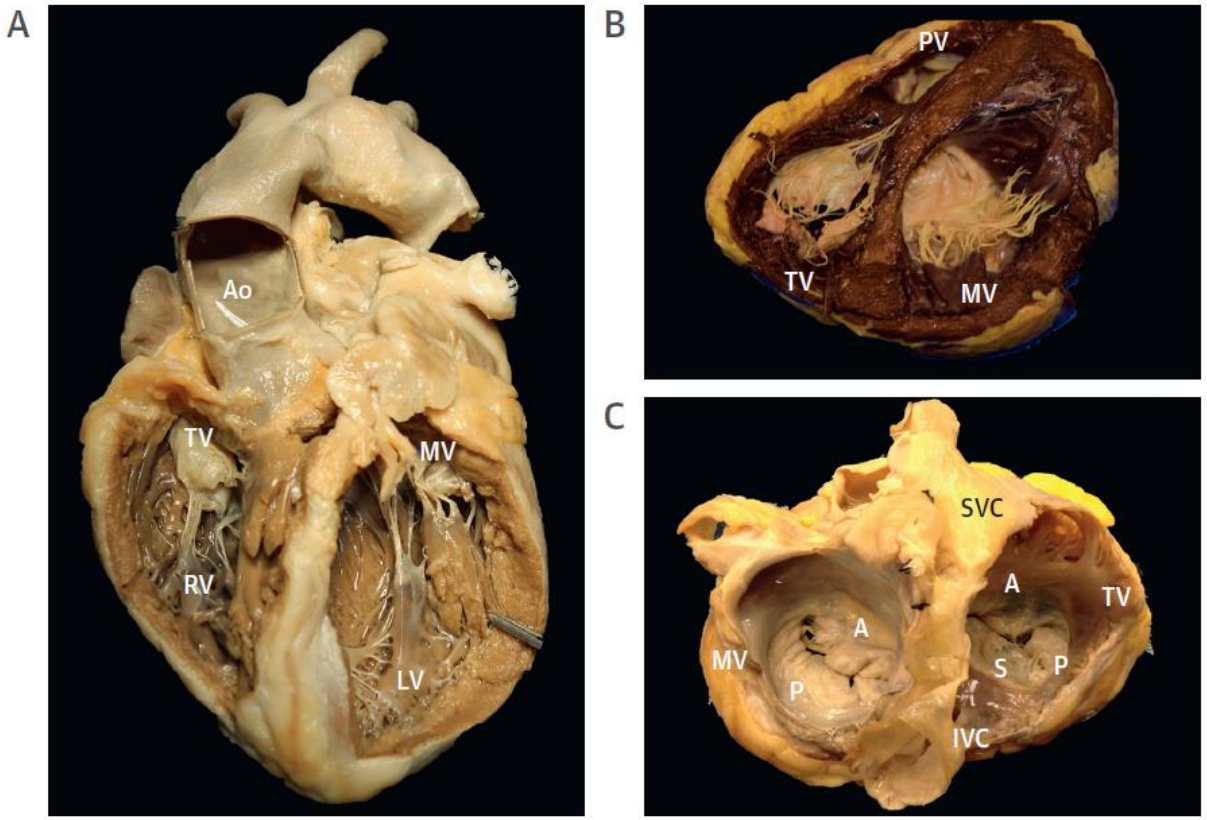
Judy Hung, MD, Sammy Elmariah, MD, MPH

JACC Imaging, March 2019

In patients with heart failure with reduced ejection fraction, tricuspid regurgitation (TR) is commonly observed in 20% to 35% of patients

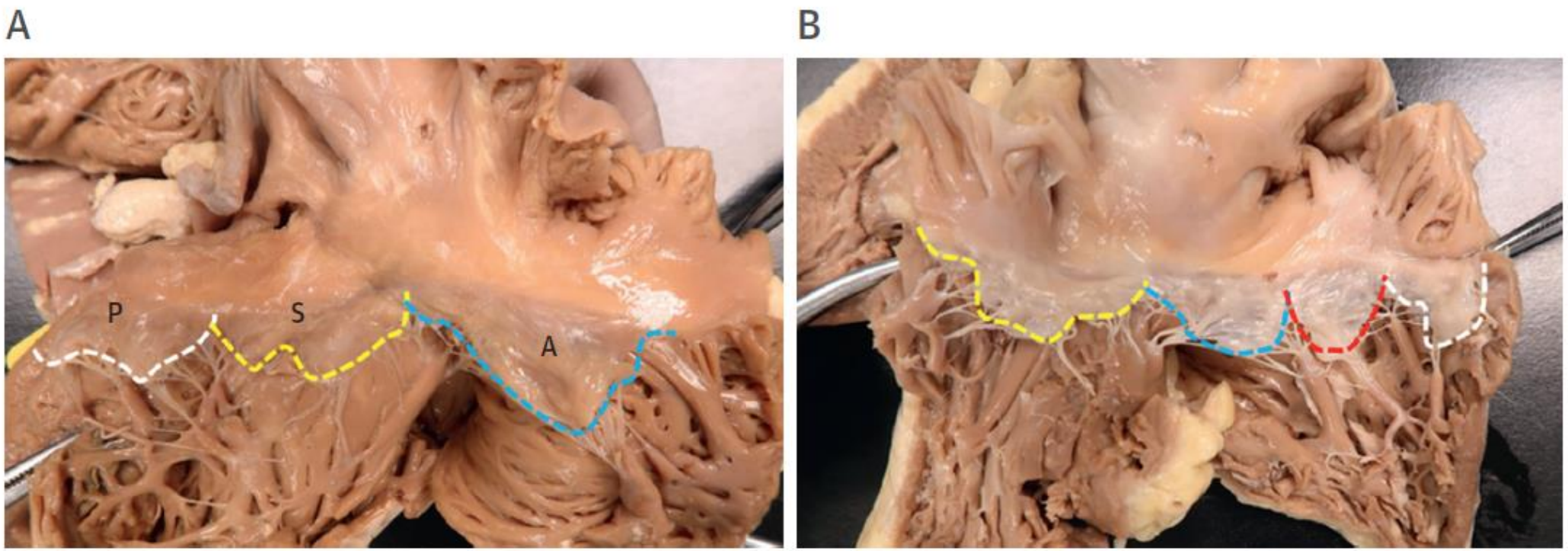
Clinical decision-making for patients with heart failure and TR is dependent on accurate and reproducible quantification of TR. However, assessment of

FIGURE 1 Gross Anatomy of the TV



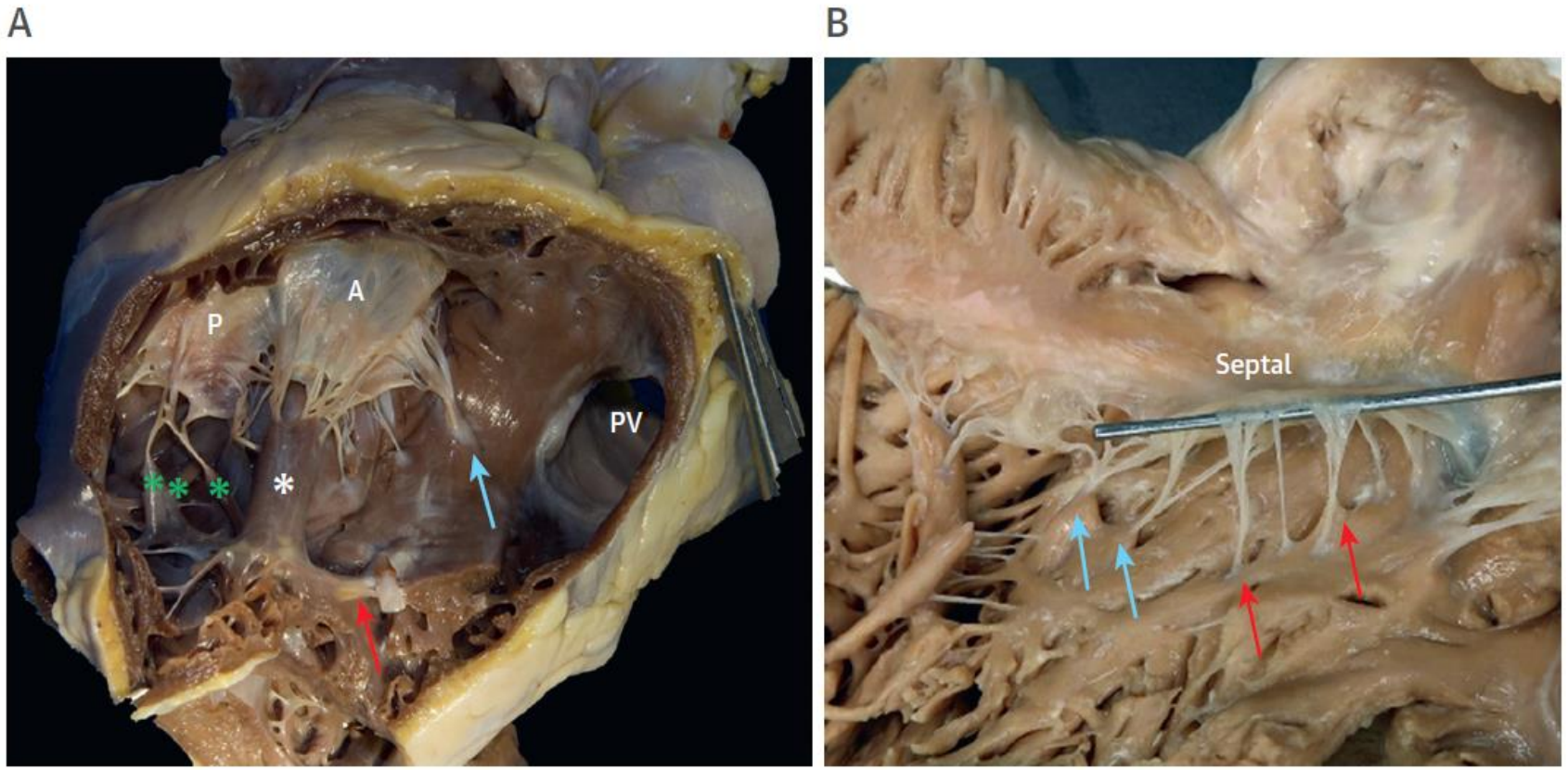
(A) Relationship of the TV to the left heart structures. Although typically shown in this orientation, the TV actually is the most anterior and apical of the 4 cardiac valves. **(B)** Relationship of the TV to the right ventricular outflow tract and the PV. Of note, there is no fibrous continuity between these 2 valves. **(C)** Relative position of the TV from the atrial aspect. A = anterior leaflet; Ao = aorta; IVC = inferior vena cava; LV = left ventricle; MV = mitral valve; P = posterior leaflet; PV = pulmonic valve; S = septal leaflet; SVC = superior vena cava; TV = tricuspid valve.

FIGURE 2 Variable Tricuspid Leaflets



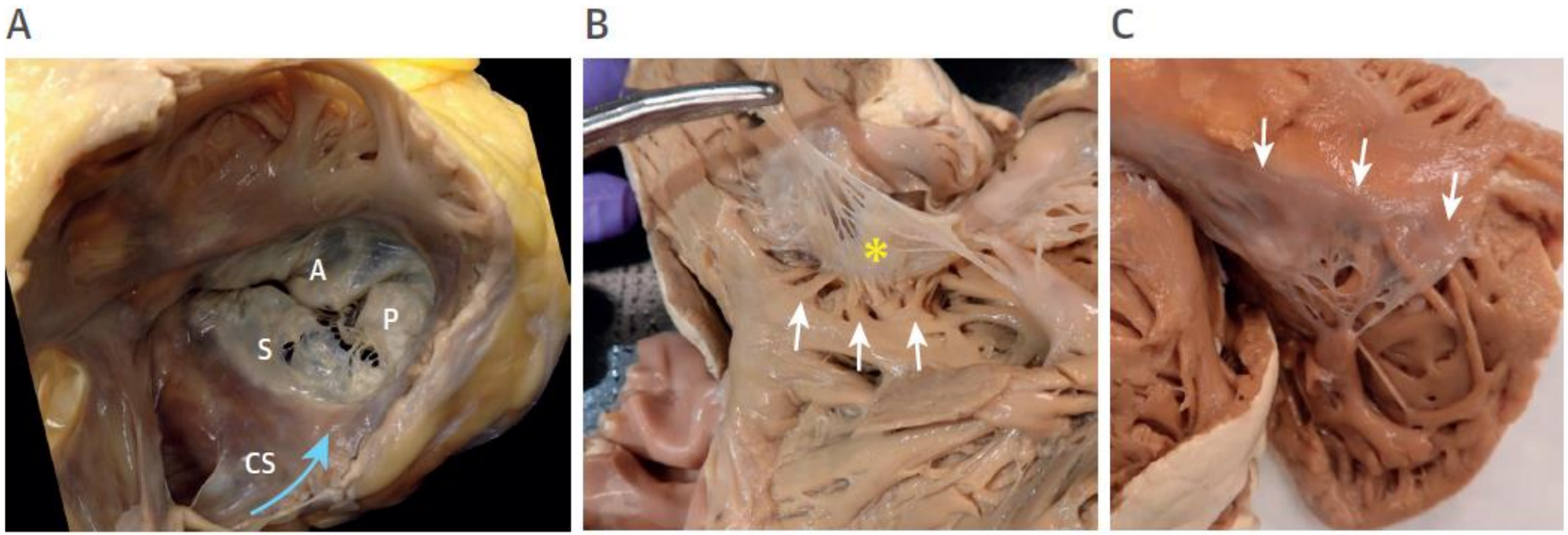
The number of tricuspid leaflets is highly variable. The most common configuration is a 3- leaflet valve **(A)**. In this figure, the **white line** indicating the P leaflet, the **yellow line** indicates the S leaflet, and the **blue line** indicates the A leaflet. Frequently, more than 3 leaflets are seen **(B)**. The **orange line (B)** represents the fourth leaflet in this quadricuspid valve. A = anterior leaflet; P = posterior leaflet; S = septal leaflet.

FIGURE 3 Papillary Muscles



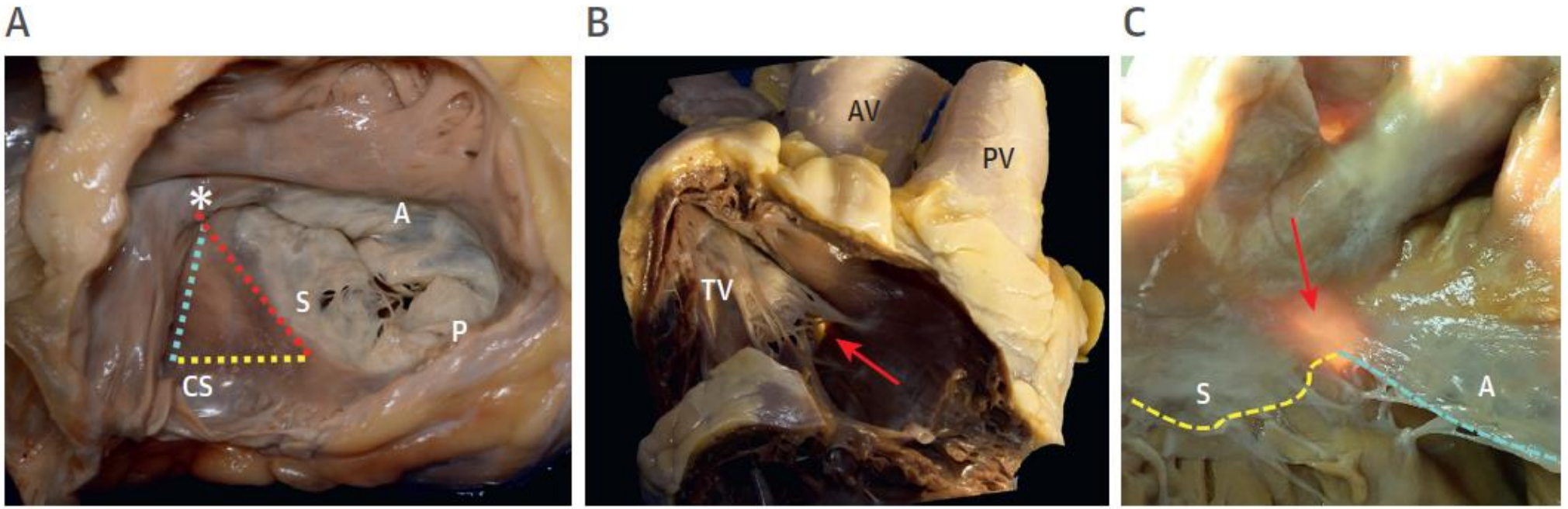
(A) Typical papillary muscle distribution for the tricuspid valve. The anterior papillary muscle is typically the largest **(white asterisk)**, which provides chordal support for the A and P leaflets. The moderator band **(orange arrows)** may join this papillary muscle. The posterior papillary muscle is often bifid or trifid **(green asterisks)** and lends chordal support to the posterior and septal leaflets. The septal papillary muscle is variable **(blue arrow)**. **(B)** Septal leaflet chordal attachments to the septal papillary muscle are shown **(blue arrows)** and directly from the septal myocardium **(orange arrows)**. Abbreviations as in Figures 1 and 2.

FIGURE 4 Tricuspid Valve Annulus



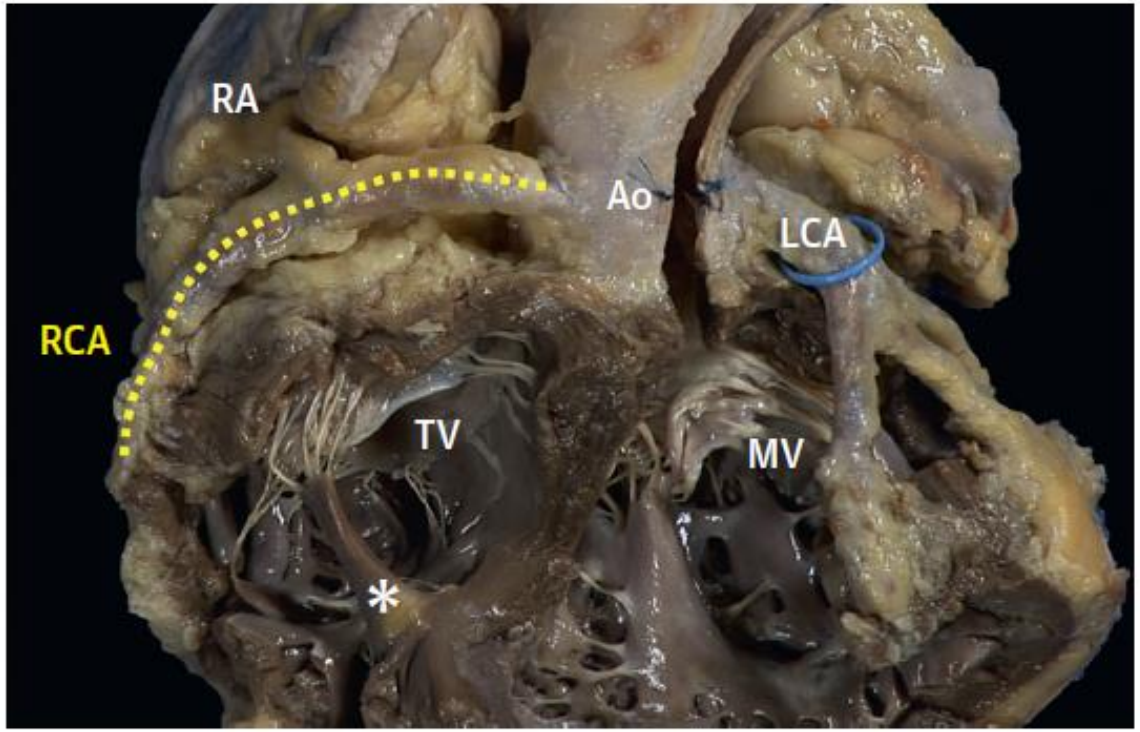
(A) The tricuspid valve is seen from the atrial side with the typically D-shaped annulus composed of a flat septal region and curved anterior and posterior regions. **(B)** The ventricular surface of the anterior leaflet **(asterisk)** with multiple "crisscrossing" muscle attachments **(arrows)** directly to the base of the leaflet. **(C)** The atrial surface of the anterior leaflet annulus **(white arrows)**, which is not fibrous and has a smooth transition from atrium to ventricle. CS = coronary sinus **(curved blue arrow)**; other abbreviations as in Figure 1.

FIGURE 5 Triangle of Koch and Membranous Septum



(A) The anatomic landmarks of the triangle of Koch. The tendon of Todaro **(blue line)** lies above the eustachian valve forming one side of the triangle. The hinge point of the septal leaflet **(orange line)** forms a second side, and the CS forms the base of the triangle **(yellow line)** with the apex of the triangle **(asterisk)**, marking the location of the atrioventricular conduction axis near the membranous septum. **(B)** The ventricular view and **(C)** the atrial view of the membranous septum **(orange arrow = backlit)** at the commissure between the S and and A leaflets of the tricuspid valve. AV = atrioventricular node; other abbreviations as in Figures 1 and 4.

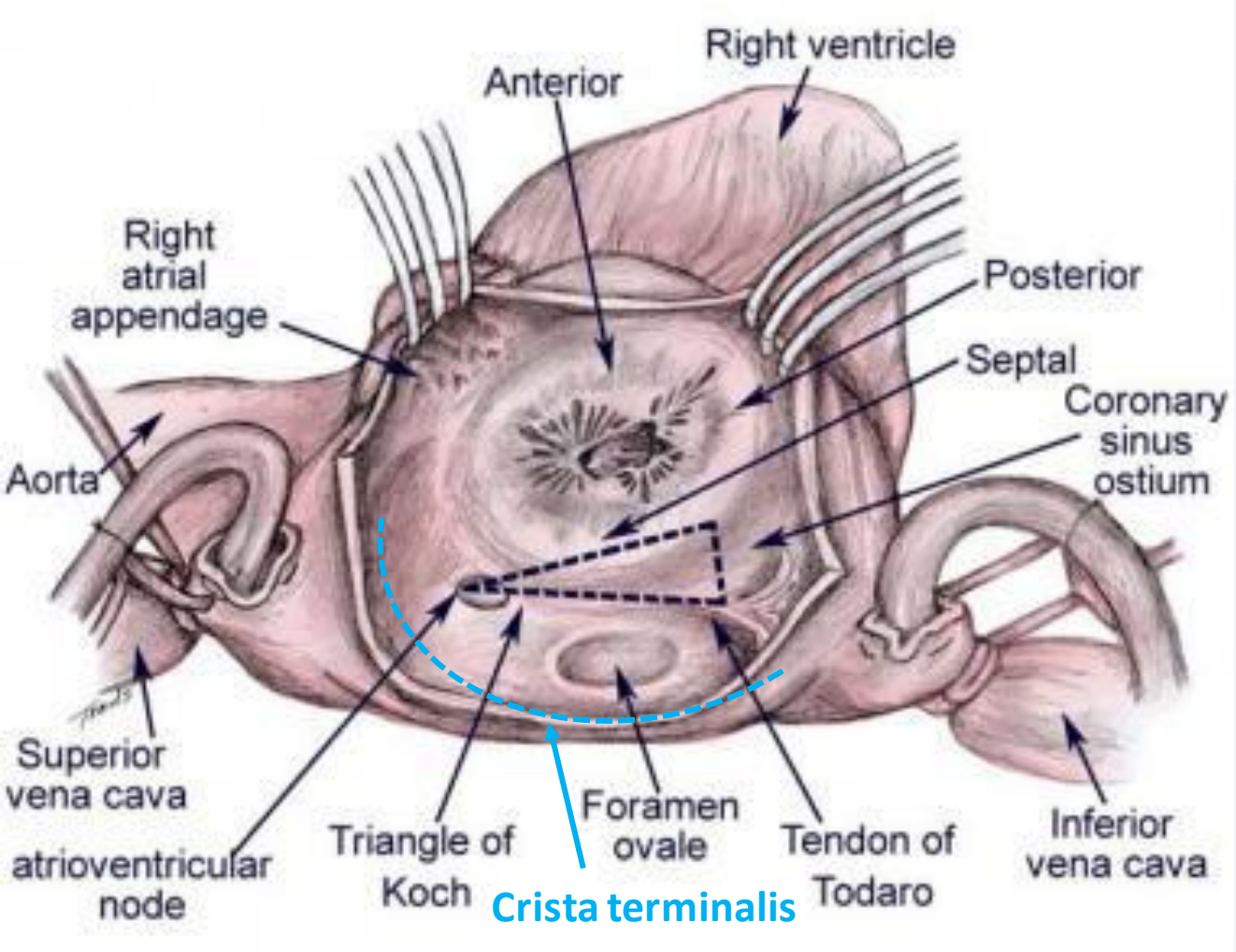
FIGURE 6 Right Coronary Artery

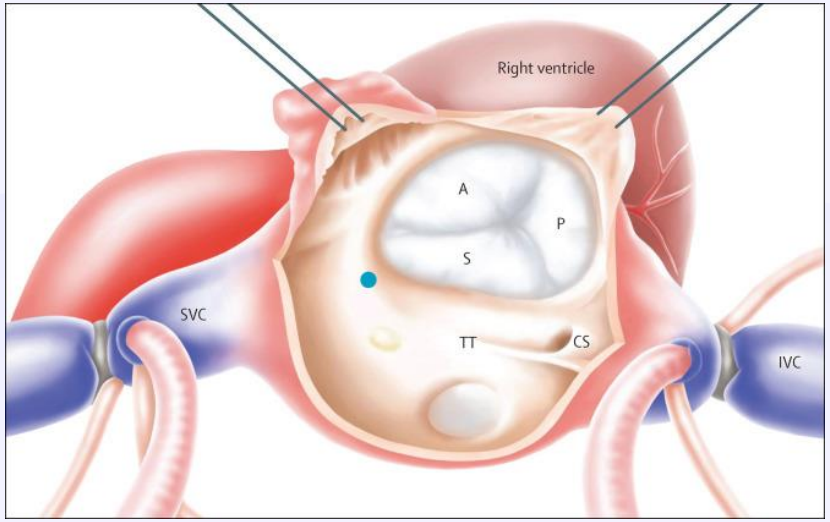


The proximal RCA exits the right coronary sinus of Valsalva of the Ao and courses in the atrioventricular groove within adipose tissue **(yellow dashed line)**. The anterior papillary muscle is marked by an **asterisk**. LCA = left coronary artery; MV = mitral valve; RA = right atrium; RCA = right coronary artery; other abbreviations as in Figure 1.

TABLE 1 Causes of Tricuspid Regurgitation

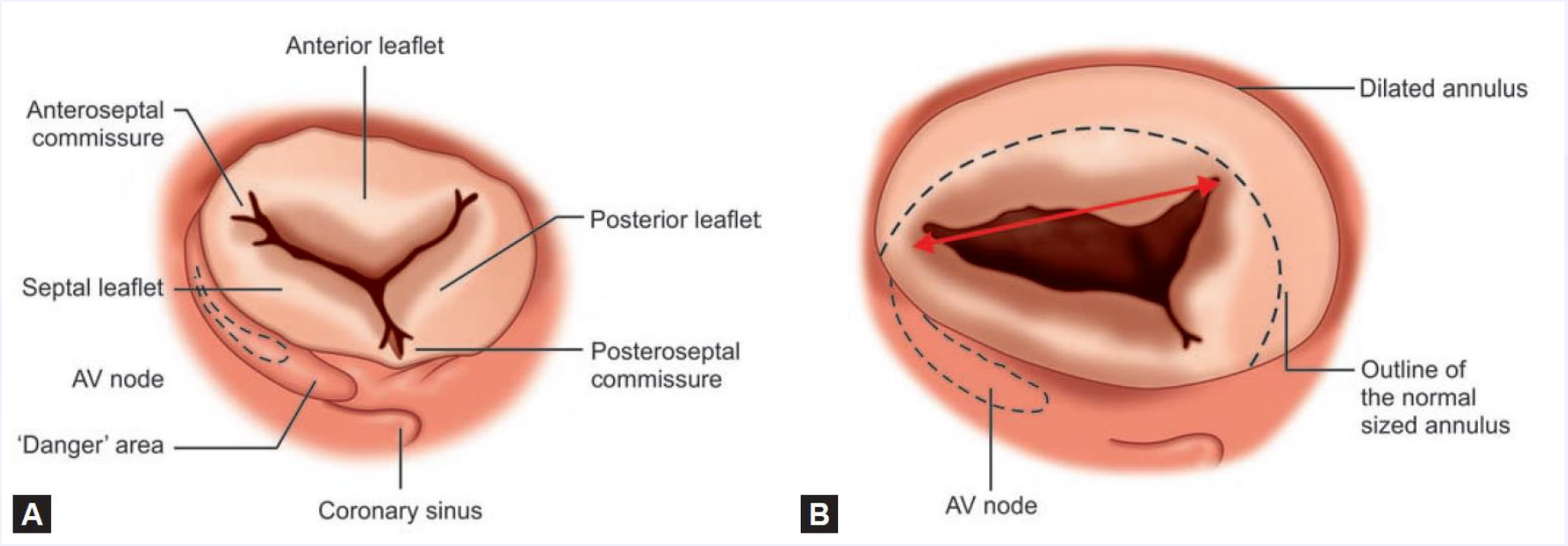
- Primary TR
  - Congenital
    - Ebstein's anomaly
    - Tricuspid valve tethering associated with perimembranous ventricular septal aneurysm or defect
    - Tricuspid valve dysplasia, hypoplasia, or cleft
    - Double orifice tricuspid valve
    - Other (giant RA)
  - Acquired
    - Myxomatous degeneration (Barlow's disease): TV prolapse, flail
    - Endocarditis
    - Carcinoid syndrome
    - Rheumatic disease
    - Trauma (chest wall trauma or TV trauma following intracardiac procedures: RV intramyocardial biopsy, and so on)
    - Pacemaker/device-related
- Secondary TR
  - According to the underlying disease:
    - Left-sided heart disease (valve disease and/or left ventricular dysfunction)
    - Pulmonary arterial hypertension from any cause
    - RV dysfunction from any cause
    - Idiopathic (no detectable cause) often associated with atrial fibrillation
  - According to the morphologic abnormality:
    - Tethering or tenting of TV leaflets
    - Displacement of the papillary muscles
    - RV dysfunction/dilation
    - Annular dilation

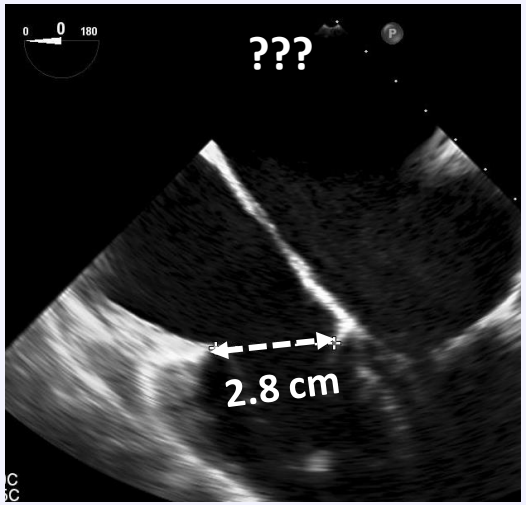




Note: Triangle of the Koch is an important landmark for ablation of the slow pathway in atrioventricular nodal reentrant tachycardia (AVNRT).
Crista terminalis is the landmark during SN ablation

Surgical view of the tricuspid valve and right atrium


Anterior leaflet
Anteroseptal commissure
Posterior leaflet
Septal leaflet
AV node
Posteroseptal commissure
'Danger' area
Coronary sinus
A
Dilated annulus
Outline of the normal sized annulus
AV node
B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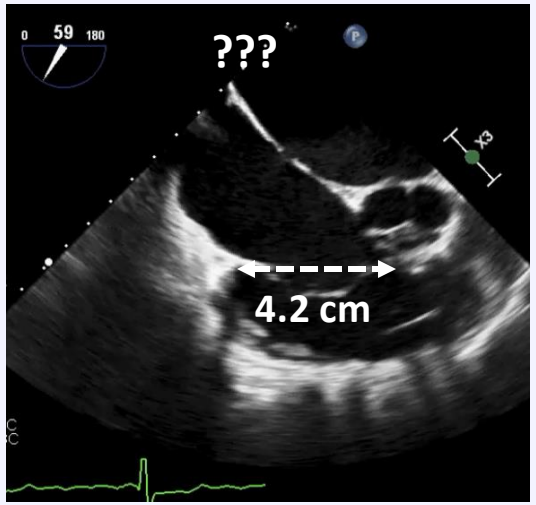
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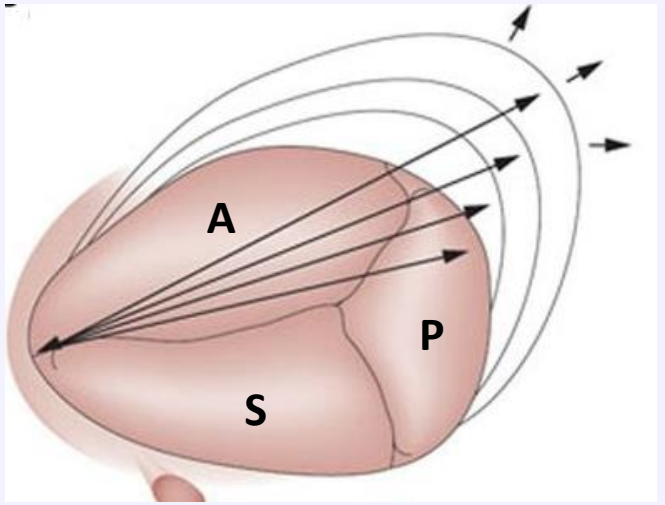
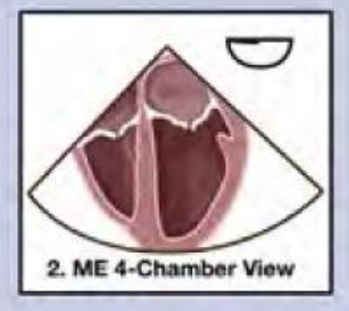
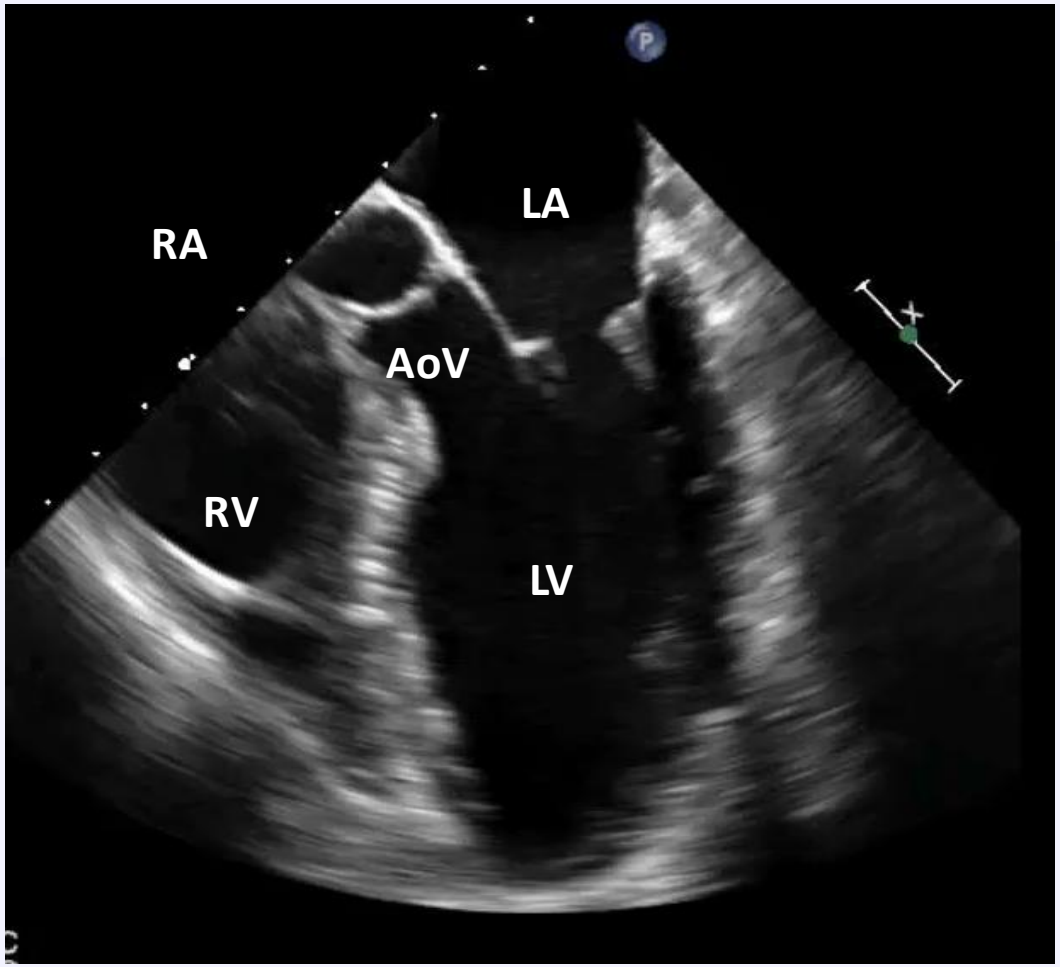
4.2 cm

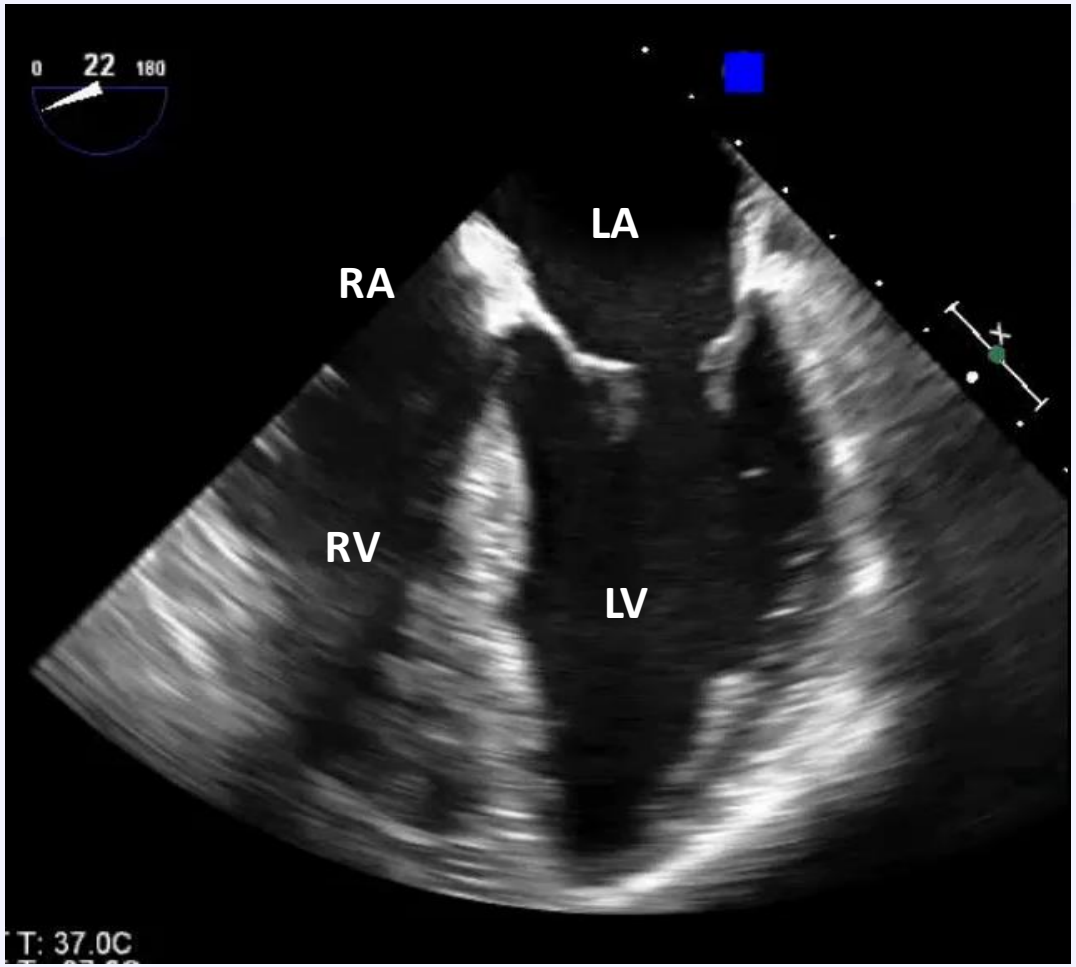

A
P
S

How to image the tricuspid valve?

Imaging Plane	3D Model	2D TEE Image	Acquisition Protocol	Structures Imaged
Midesophageal Views				
 1. ME 5-Chamber View			**Transducer Angle:** ~ 0 - 10^0 **Level:** Mid-esophageal **Maneuver** (from prior image): NA	Aortic valve LVOT Left atrium/Right atrium Left ventricle/Right ventricle/IVS Mitral valve (A_2A_1-P_1) Tricuspid valve
 2. ME 4-Chamber View			**Transducer Angle:** ~ 0 - 10^0 **Level:** Mid-esophageal **Maneuver** (from prior image): Advance ± Retroflex	Left atrium/Right atrium IAS Left ventricle/Right ventricle/IVS Mitral valve (A_3A_2-P_2P_1) Tricuspid valve



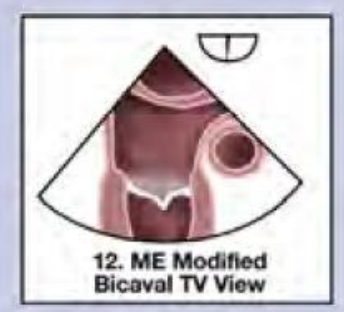
1- ME 5-Chamber View



2- ME 4-Chamber View

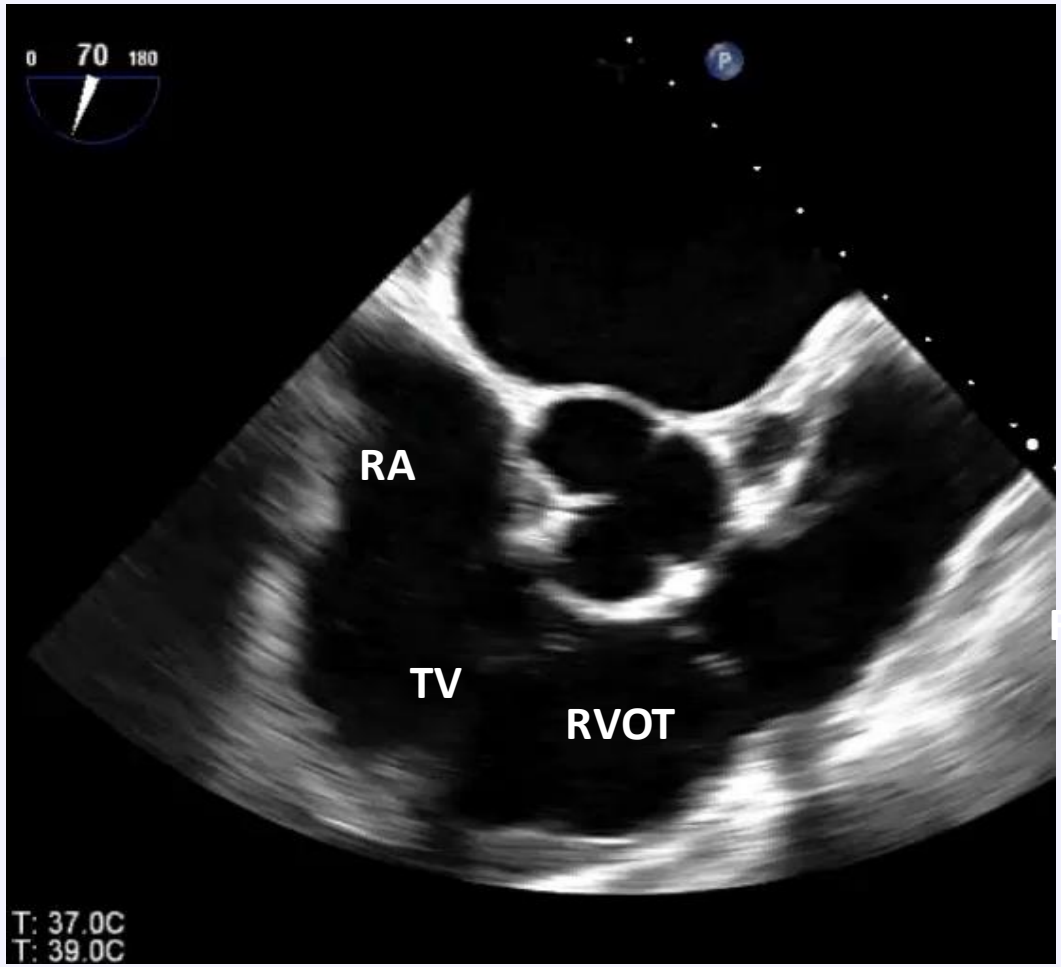
Transducer Angle:
~ 50 - 70^0
Level: Mid-esophageal
Maneuver (from prior image): CW, Advance

Aortic valve
Right atrium
Left atrium
Superior IAS
Tricuspid Valve
RVOT
Pulmonary Valve

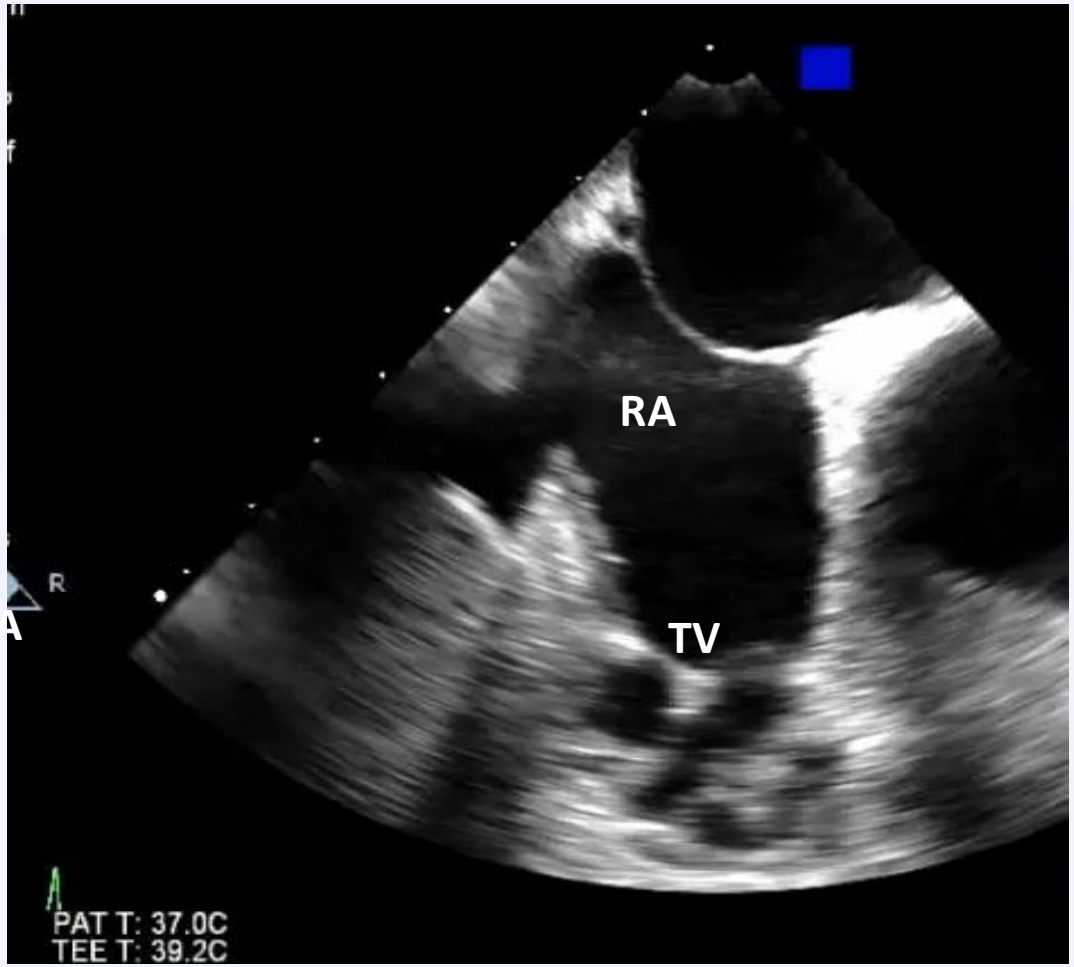


Transducer Angle:
~ 50 - 70^0
Level: Mid-esophageal
Maneuver (from prior image): CW

Right atrium
Left atrium
Mid-IAS
Tricuspid Valve
Superior vena cava
Inferior vena cava/coronary sinus



11- ME RV Inflow-Outflow View



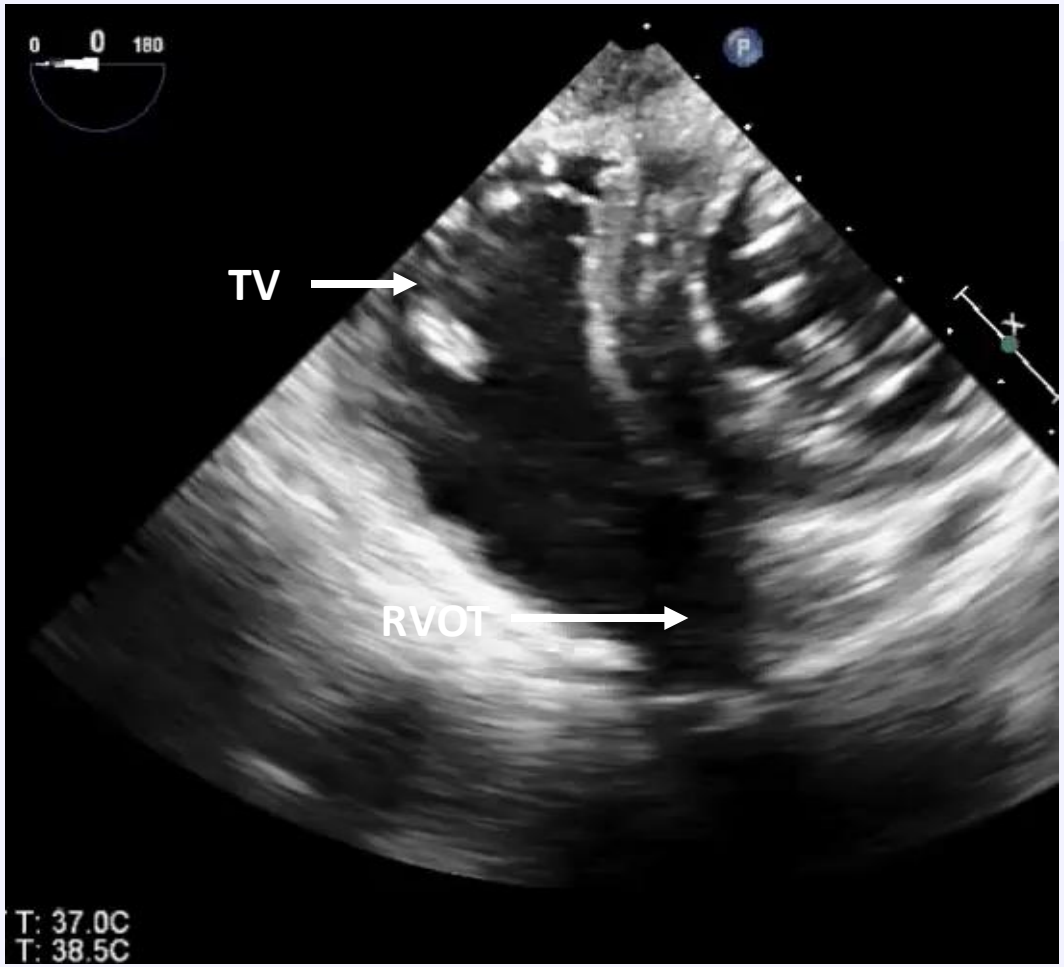
12- ME Modified Bicaval TV View

Transducer Angle:
~ 0 - 20°
Level: Transgastric
Maneuver (from prior image): Anteflex

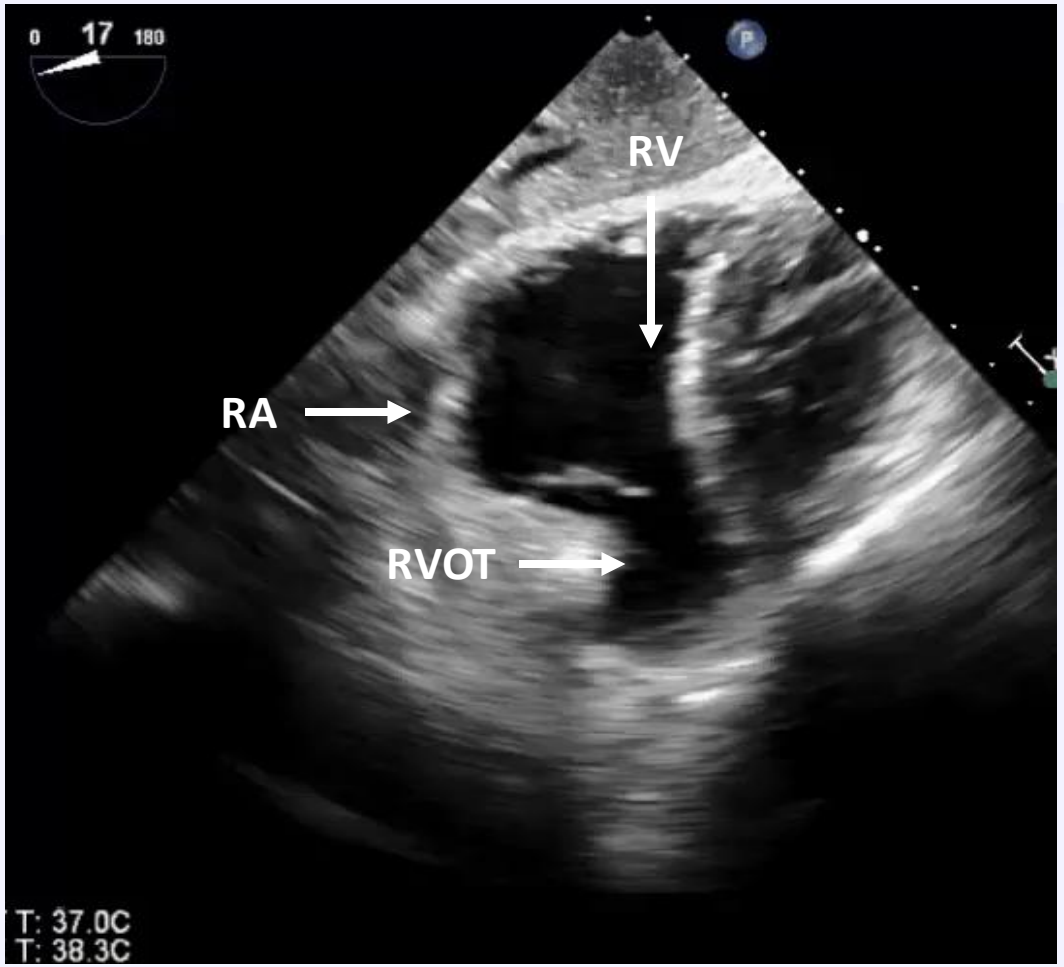
Left ventricle (mid)
Right ventricle (mid)
Right ventricular outflow tract
Tricuspid Valve (SAX)
Pulmonary Valve

Transducer Angle:
~ 0 - 20°
Level: Transgastric
Maneuver (from prior image): Right-flex

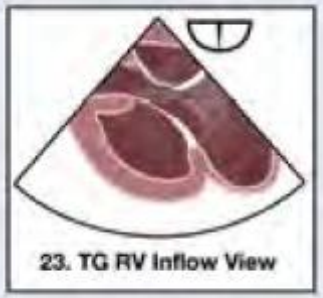
Right atrium
Right ventricle
Right ventricular outflow tract
Pulmonary valve
Tricuspid Valve



19- TG RV Basal View

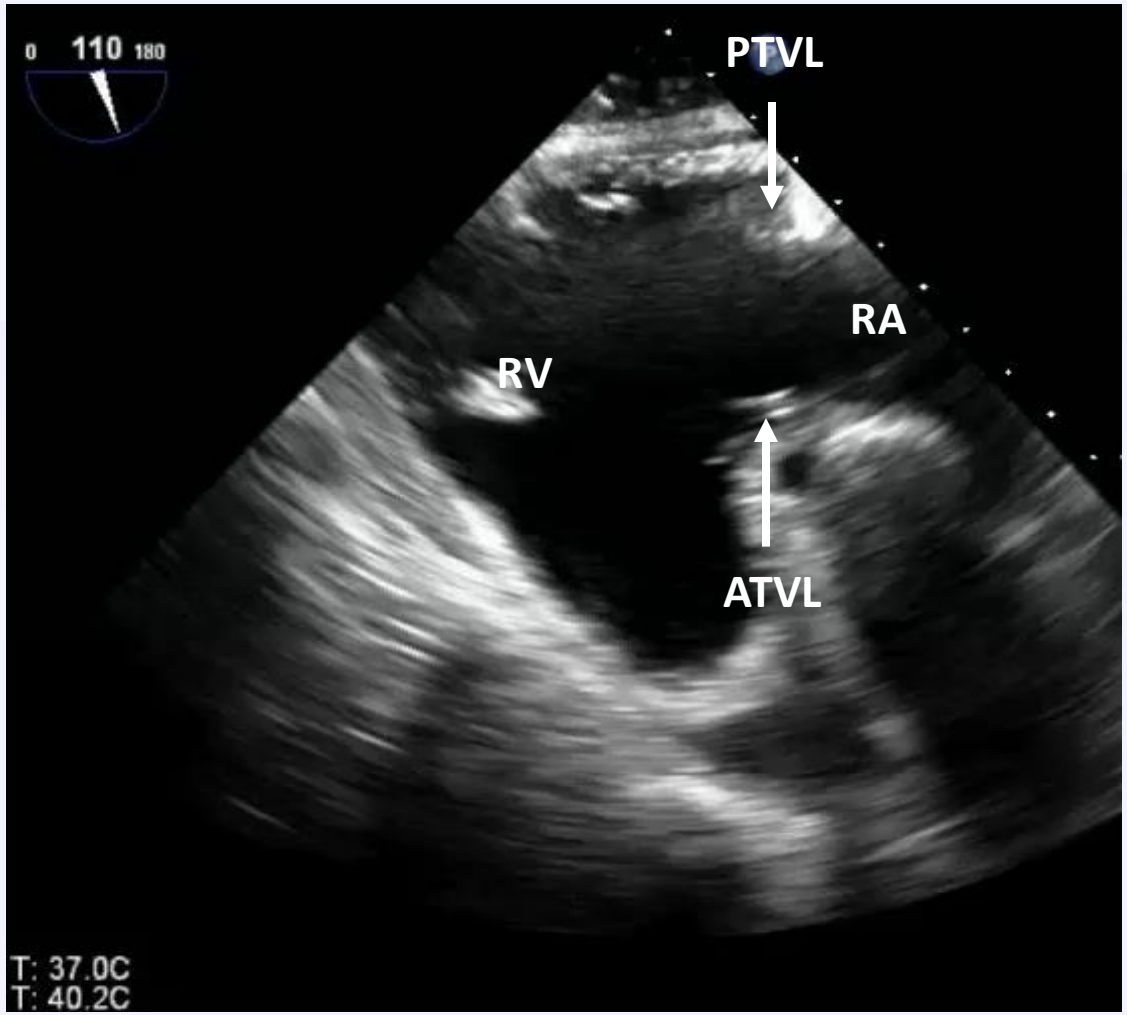


20- TG RV Inflow-Outflow View

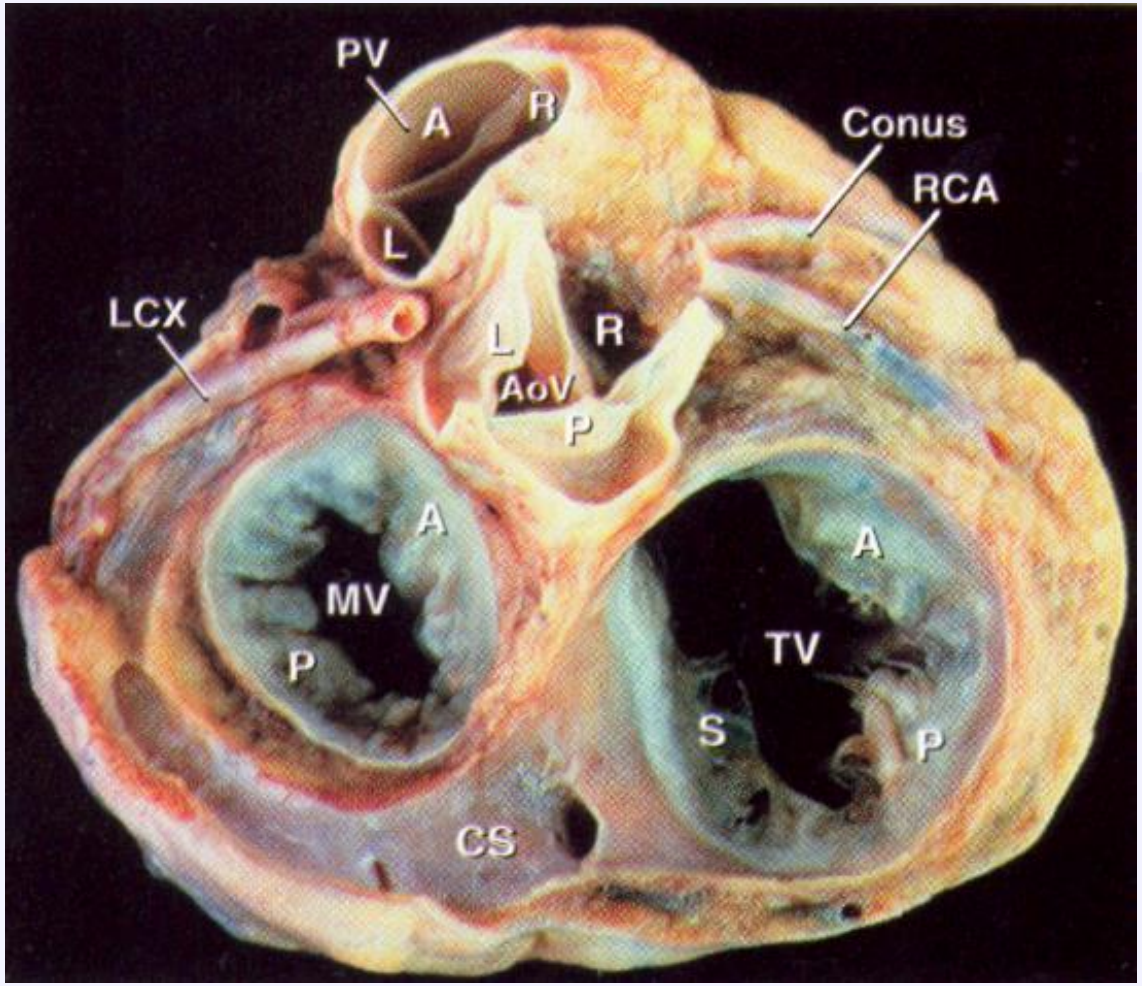


Transducer Angle:
~ 90 - 110º
Level: Transgastric
Maneuver (from prior image): CW

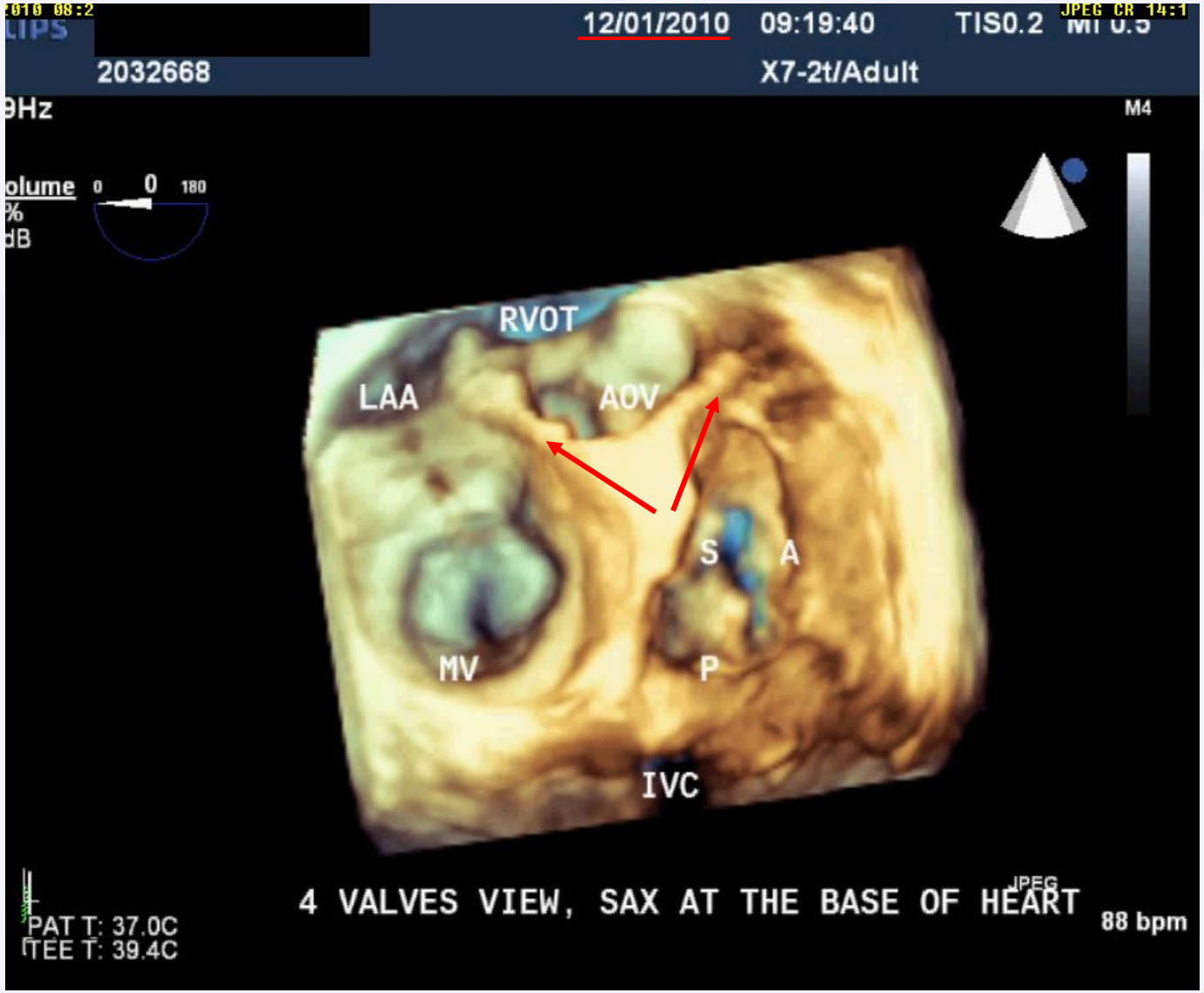
Right ventricle
Right atrium
Tricuspid valve



23- TG RV Inflow View



Base of the heart with atria removed, looking from posterior to anterior, showing four cardiac valves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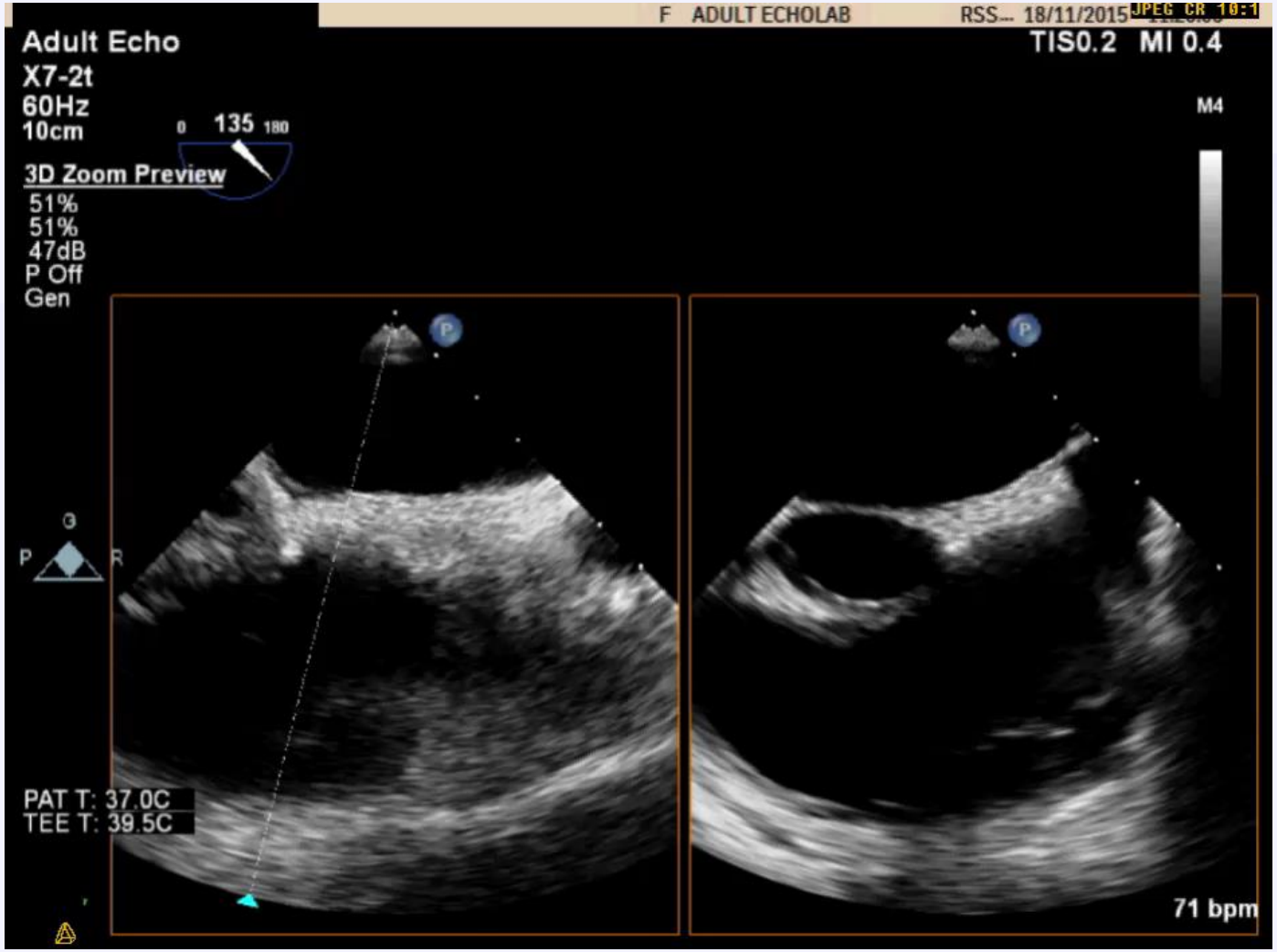
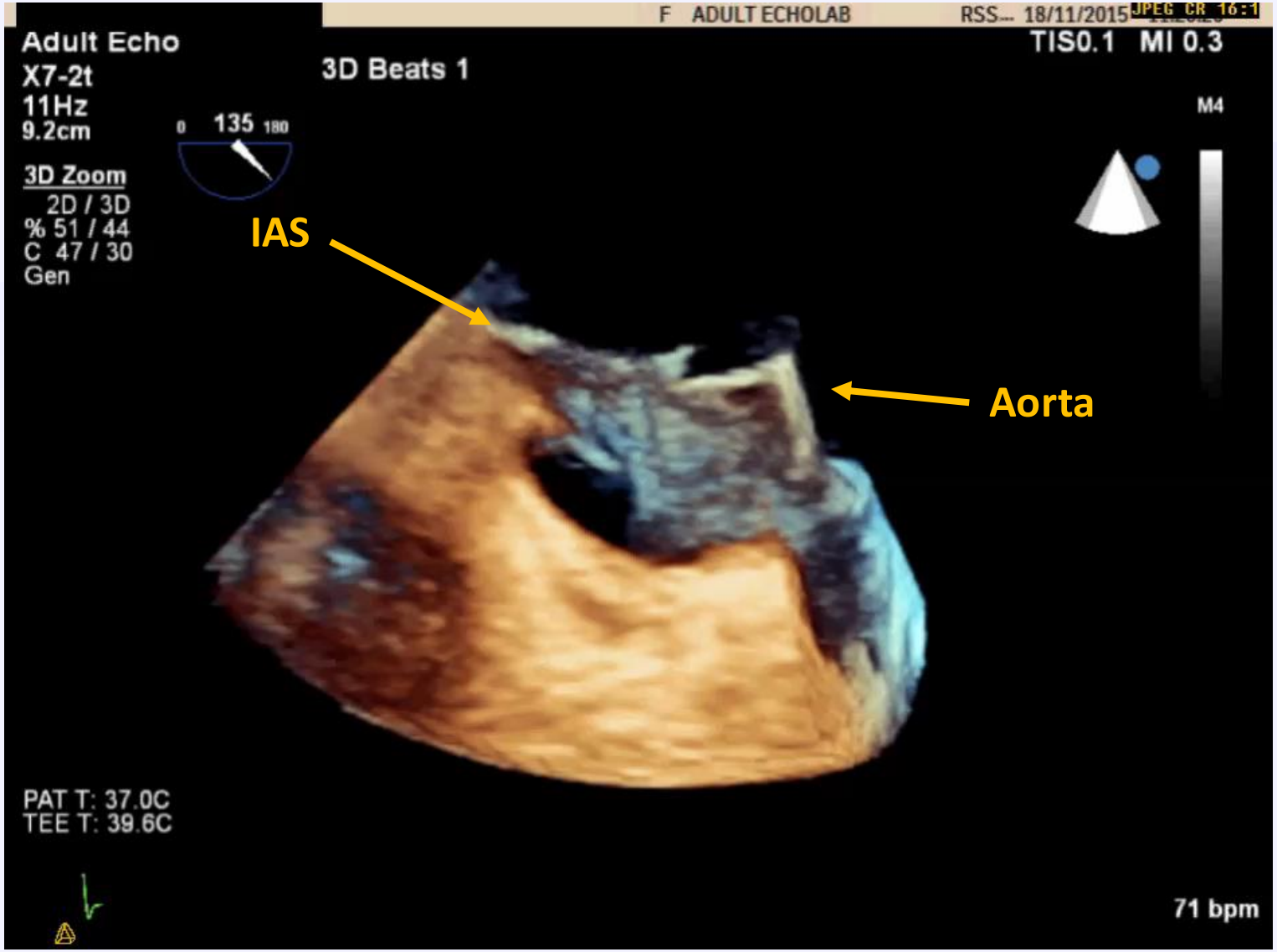
88 bpm
PAT T: 37.0C
TEE T: 39.4C



TEE imaging of the TV, 3D zoom mode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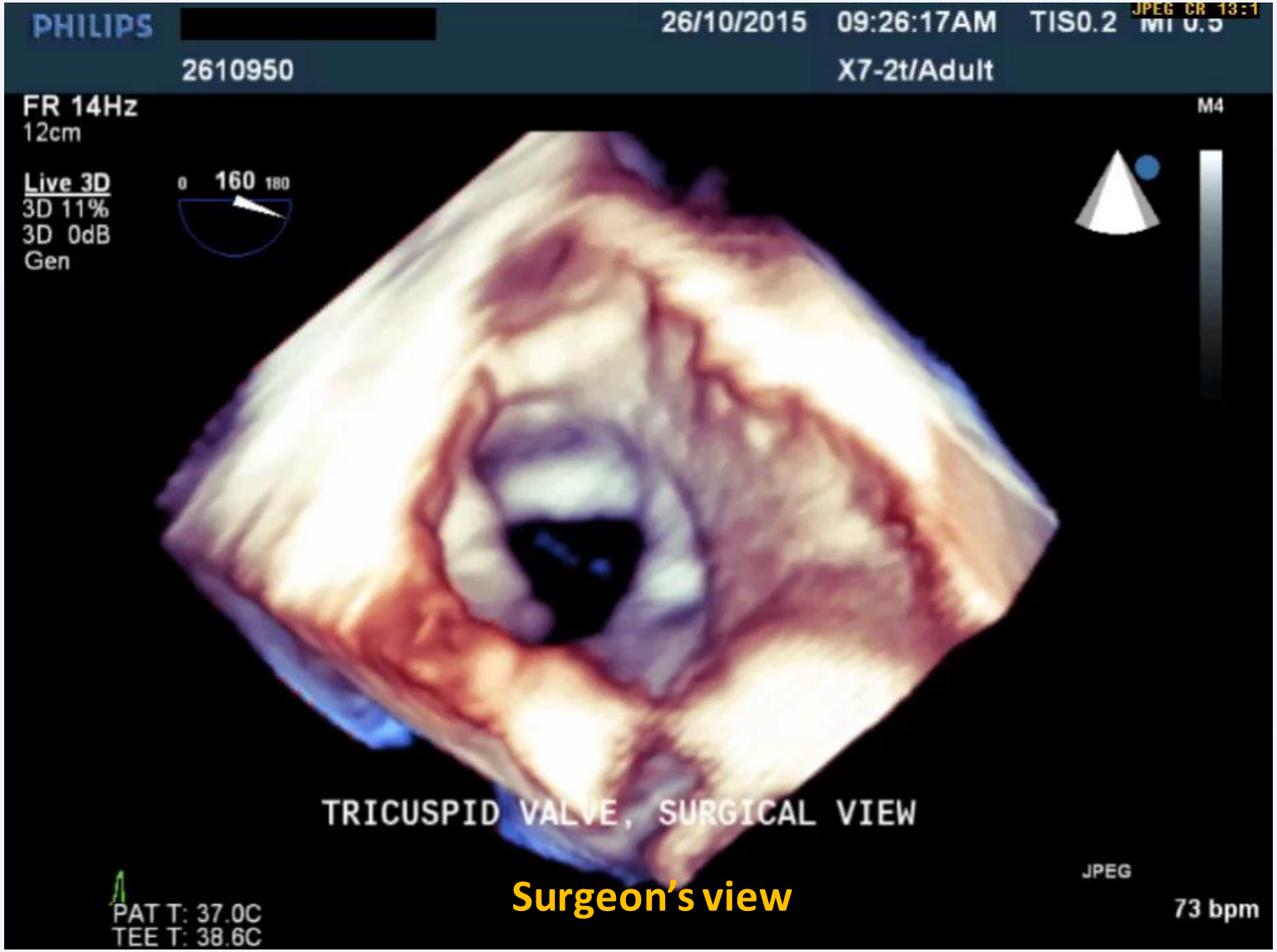
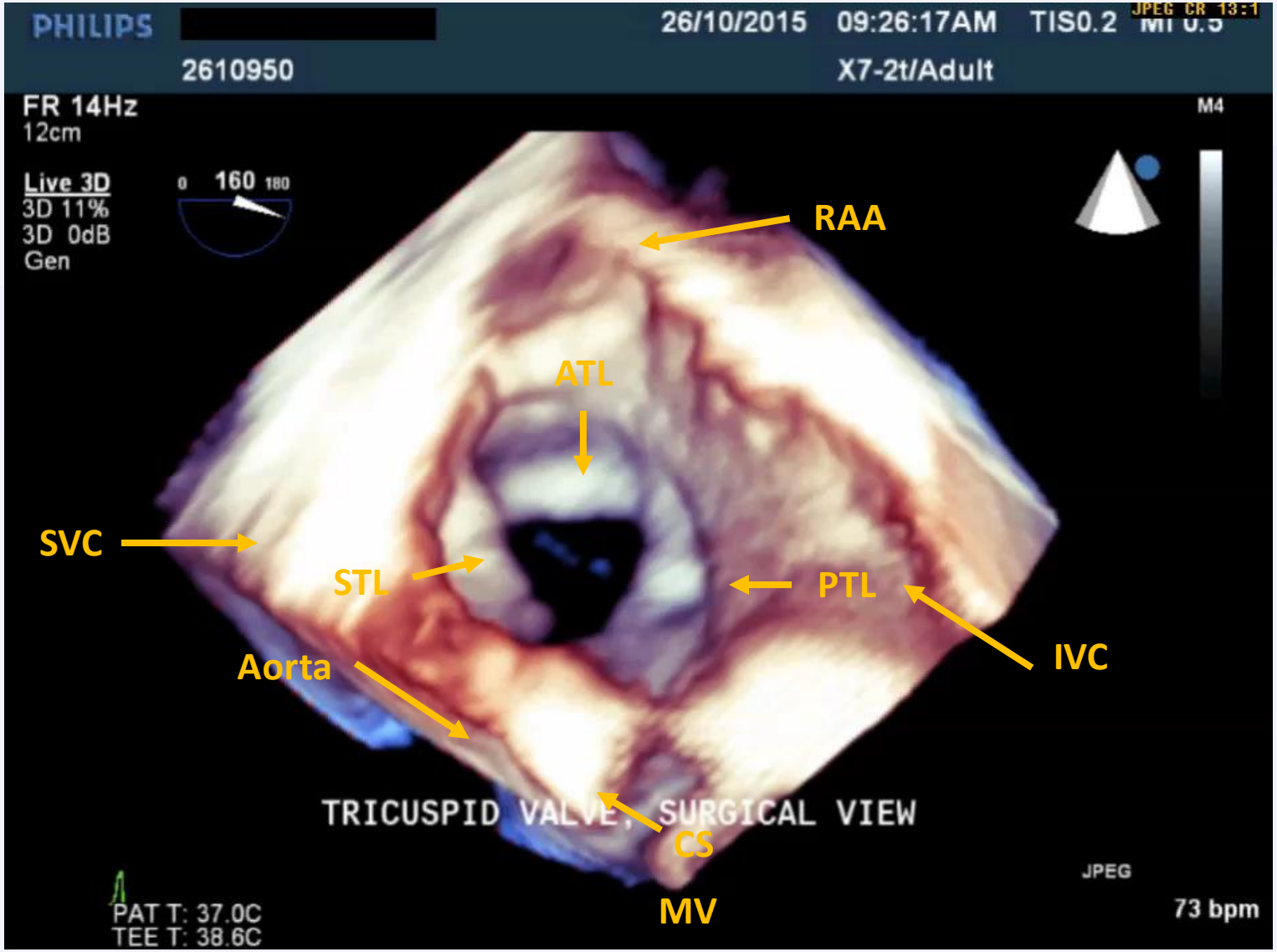
PAT T: 37.0C
TEE T: 39.6C
71 bpm



Surgeon's view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STL
PTL
IVC
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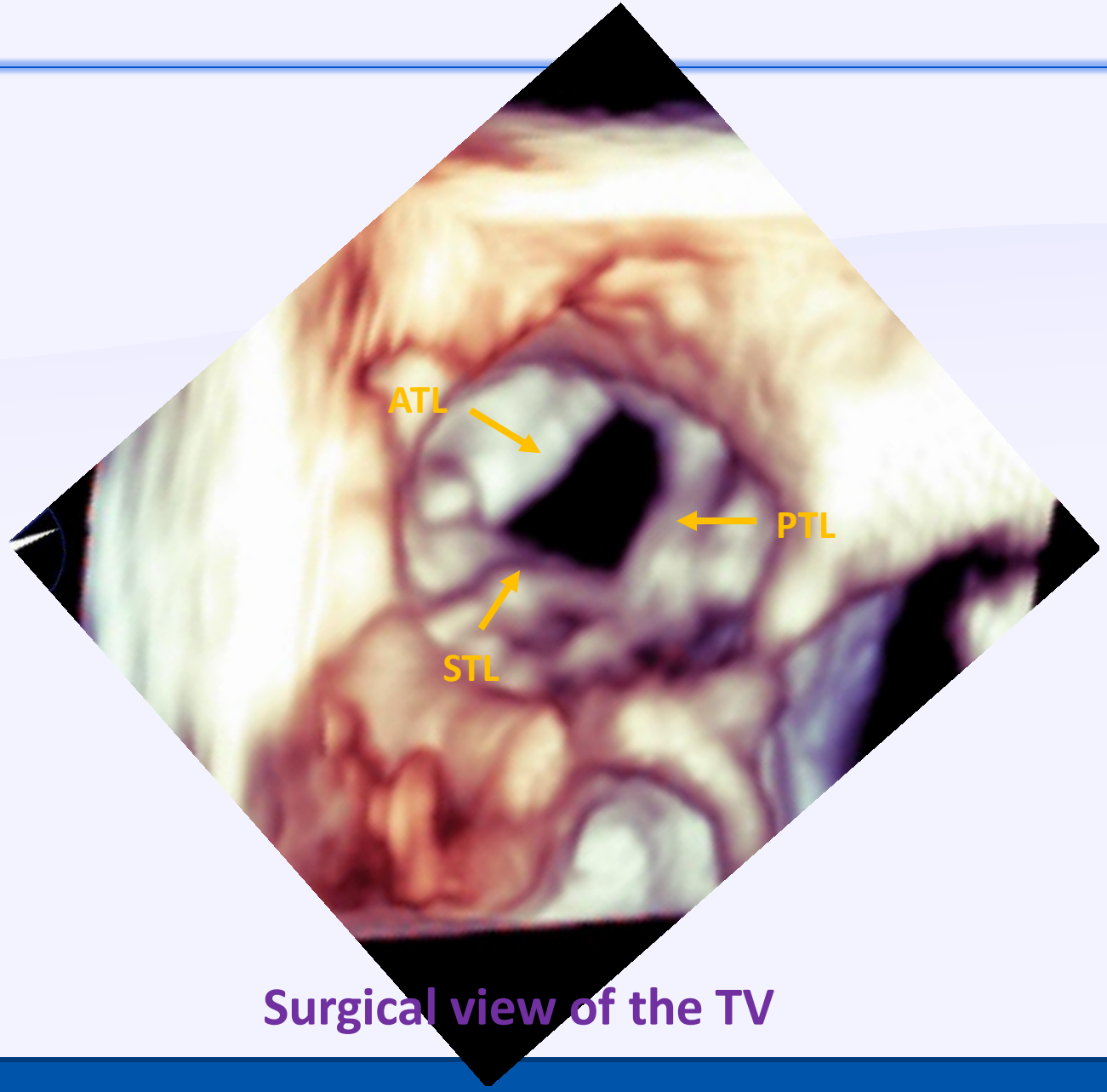
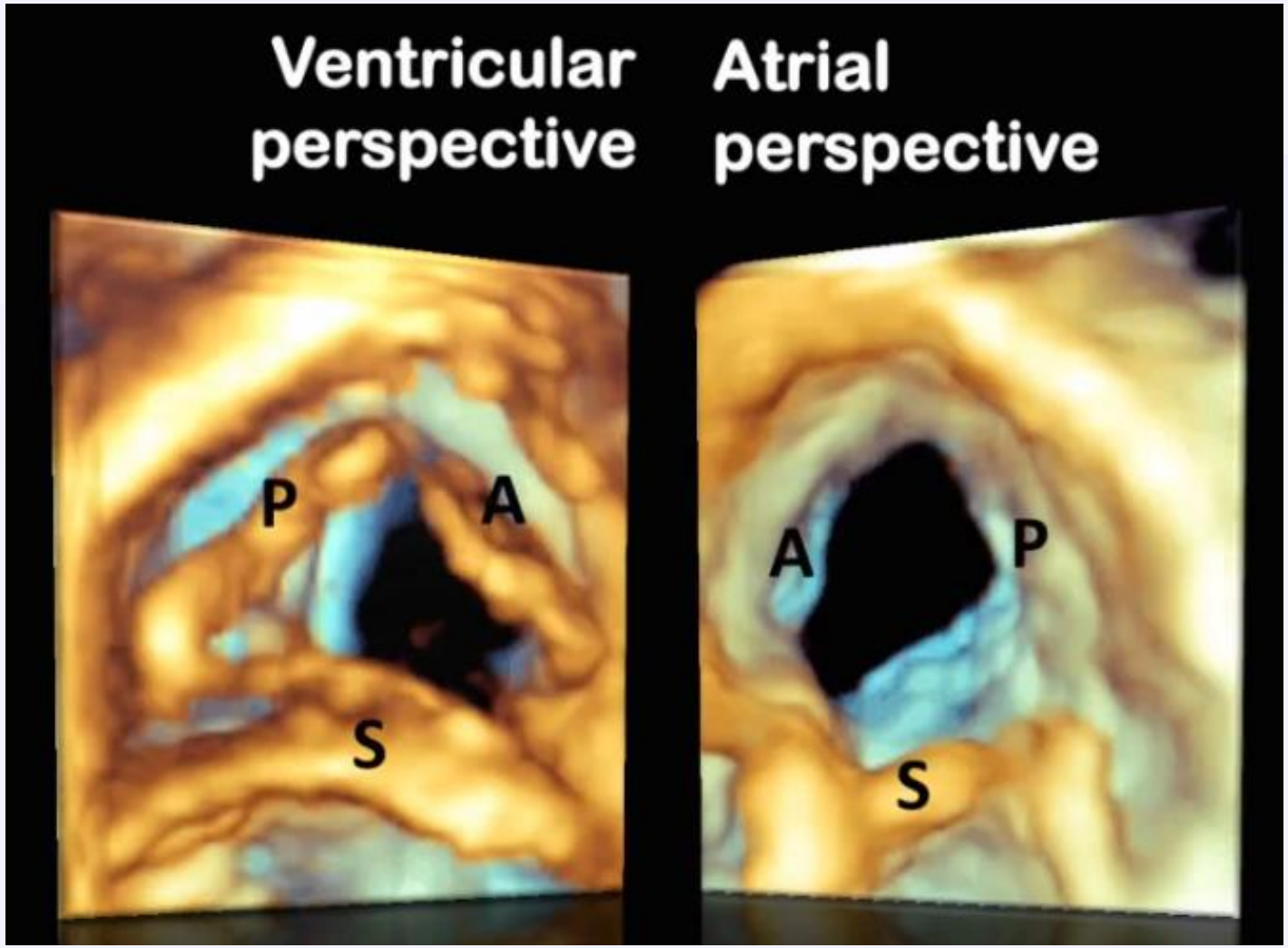
TRICUSPID VALVE, SURGICAL VIEW
JPEG
PAT T: 37.0C
TEE T: 38.6C
73 bpm

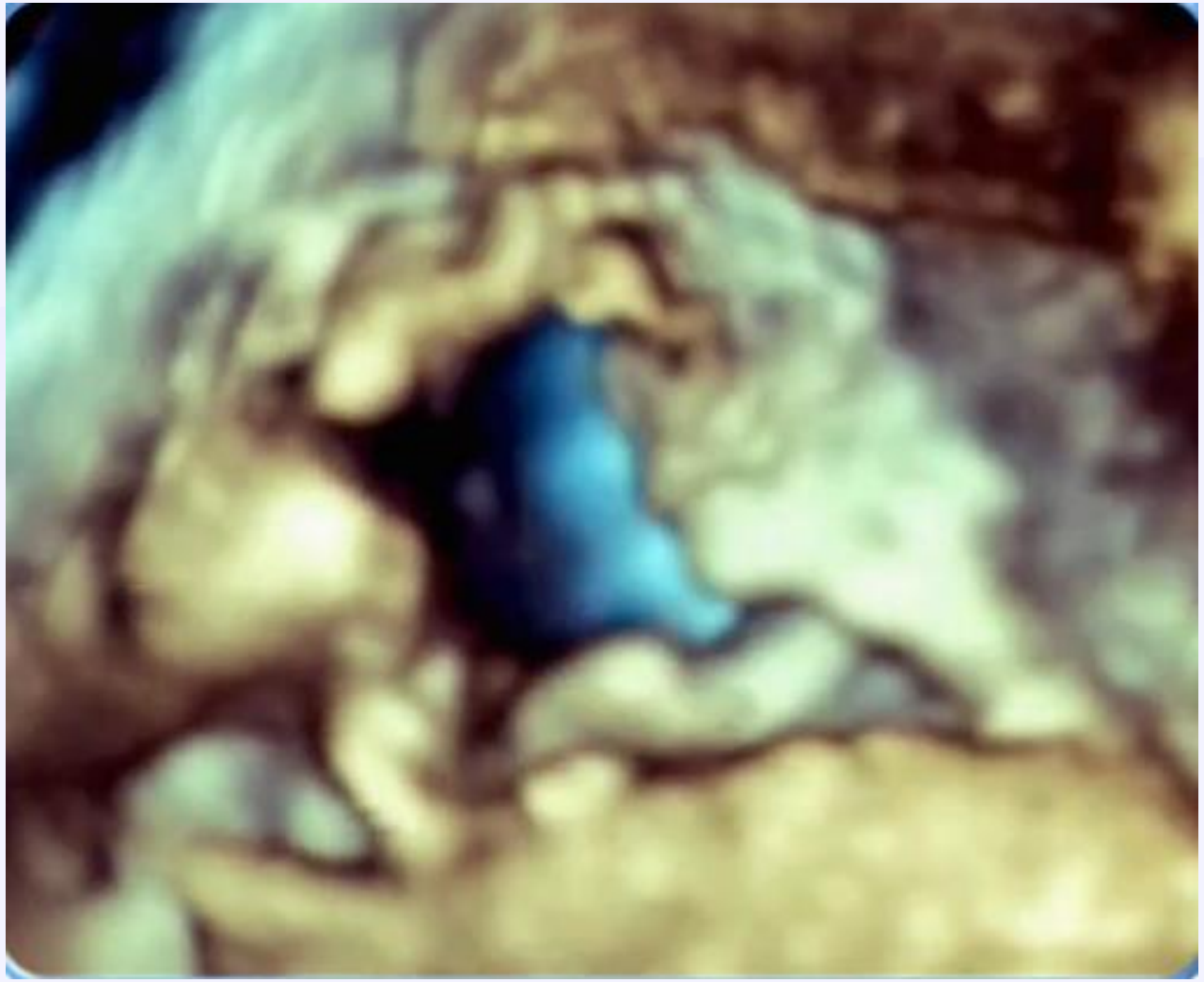


Surgical view of the TV

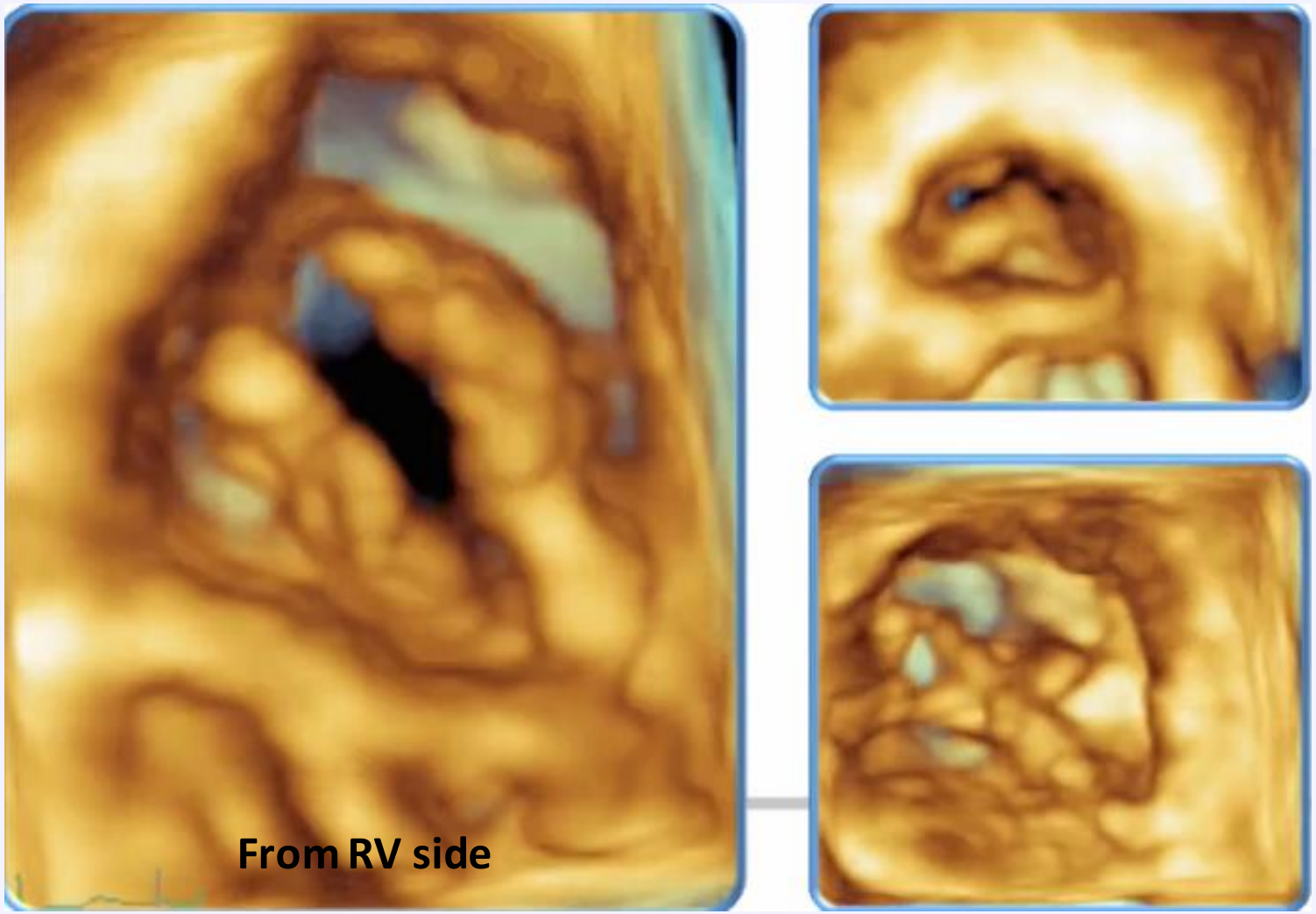


3D TTE **of the tricuspid valve**

R. Lang, Chicago



How many cups TV can have? TV with 4 cups from RV side



TV with 2 cups and small PTL (ITL)

Tricuspid stenosis (TS)

Etiology of tricuspid valve stenosis (TS)

TS is the least common valvular lesion

1. Rheumatic (associated with MV, rarely isolated)
2. Congenital malformation
3. Carcinoid disease
4. Lupus valvulitis
5. Masses obstructing flow (i.e. myxoma, metastasis, thrombus)
6. Device lead impairing valve function (i.e. pacemaker)
7. Drug related valvulitis

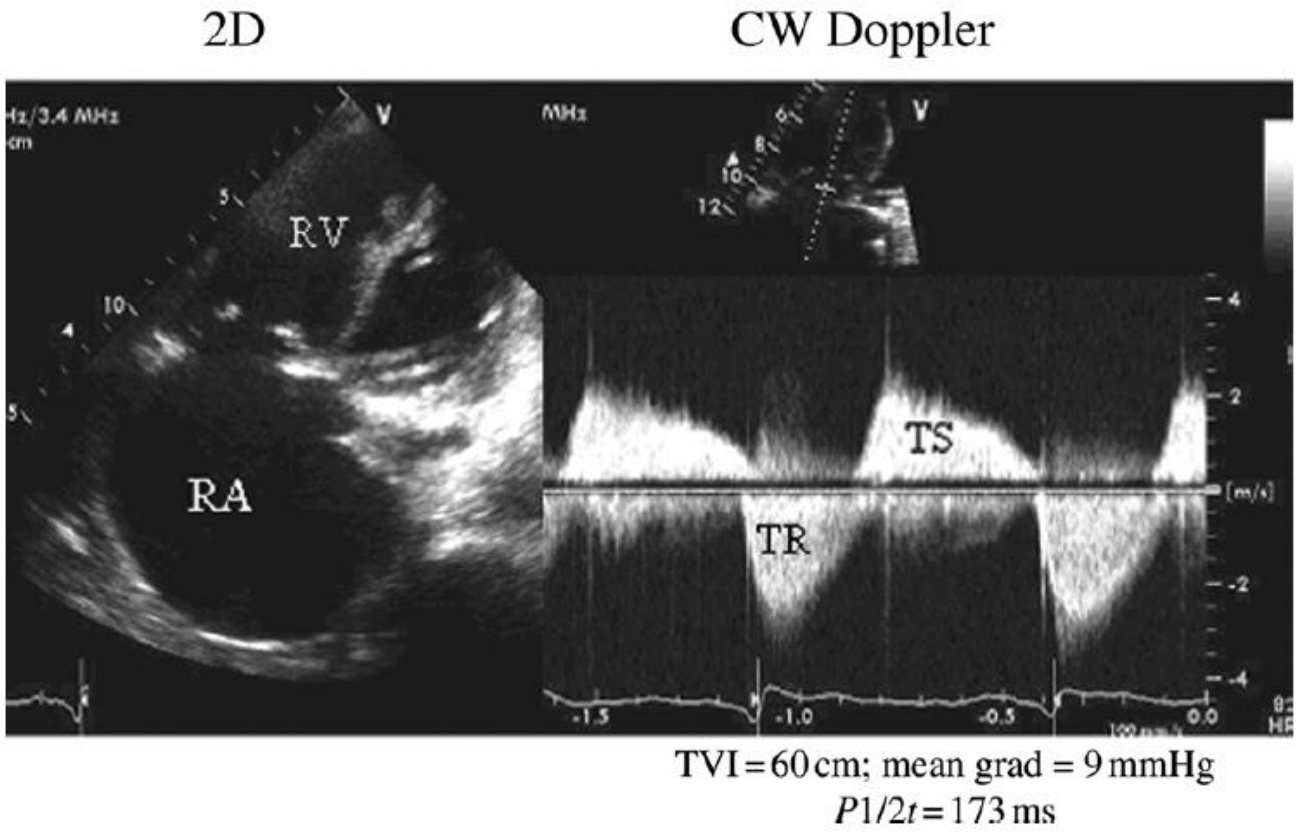


Figure 11 The left panel illustrates a 2D echocardiographic image of a stenotic tricuspid valve obtained in a modified apical four-chamber view during diastole. Note the thickening and diastolic doming of the valve, and the marked enlargement of the right atrium (RA). The right panel shows a CW Doppler recording through the tricuspid valve. Note the elevated peak diastolic velocity of 2 m/s and the systolic tricuspid regurgitation (TR) recording. The diastolic time–velocity integral (TVI), mean gradient (Grad), and pressure half-time ($T_{1/2}$) values are listed.

2009 ASE guideline

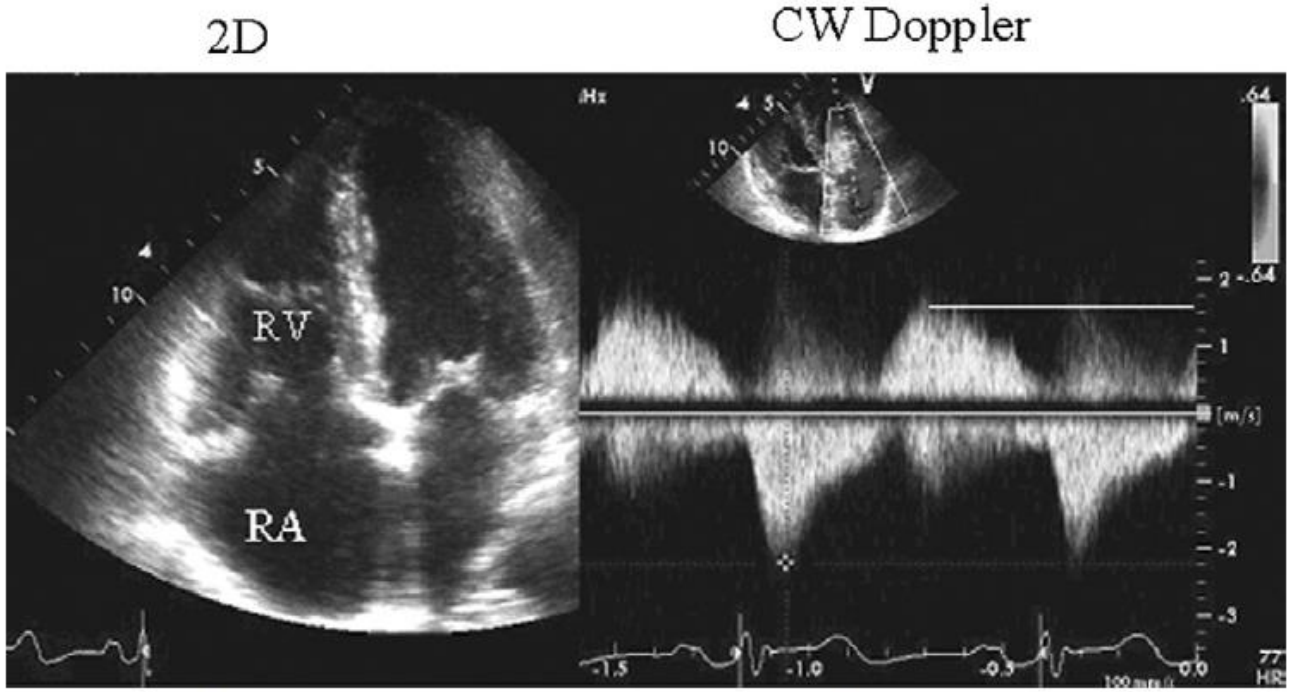


Figure 12 The left panel illustrates a 2D echocardiographic image of a tricuspid valve in a patient with carcinoid syndrome, obtained in an apical four-chamber view during systole. Note the thickening and opened appearance of the valve. The right panel shows a continuous-wave Doppler recording through the tricuspid valve. Note an elevated peak diastolic velocity of 1.6 m/s and the systolic TR recording.

Table 10 Findings indicative of haemodynamically significant tricuspid stenosis

Specific findings	
Mean pressure gradient	≥5 mmHg
Inflow time–velocity integral	>60 cm
$T_{1/2}$	≥190 ms
Valve area by continuity equation[a]	≤1 cm^{2a}
Supportive findings	
Enlarged right atrium ≥moderate	
Dilated inferior vena cava	

[a]Stroke volume derived from left or right ventricular outflow. In the presence of more than mild TR, the derived valve area will be underestimated. Nevertheless, a value ≤1 cm^2 implies a significant haemodynamic burden imposed by the combined lesion.

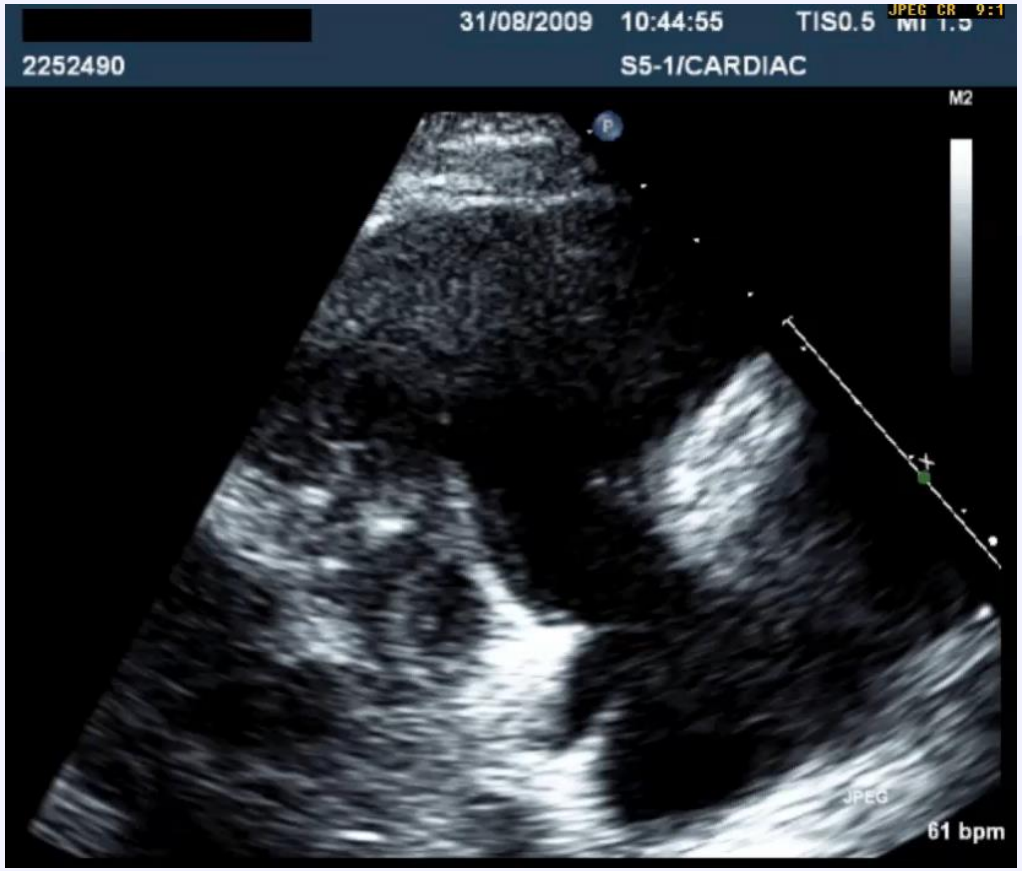
Tricuspid Stenosis: Intervention

Recommendations	COR	LOE
Tricuspid valve surgery is recommended for patients with severe TS at the time of operation for left-sided valve disease	I	C
Tricuspid valve surgery is recommended for patients with isolated, symptomatic severe TS	I	C
Percutaneous balloon tricuspid commissurotomy might be considered in patients with isolated, symptomatic severe TS without accompanying TR	IIb	C

Severe TS: PHT ≥ 190 ms, TVA ≤ 1cm2
Mean gradient ≥ 5 mmHg

Case 1

17-year-old boy presented with fatigue and mild cyanosis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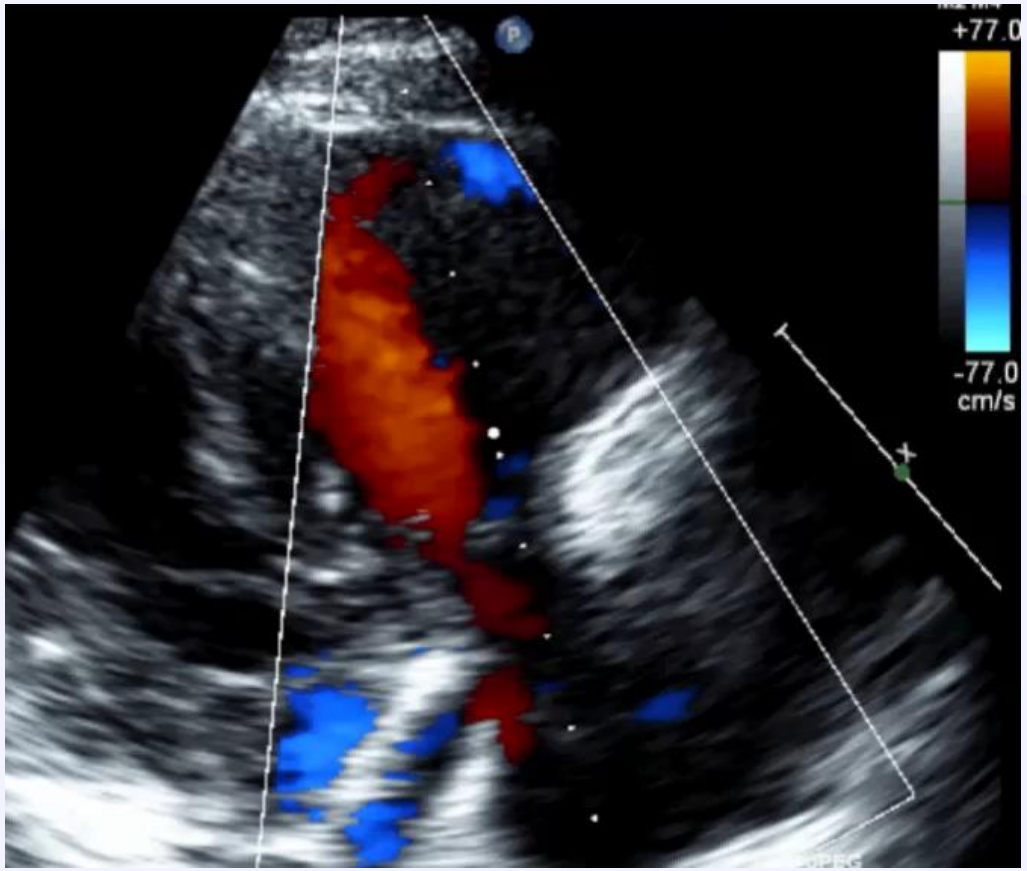
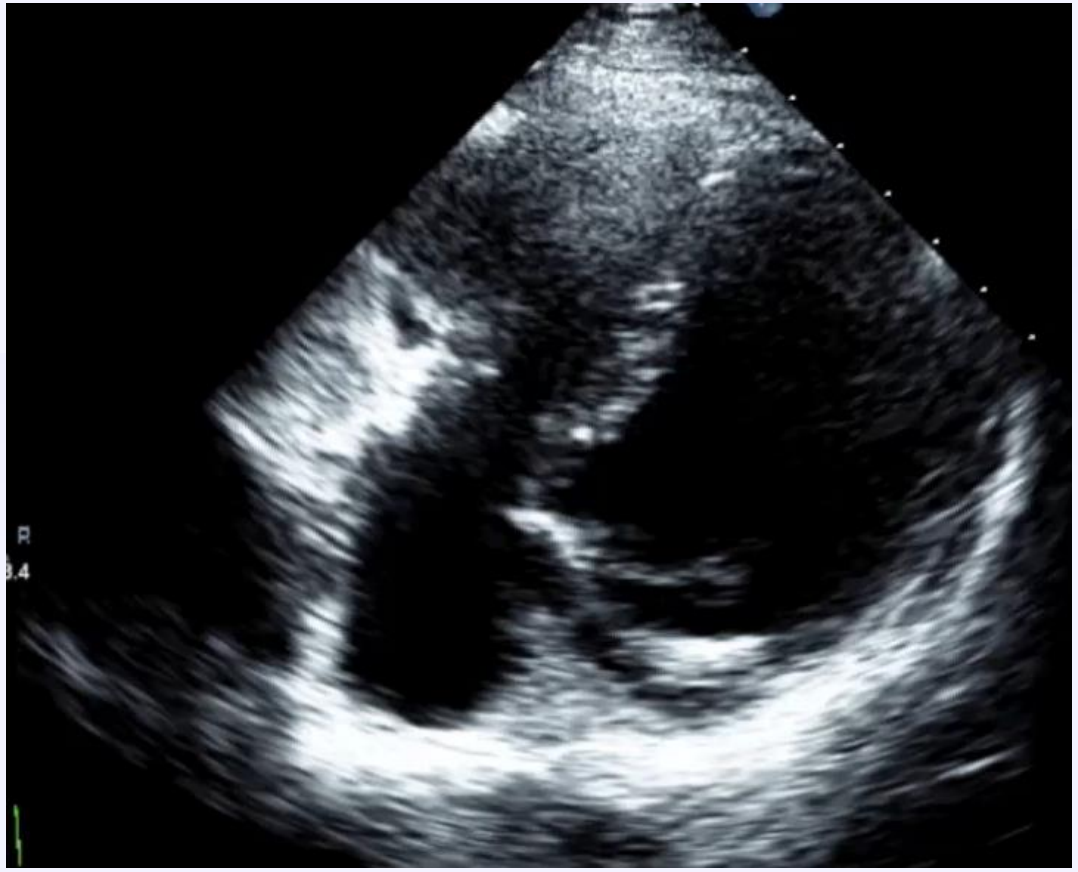
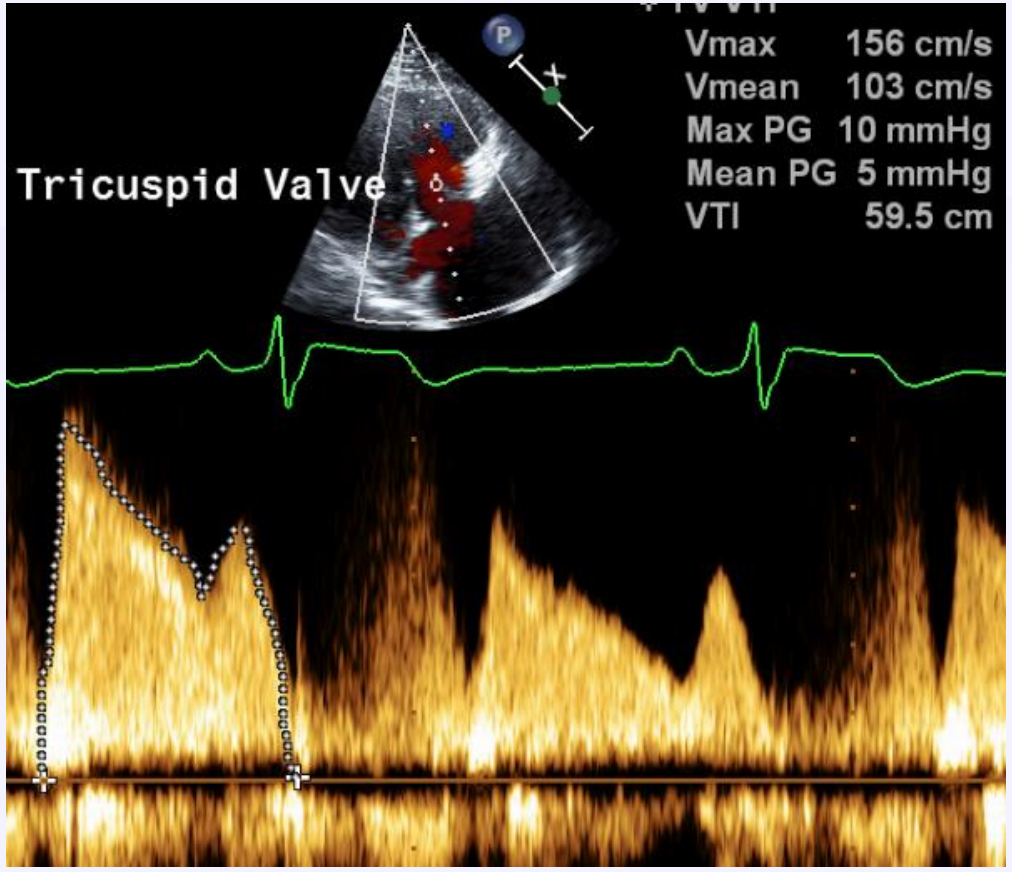
2252490
S5-1/CARDIAC
M2
JPEG
61 bpm


+77.0
-77.0
cm/s





Diastolic doming of the TV leaflets, mean gradient = 5 mmHg

Dr. Najm, KACC, Aug 2009

Tricuspid regurgitation (TR)

Etiology of tricuspid regurgitation (TR)

Nearly 60% of young adults have mild physiologic TR. **Etiology of Primary (organic or structural) TR (10% of all TR cases)**

1. Rheumatic
2. Degenerative or Barlow's disease
3. Infective endocarditis
4. Carcinoid
5. Traumatic
6. Pacemaker related
7. Congenital (Ebstein's anomaly, AVSD)
8. ? Idiopathic (most of these patients have atrial fibrillation)

Etiology of tricuspid regurgitation (TR) Cont.

Secondary (functional, non-structural): TV malcoaptation due to enlargement and / or dysfunction of TV annulus/ RV/RA (90% of all TR cases)

1. Pulmonary hypertension
2. RV dilatation
3. RV dysfunction
4. Atrial fibrillation

(Note: In the US, the prevalence of moderate and severe TR is estimated to be around 1,600,000. Only 8000 per year are being surgically treated today)

Table 12 Etiology of TR

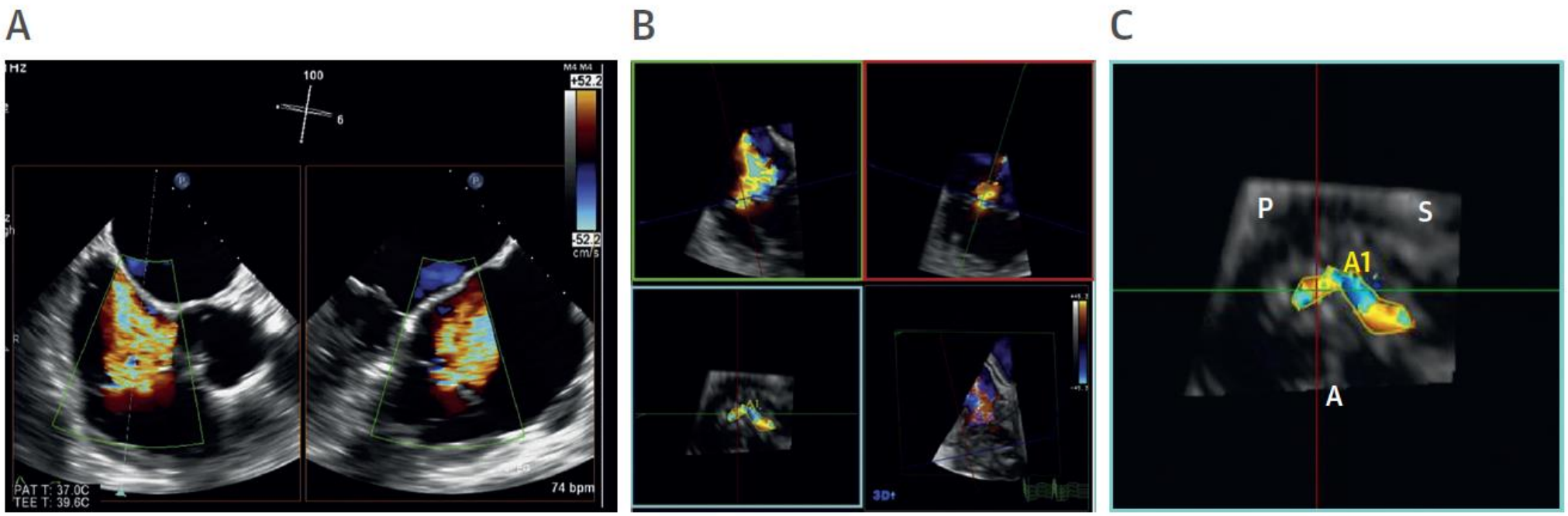
Morphologic classification	Disease subgroup	Specific abnormality
Primary leaflet abnormality	Acquired disease	Degenerative, myxomatous Rheumatic Endocarditis Carcinoid Endomyocardial fibrosis Toxins Trauma Iatrogenic (pacing leads, RV biopsy) Other (e.g., ischemic papillary muscle rupture)
	Congenital	Ebstein's anomaly TV dysplasia TV tethering associated with perimembranous ventricular septal defect and ventricular septal aneurysm Repaired tetralogy of Fallot Congenitally corrected transposition of the great arteries Other (giant right atrium)
Secondary (functional)	Left heart disease	LV dysfunction or valve disease
	RV dysfunction	RV ischemia RV volume overload RV cardiomyopathy
	Pulmonary hypertension	Chronic lung disease Pulmonary thromboembolism Left-to-right shunt
	Right atrial abnormalities	Atrial fibrillation

2017 ASE guideline

Parameters	Mild	Moderate	Severe
Structural			
TV morphology	**Normal or mildly abnormal leaflets**	Moderately abnormal leaflets	**Severe valve lesions** (e.g., flail leaflet, severe retraction, large perforation)
RV and RA size	Usually normal	Normal or mild dilatation	Usually dilated*
Inferior vena cava diameter	Normal < 2 cm	Normal or mildly dilated 2.1- 2.5 cm	Dilated > 2.5 cm
Qualitative Doppler			
Color flow jet area†	**Small, narrow, central**	Moderate central	**Large central jet** or eccentric wall-impinging jet of variable size
Flow convergence zone	**Not visible, transient or small**	Intermediate in size and duration	**Large throughout systole**
CWD jet	**Faint/partial**/parabolic	Dense, parabolic or triangular	Dense, often triangular
Semiquantitative			
Color flow jet area (cm^2)†	Not defined	Not defined	**>10**
VCW (cm)†	<0.3	0.3-0.69	**≥0.7**
PISA radius (cm)‡	≤0.5	0.6-0.9	**>0.9**
Hepatic vein flow§	Systolic dominance	Systolic blunting	**Systolic flow reversal**
Tricuspid inflow§	**A-wave dominant**	Variable	E-wave >1.0 m/sec
Quantitative			
EROA (cm^2)	<0.20	0.20-0.39‖	**≥0.40**
RVol (2D PISA) (mL)	<30	30-44‖	≥45

Grading the severity of chronic TR by echocardiography

2017 ASE guideline



Because the shape of the TR jet is frequently irregular, the vena contracta (VC) diameters vary based on the imaging window. **(A)** Simultaneous multiplane imaging shows different VC diameters. The 3D color Doppler image **(B)** aligns the **green** and **red** planes to image the VC in the **blue plane**. **(C)** The blue plane with S, P, and A leaflets with the regurgitant jet between both the A-S and A-P commissures. A = anterior leaflets; P = posterior leaflets; S = septal leaflets; other abbreviations in Figure 1.

Color flow Doppler: 3D vena contracta

Tricuspid Regurgitation: Intervention

Recommendations	COR	LOE
Tricuspid valve surgery is recommended for patients with severe TR (stages C and D) undergoing left-sided valve surgery	I	C
Tricuspid valve repair can be beneficial for patients with mild, moderate, or greater functional TR (stage B) at the time of left-sided valve surgery with either 1) tricuspid annular dilation or 2) prior evidence of right HF	IIa	B
Tricuspid valve surgery can be beneficial for patients with symptoms due to severe primary TR that are unresponsive to medical therapy (stage D)	IIa	C

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American Heart Association.

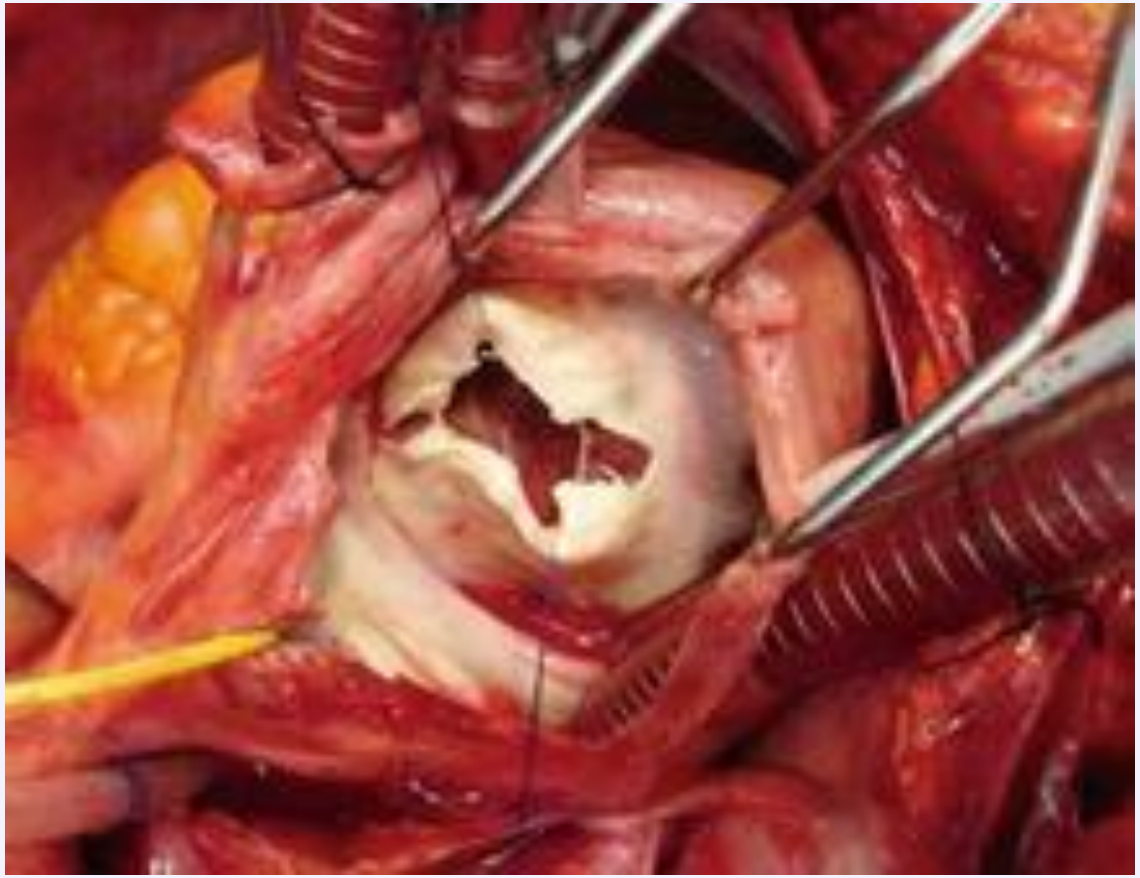
2017 ACC/ AHA guideline

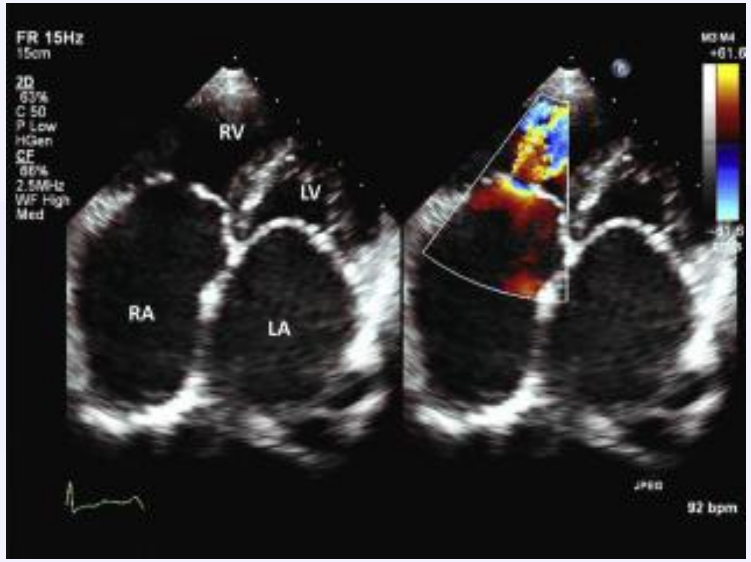
Tricuspid Regurgitation: Intervention (cont.)

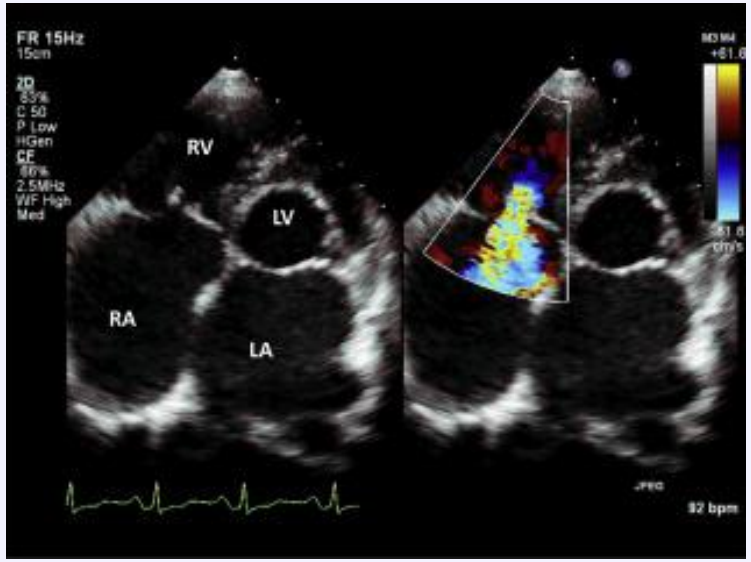
Recommendations	COR	LOE
Tricuspid valve repair may be considered for patients with moderate functional TR (stage B) and pulmonary artery hypertension at the time of left-sided valve surgery	IIb	C
Tricuspid valve surgery may be considered for asymptomatic or minimally symptomatic patients with severe primary TR (stage C) and progressive degrees of moderate or greater RV dilation and/or systolic dysfunction	IIb	C

Tricuspid Regurgitation: Intervention (cont.)

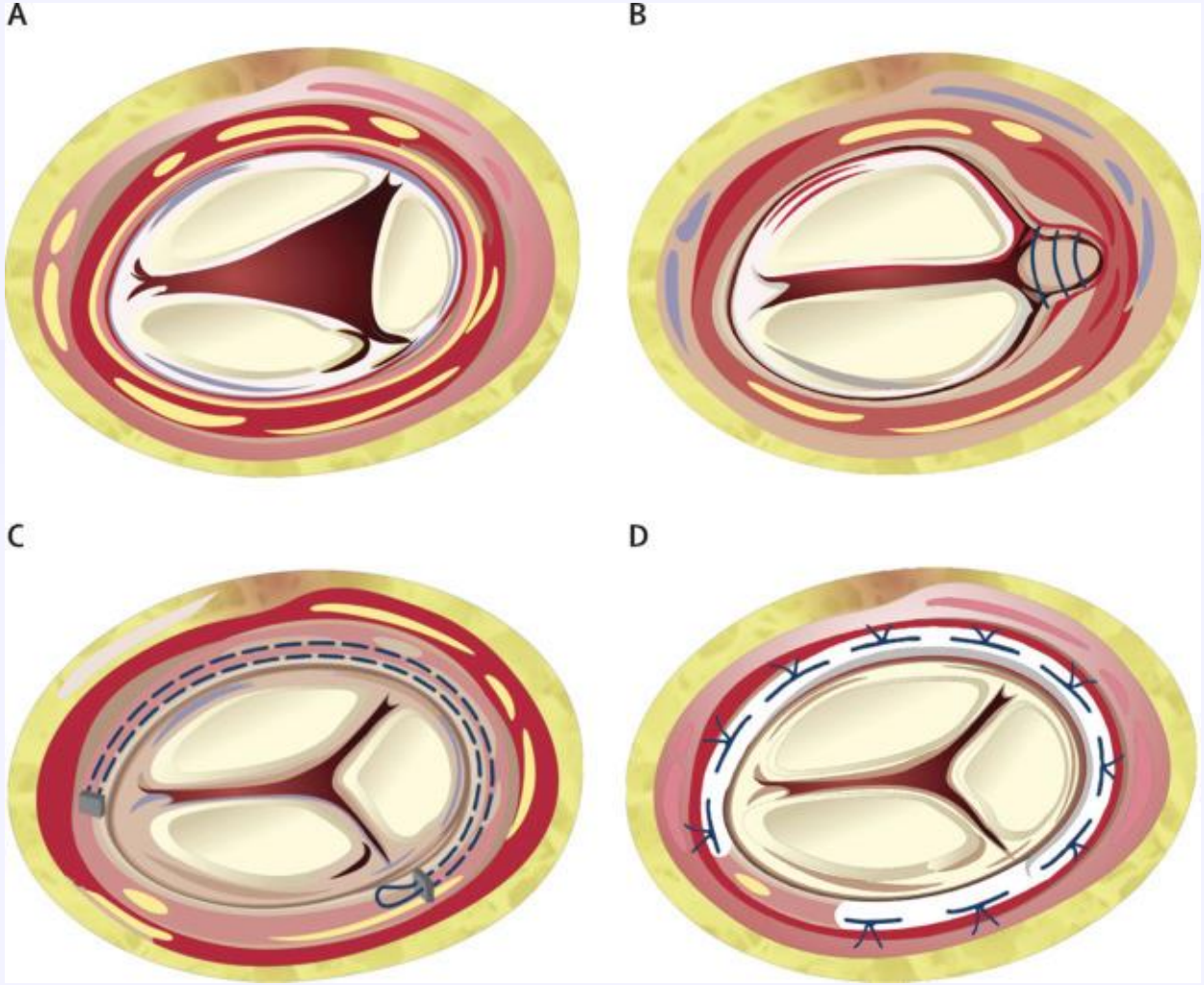
Recommendations	COR	LOE
Reoperation for isolated tricuspid valve repair or replacement may be considered for persistent symptoms due to severe TR (stage D) in patients who have undergone previous left-sided valve surgery and who do not have severe pulmonary hypertension or significant RV systolic dysfunction	IIb	C







Rheumatic tricuspid valve with thickened, retracted leaflets and fused commissures.



A- Dilated tricuspid annulus, lack of leaflets coaptation

B- Repair with bicuspidization

C- Repair with De Vega sutures (purse- string sutures)

D- Annuloplasty ring (MC-3, 3D ring, Physio ring, Simplici-T band, etc…..)

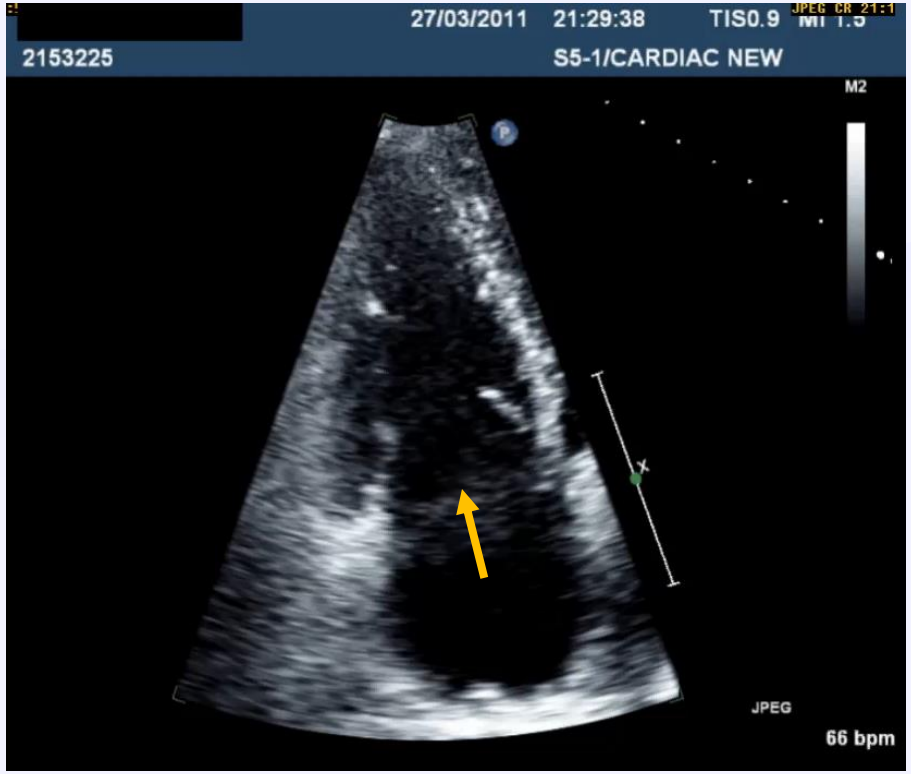
Tricuspid annuloplasty repair techniques

Dr. Arifi, KACC, 2011

Severe TR in a rheumatic patient, bicuspidization repair

Case 2

68-year-old man with history of chest trauma 6 months ago, presented with SOB and fatigue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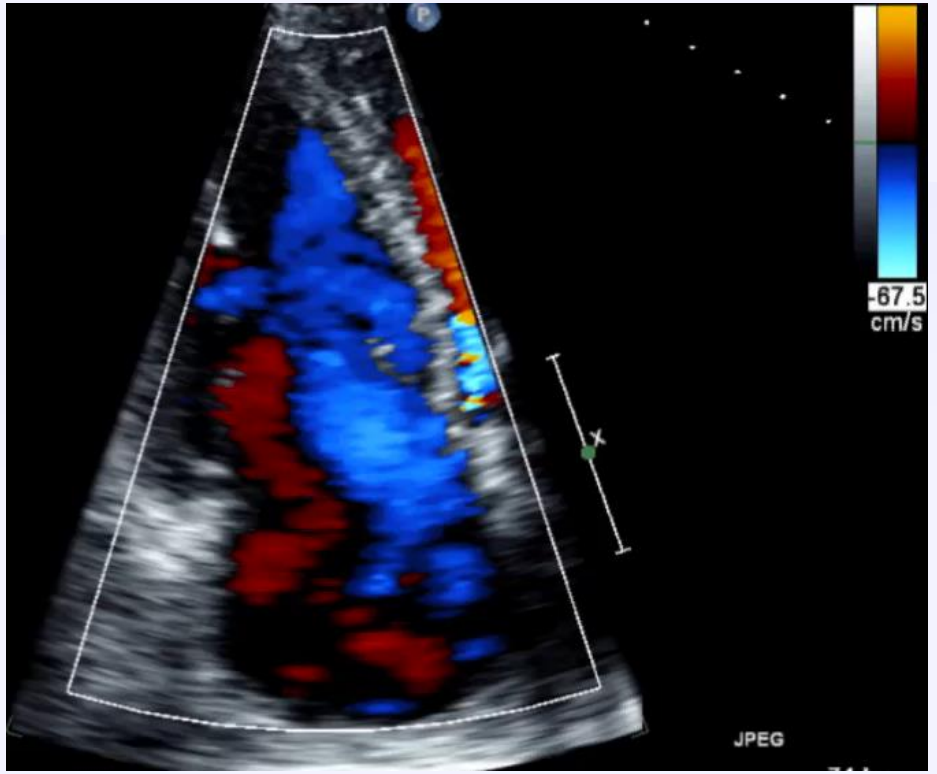
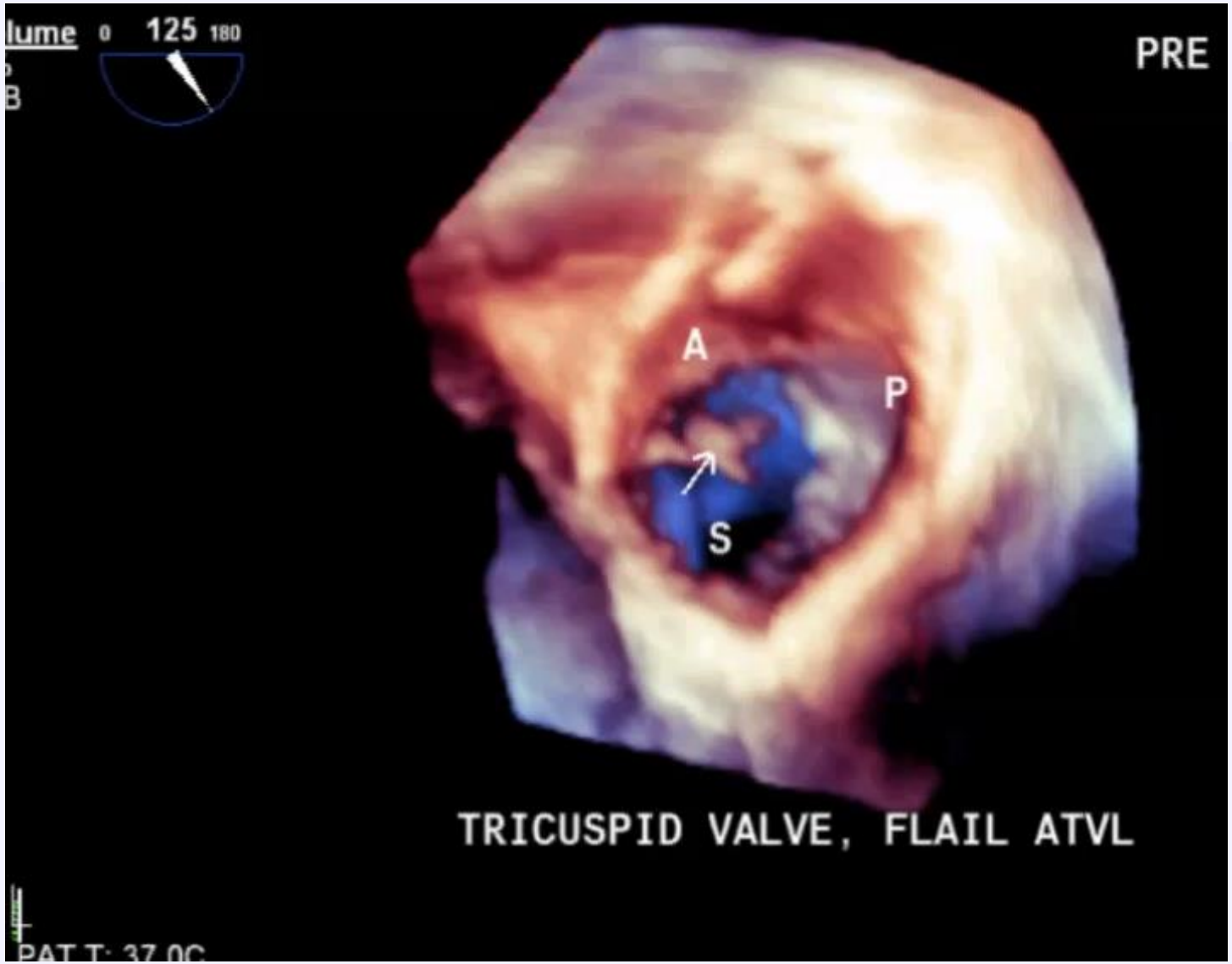
2153225
S5-1/CARDIAC NEW
M2
JPEG
66 bpm

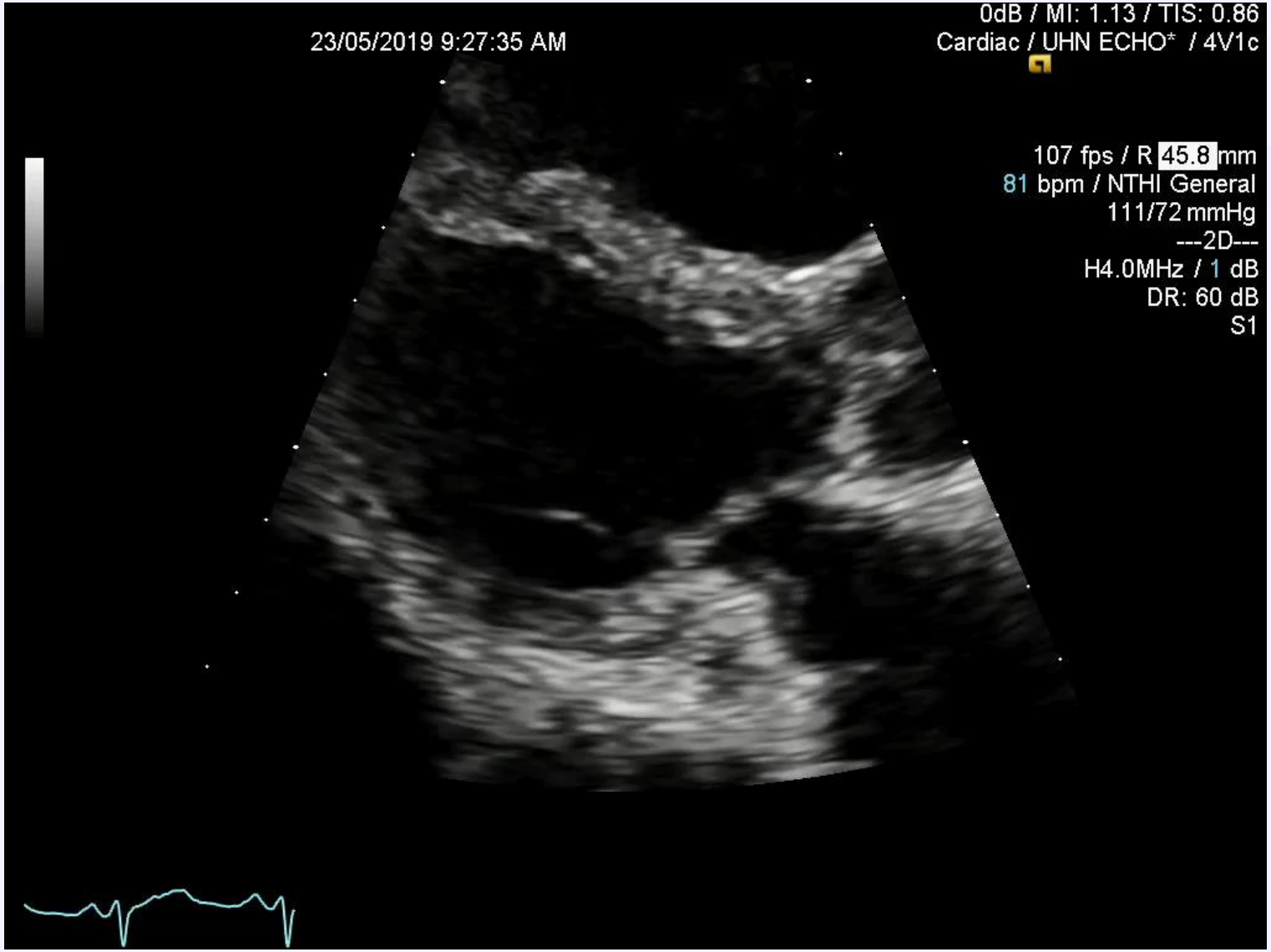

-67.5
cm/s
JPEG


lume 0 125 180
B
PRE
A
P
S
TRICUSPID VALVE, FLAIL ATVL
PAT T: 37.0C

Dr. Arifi, KACC, 2011

Case 3

73-year-old female, known case of carcinoid tumor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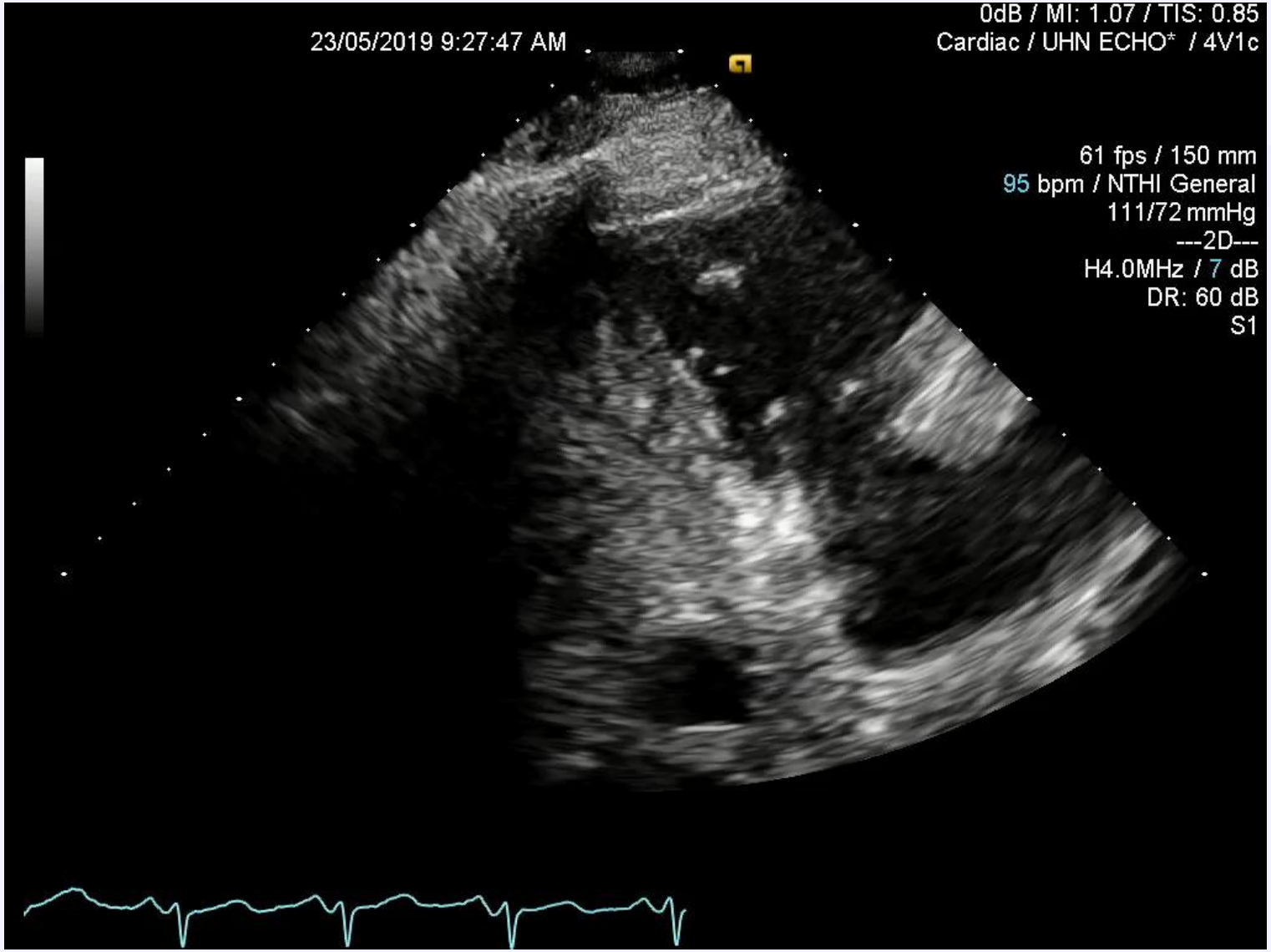
81 bpm / NTHI General
111/72 mmHg
---2D---
H4.0MHz / 1 dB
DR: 60 dB
S1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0dB / MI: 1.07 / TIS: 0.85
Cardiac / UHN ECHO* / 4V1c
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95 bpm / NTHI General
111/72 mmHg
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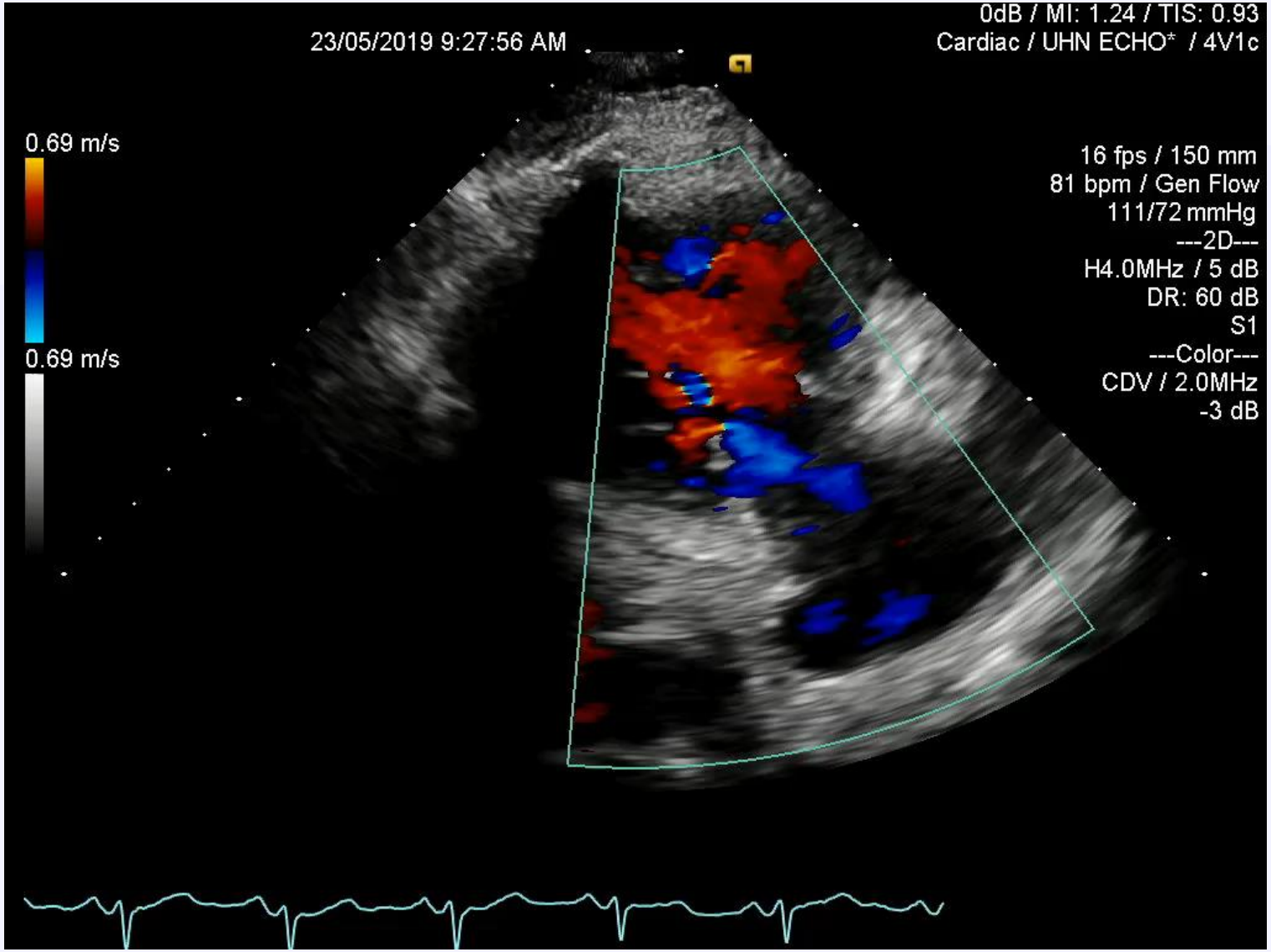
H4.0MHz / 7 dB
DR: 60 dB
S1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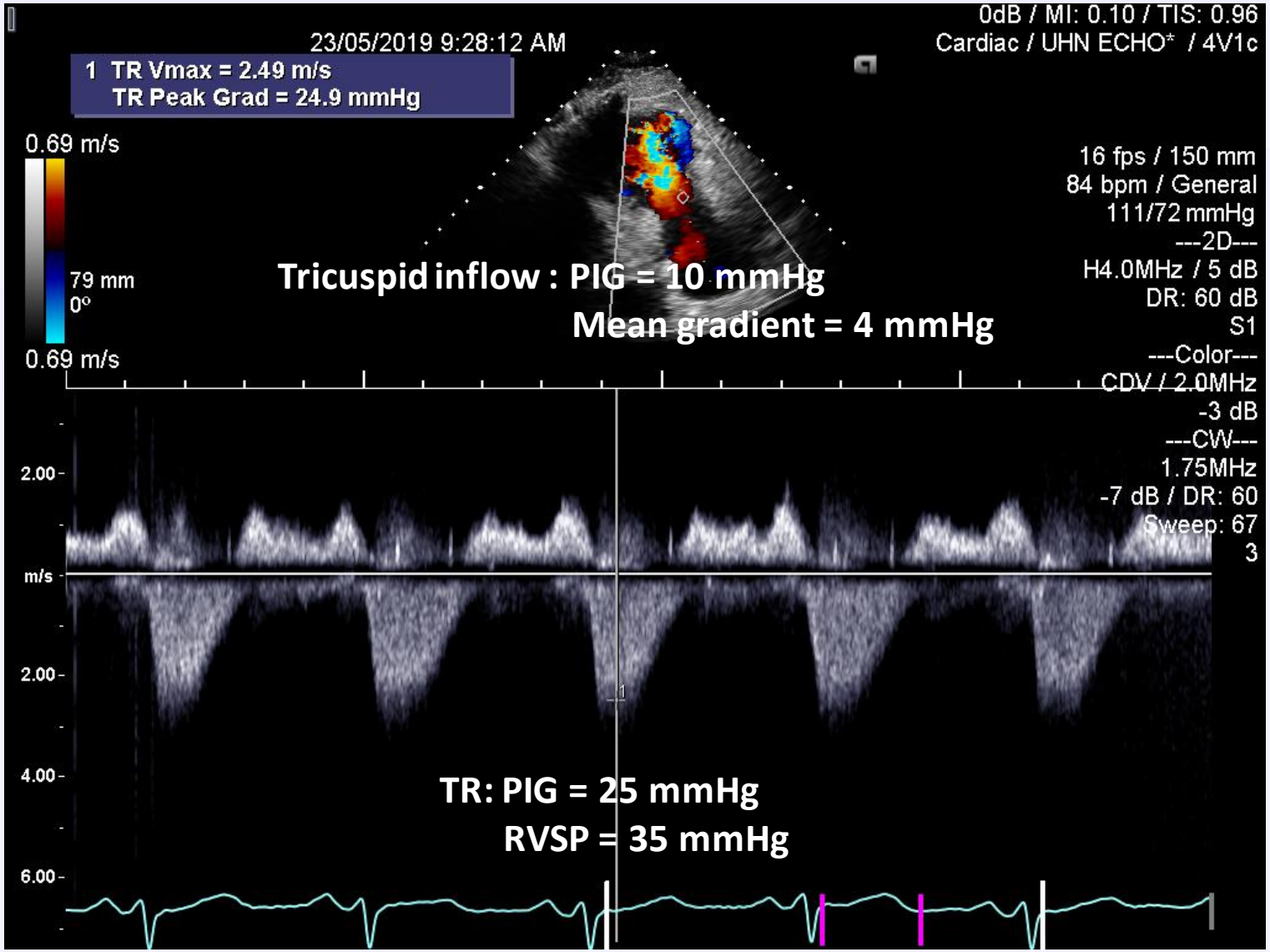
Cardiac / UHN ECHO* / 4V1c
0.69 m/s
0.69 m/s
16 fps / 150 mm
81 bpm / Gen Flow
111/72 mmHg
---2D---
H4.0MHz / 5 dB
DR: 60 dB
S1
---Color---
CDV / 2.0MHz
-3 dB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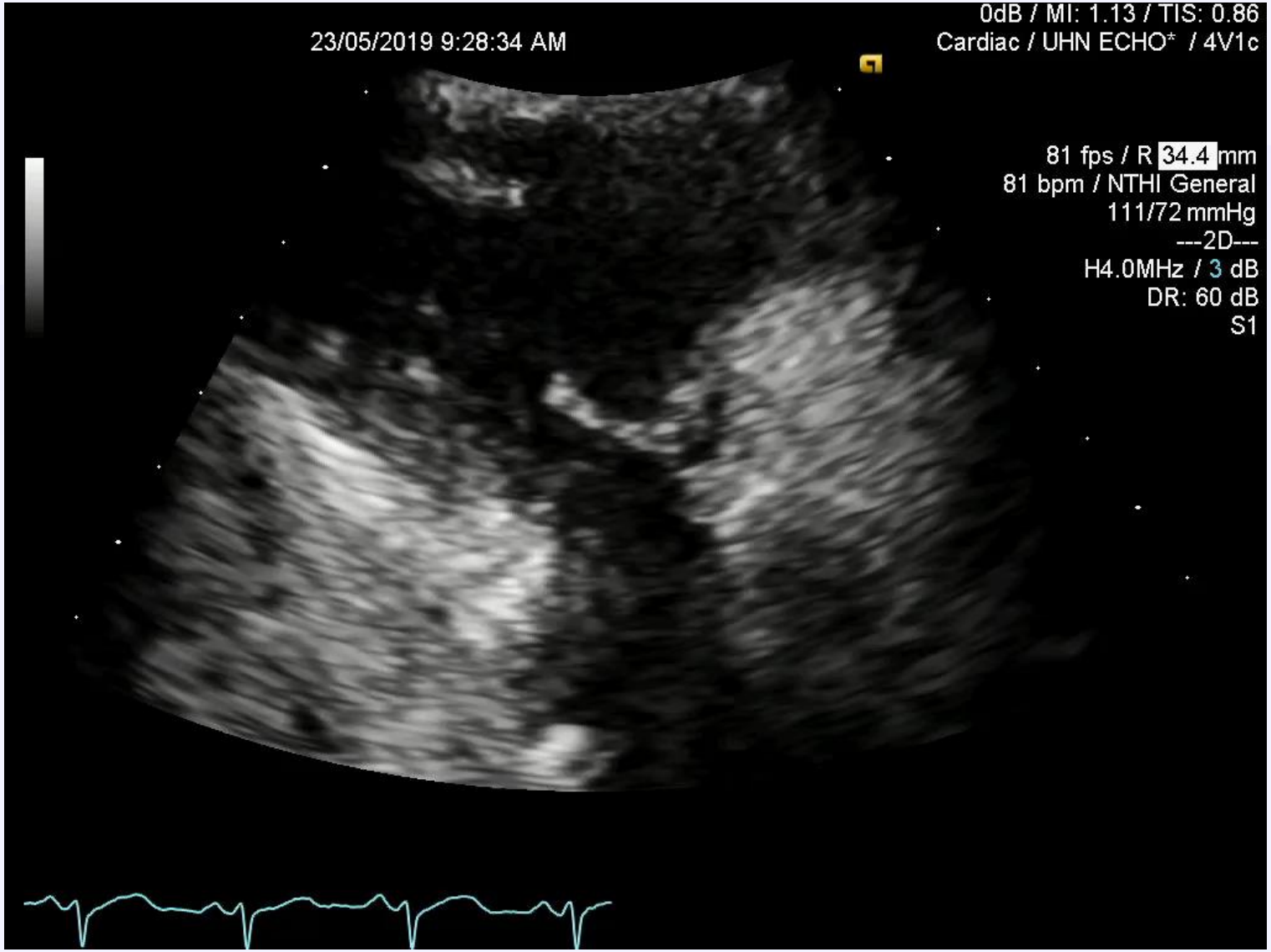
Cardiac / UHN ECHO* / 4V1c
23/05/2019 9:28:12 AM
1 TR Vmax = 2.49 m/s
TR Peak Grad = 24.9 mmHg
0.69 m/s
79 mm
0°
0.69 m/s
16 fps / 150 mm
84 bpm / General
111/72 mmHg
---2D---
H4.0MHz / 5 dB
DR: 60 dB
S1
---Color---
CDV / 2.0MHz
-3 dB
---CW---
1.75MHz
-7 dB / DR: 60
Sweep: 67
3
Tricuspid inflow : PIG = 10 mmHg
Mean gradient = 4 mmHg
2.00
m/s
2.00
4.00
6.00
TR: PIG = 25 mmHg
RVSP = 35 mmHg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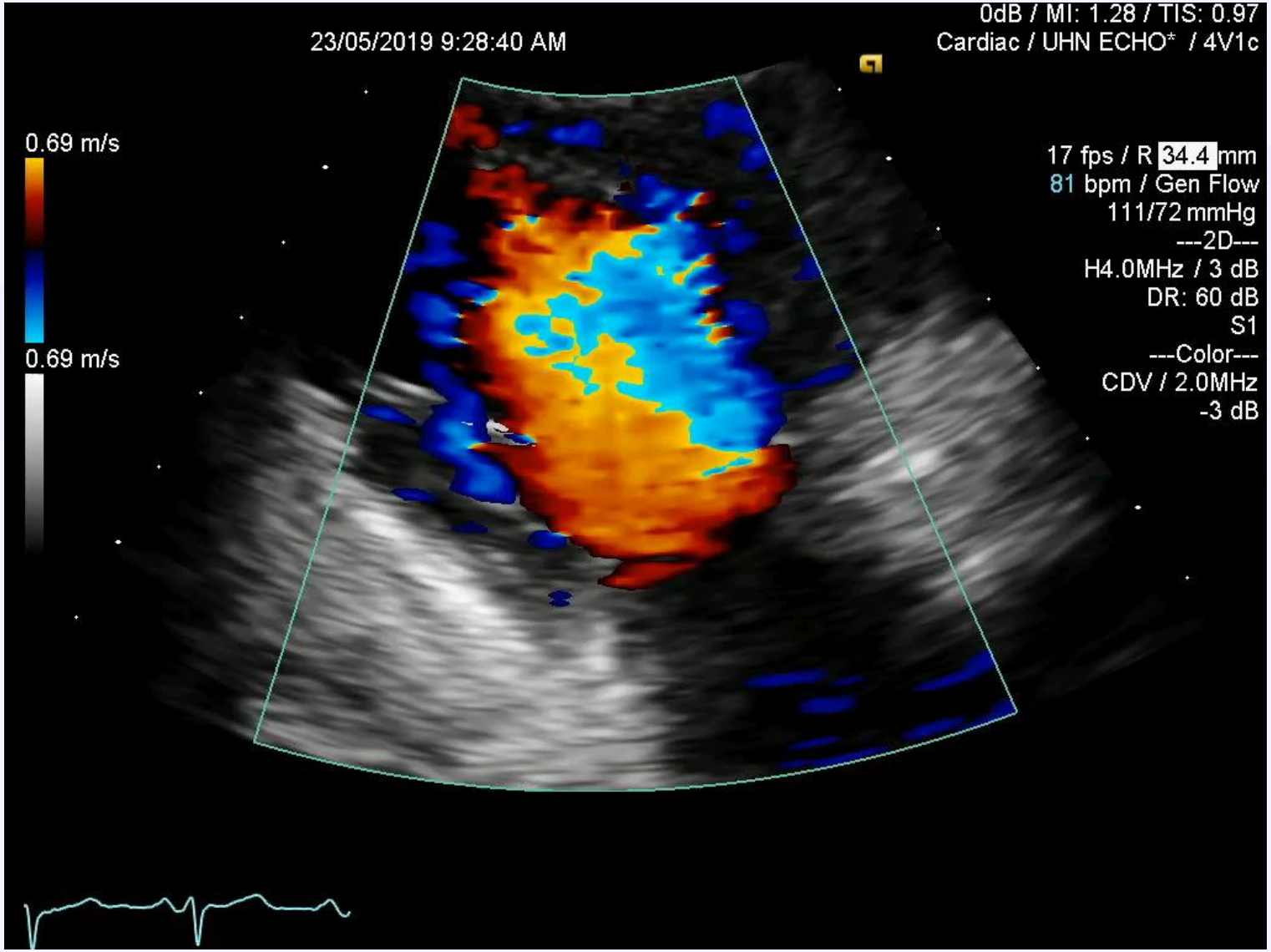
81 bpm / NTHI General
111/72 mmHg
---2D---
H4.0MHz / 3 dB
DR: 60 dB
S1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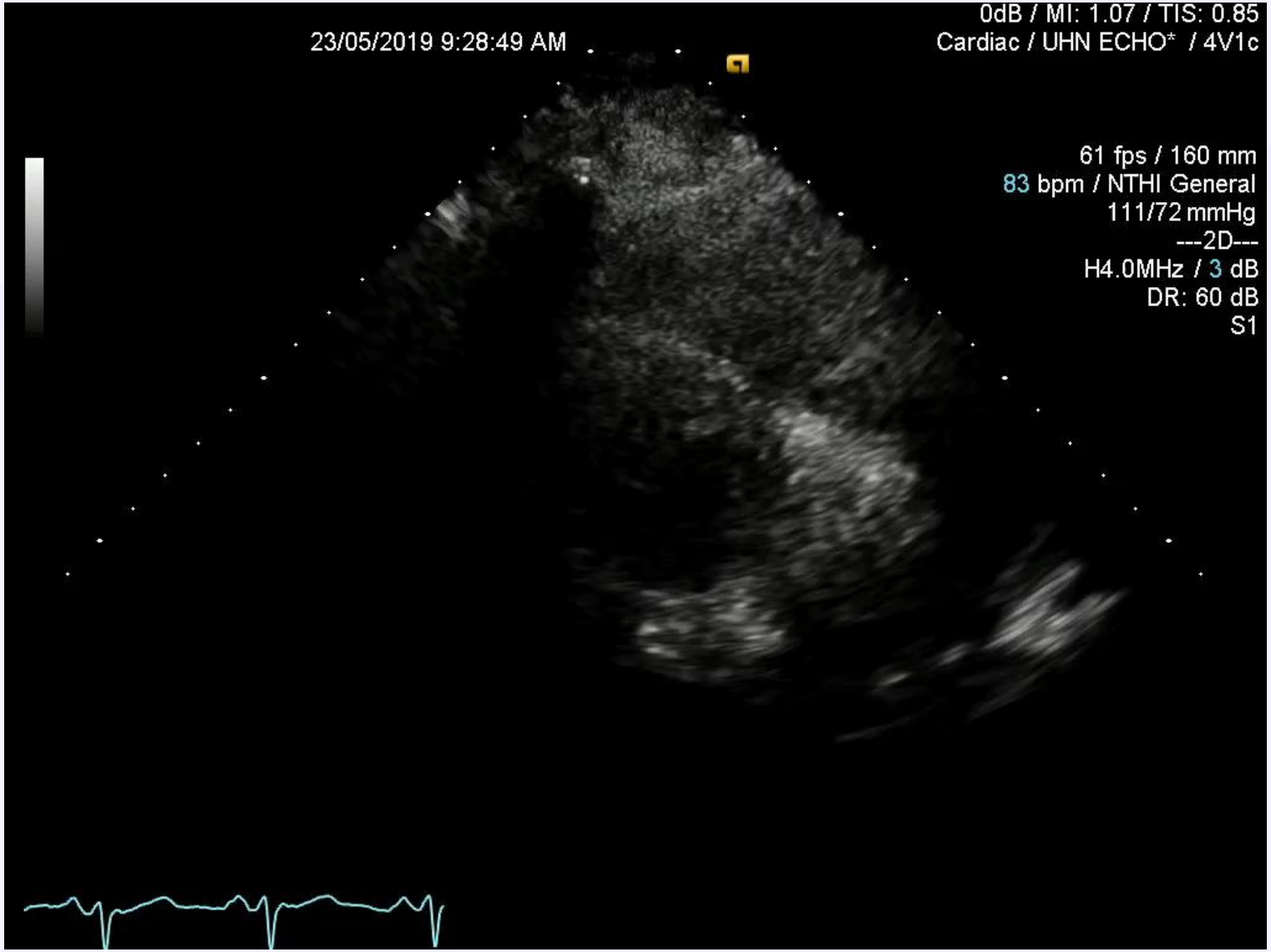
0.69 m/s
0.69 m/s
17 fps / R 34.4 mm
81 bpm / Gen Flow
111/72 mmHg
---2D---
H4.0MHz / 3 dB
DR: 60 dB
S1
---Color---
CDV / 2.0MHz
-3 dB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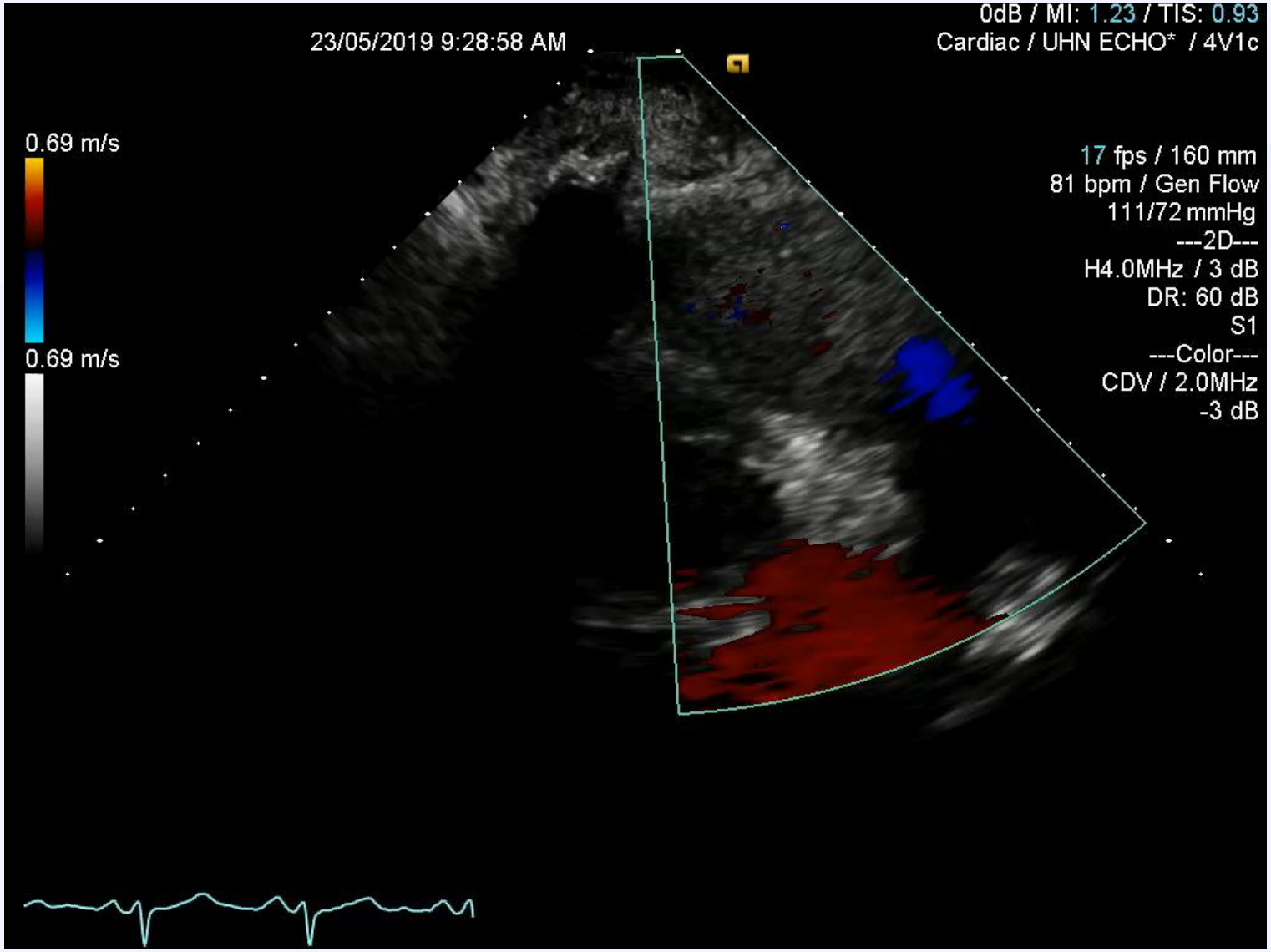
111/72 mmHg
---2D---
H4.0MHz / 3 dB
DR: 60 dB
S1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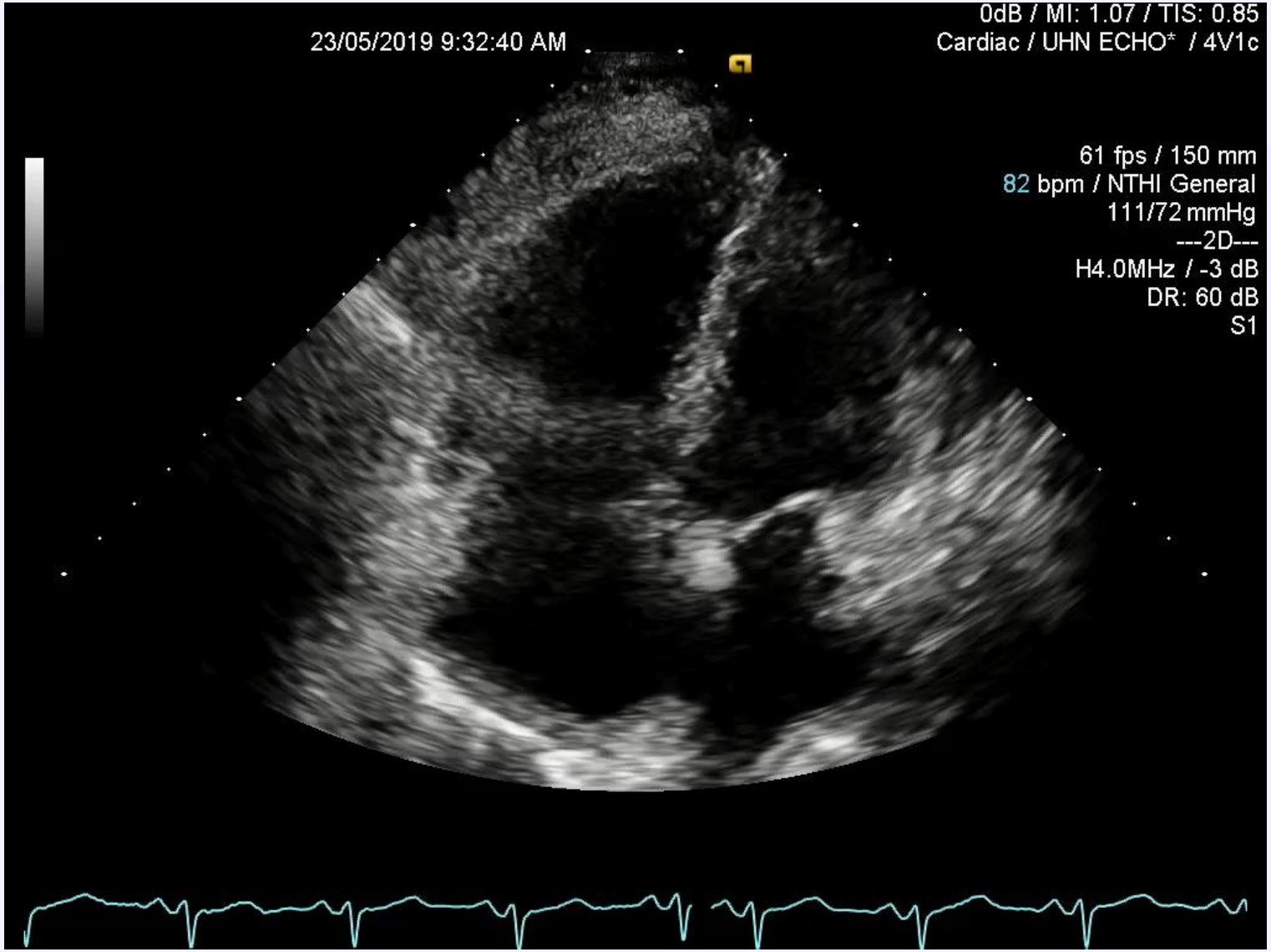
0.69 m/s
0.69 m/s
17 fps / 160 mm
81 bpm / Gen Flow
111/72 mmHg
---2D---
H4.0MHz / 3 dB
DR: 60 dB
S1
---Color---
CDV / 2.0MHz
-3 dB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82 bpm / NTHI General
111/72 mmHg
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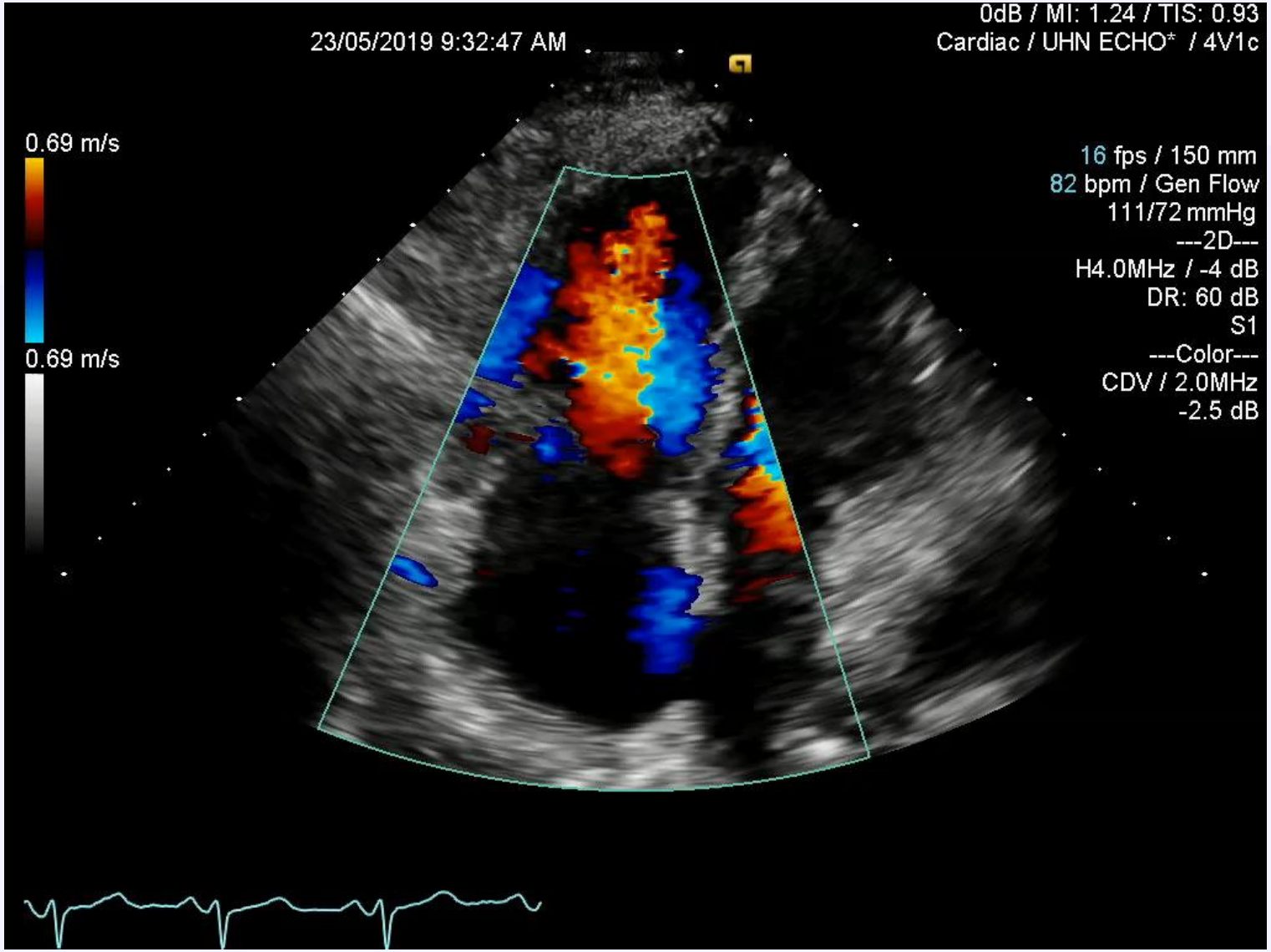
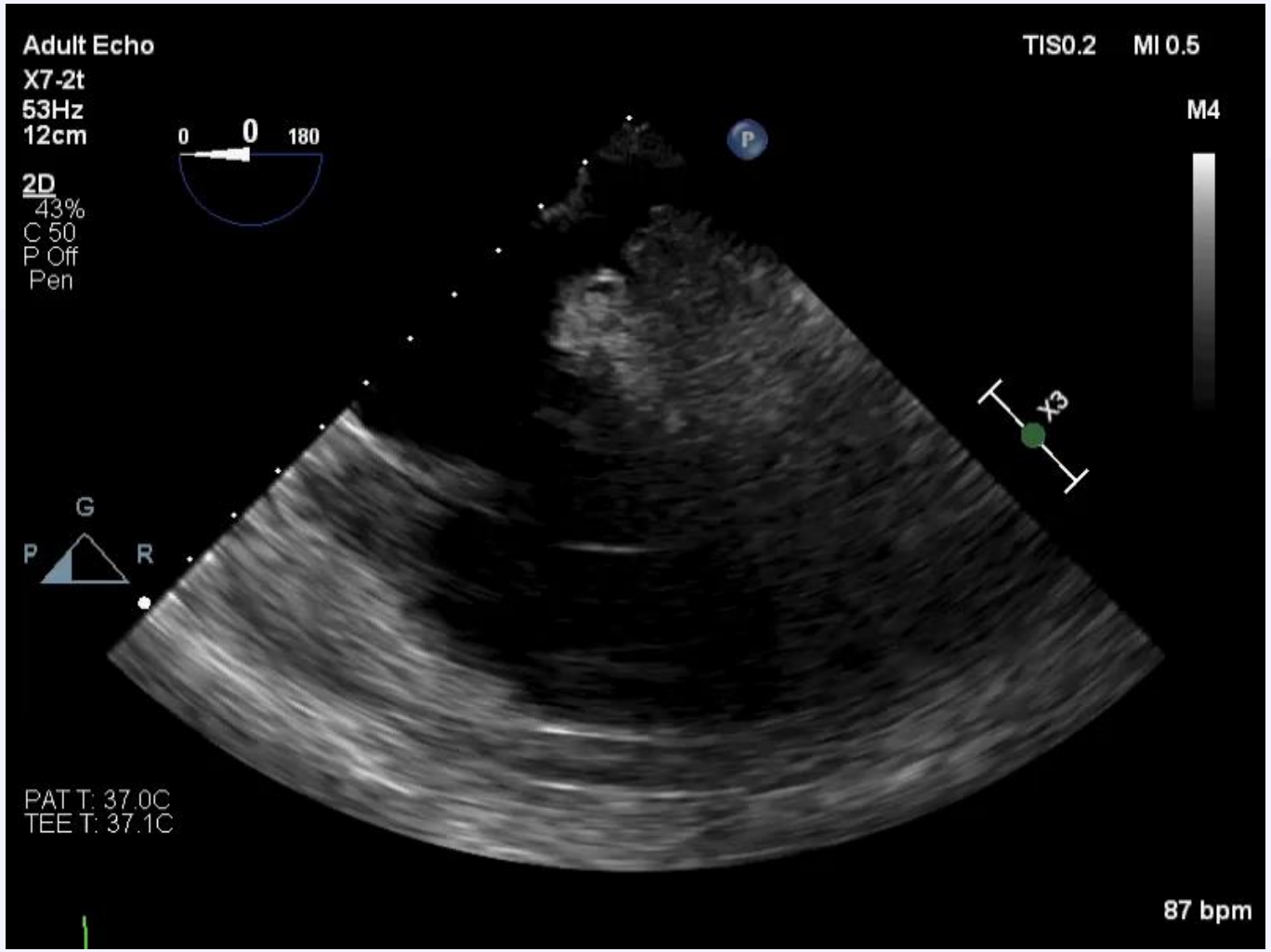
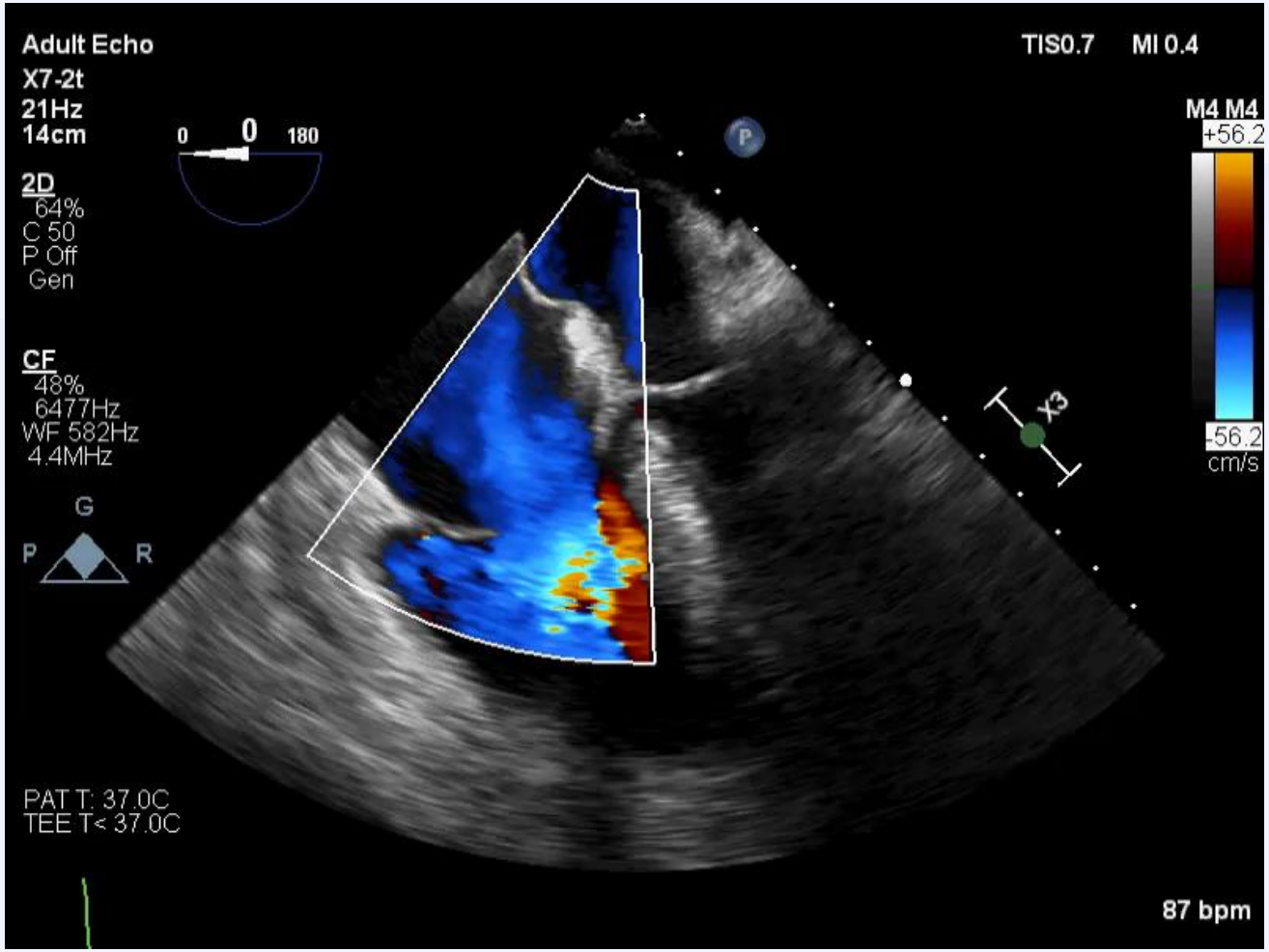
H4.0MHz / -3 dB
DR: 60 dB
S1

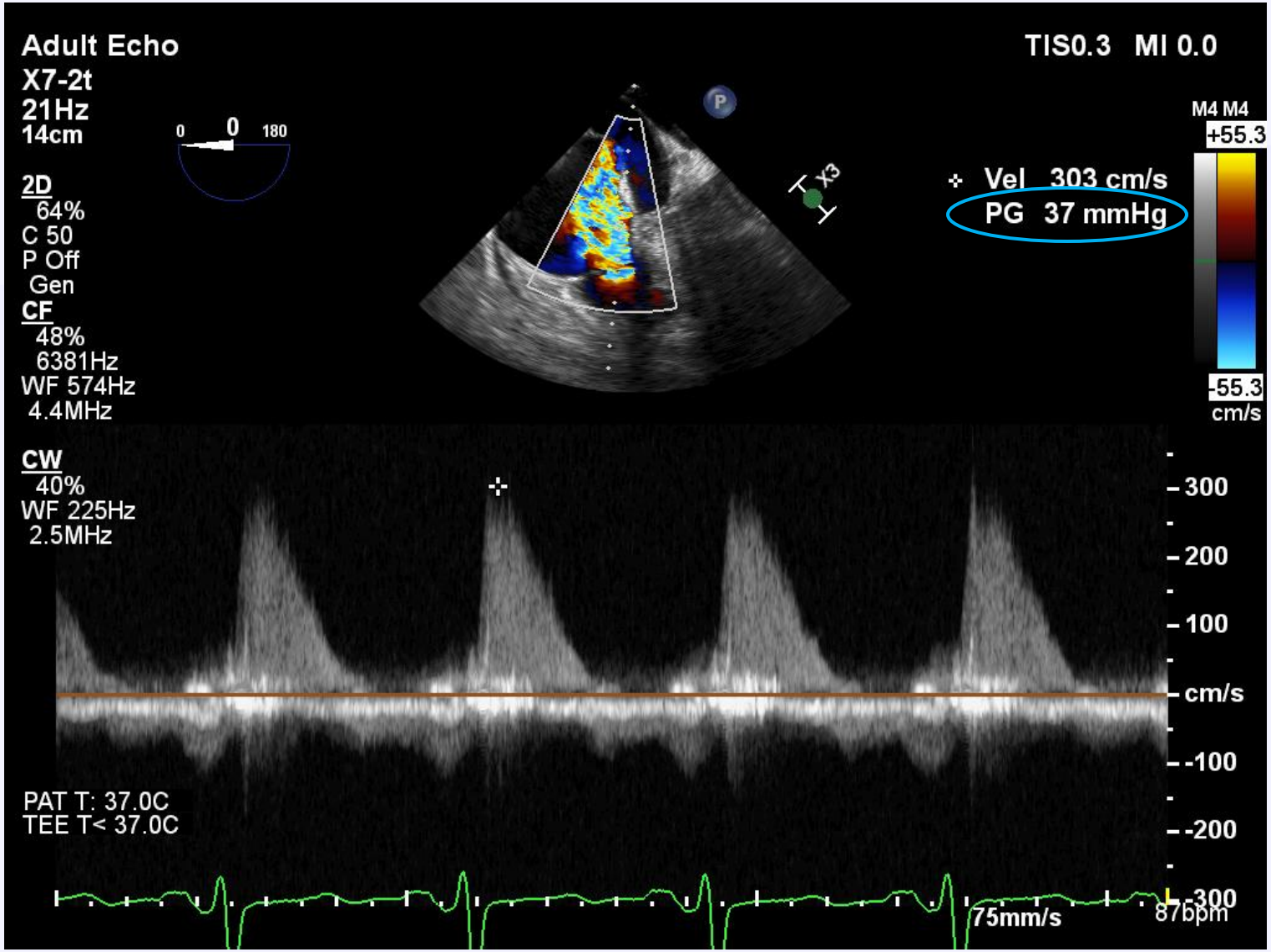

0dB / MI: 1.24 / TIS: 0.93
23/05/2019 9:32:47 AM
Cardiac / UHN ECHO* / 4V1c
0.69 m/s
0.69 m/s
16 fps / 150 mm
82 bpm / Gen Flow
111/72 mmHg
---2D---
H4.0MHz / -4 dB
DR: 60 dB
S1
---Color---
CDV / 2.0MHz
-2.5 dB

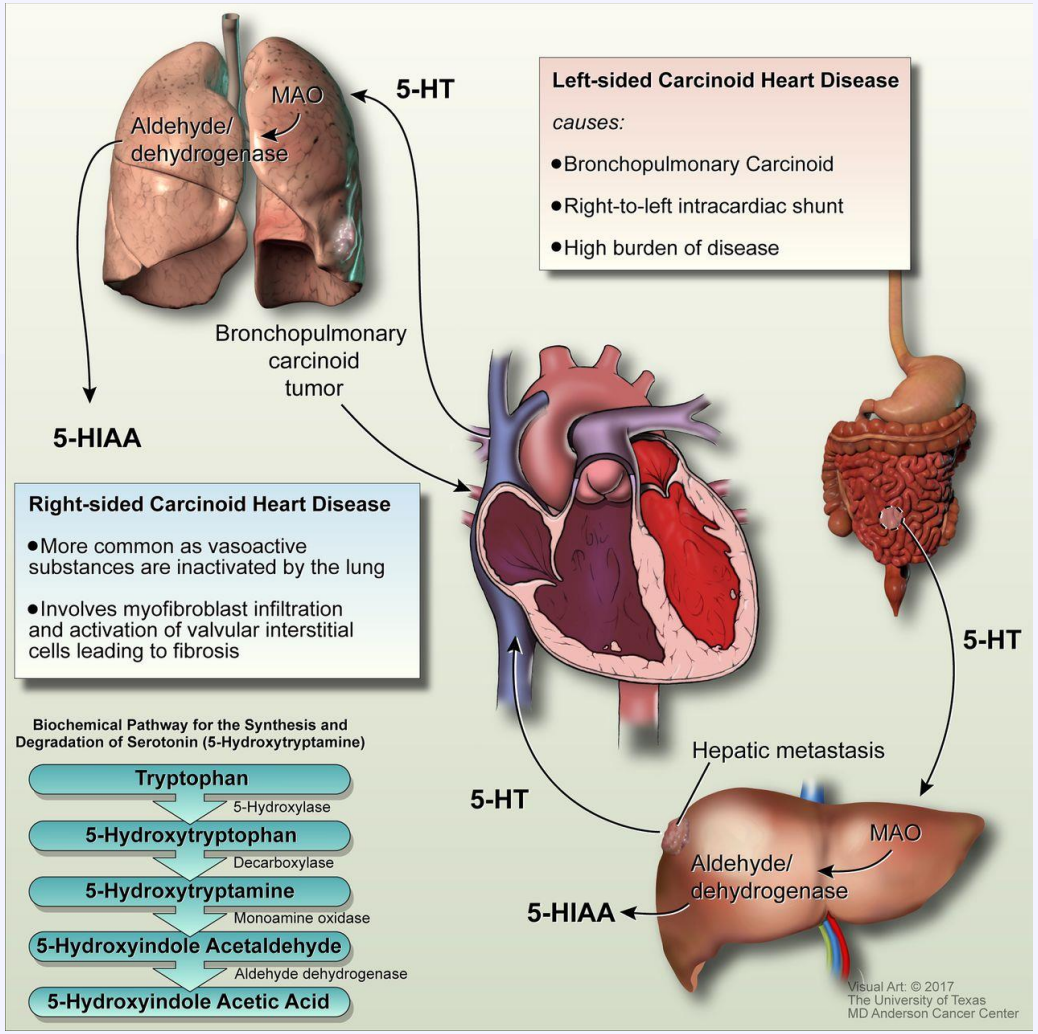


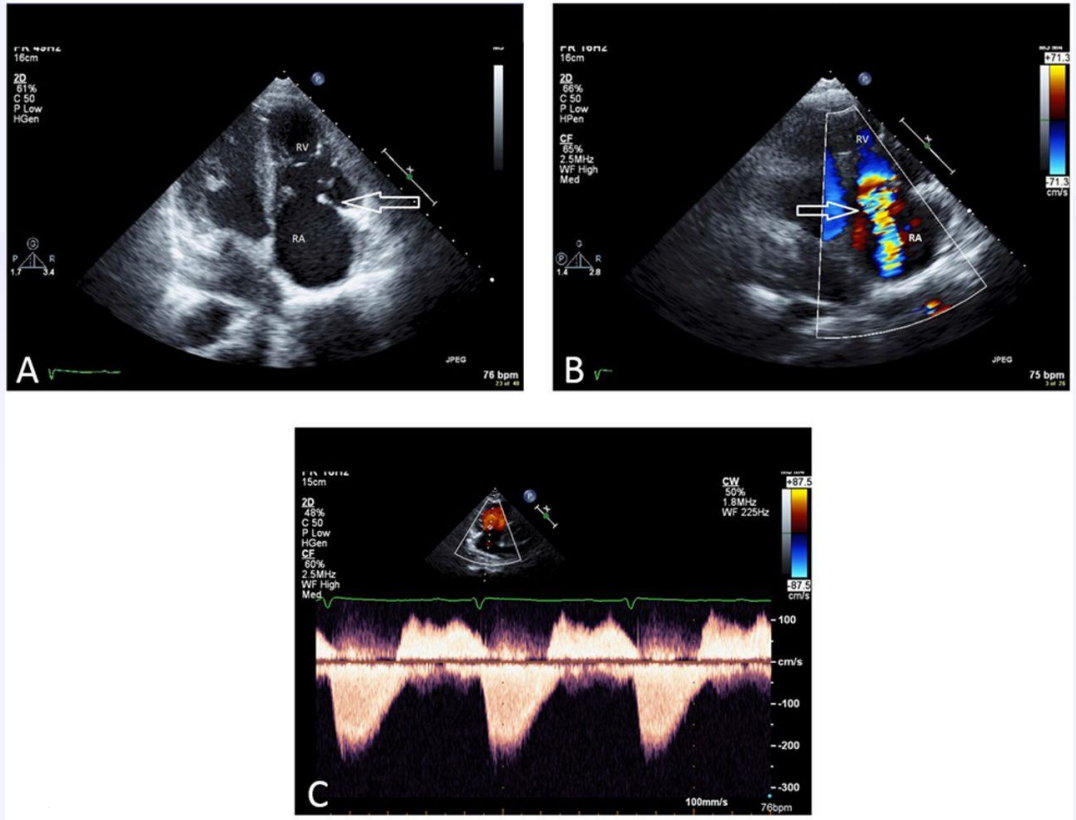
Thickened, restricted tricuspid leaflets



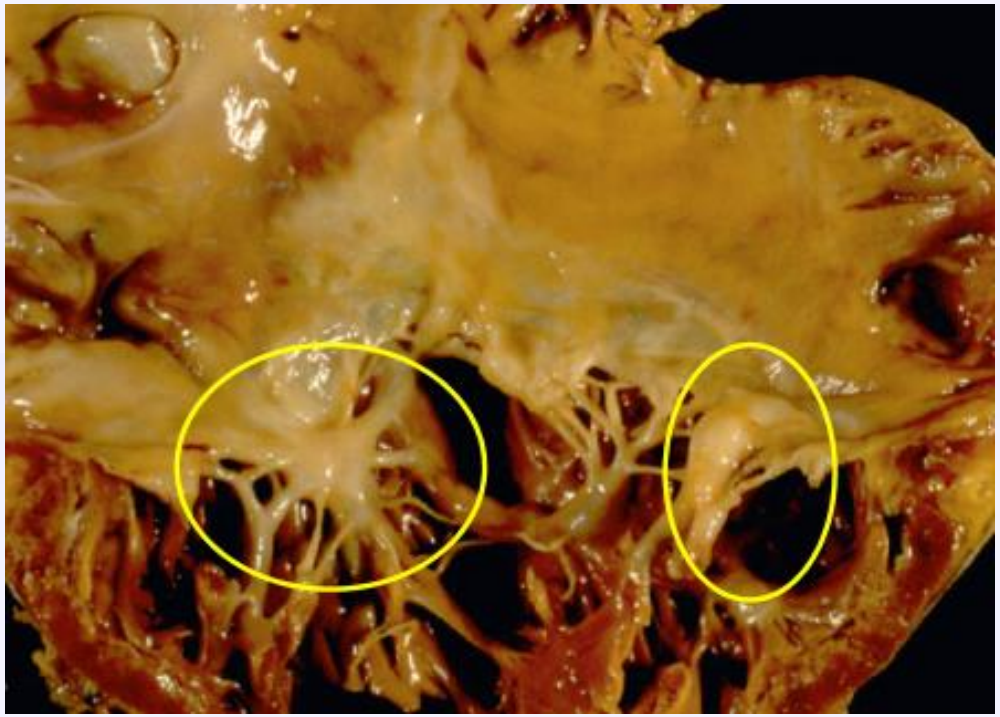
Restricted and regurgitant tricuspid valve with severe TR


Adult Echo
X7-2t
21Hz
14cm
2D
64%
C 50
P Off
Gen
CF
48%
6381Hz
WF 574Hz
4.4MHz
CW
40%
WF 225Hz
2.5MHz
TIS0.3 MI 0.0
M4 M4
+55.3
-55.3
cm/s
Vel 303 cm/s
PG 37 mmHg
300
200
100
cm/s
-100
-200
-300
PAT T: 37.0C
TEE T< 37.0C
75mm/s
87bpm





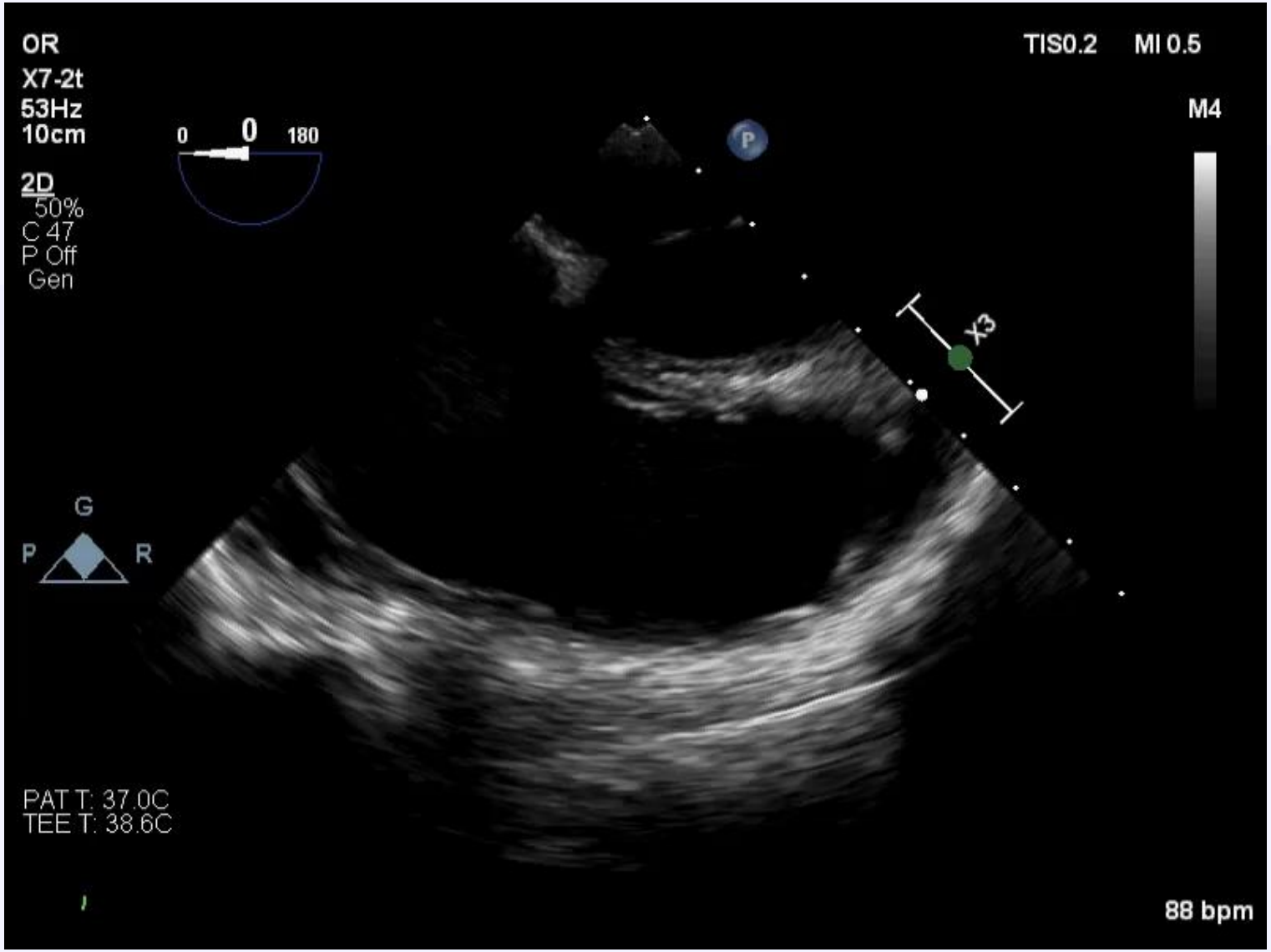
50% of patients with carcinoid tumor develop carcinoid heart disease (TS, TR, PS, PI)



Firm plaque- like endocardial fibrous thickening of the inside surfaces of the cardiac chambers, tricuspid valve, and the pulmonic valve

Case 4

22-year-old female with history of ACHD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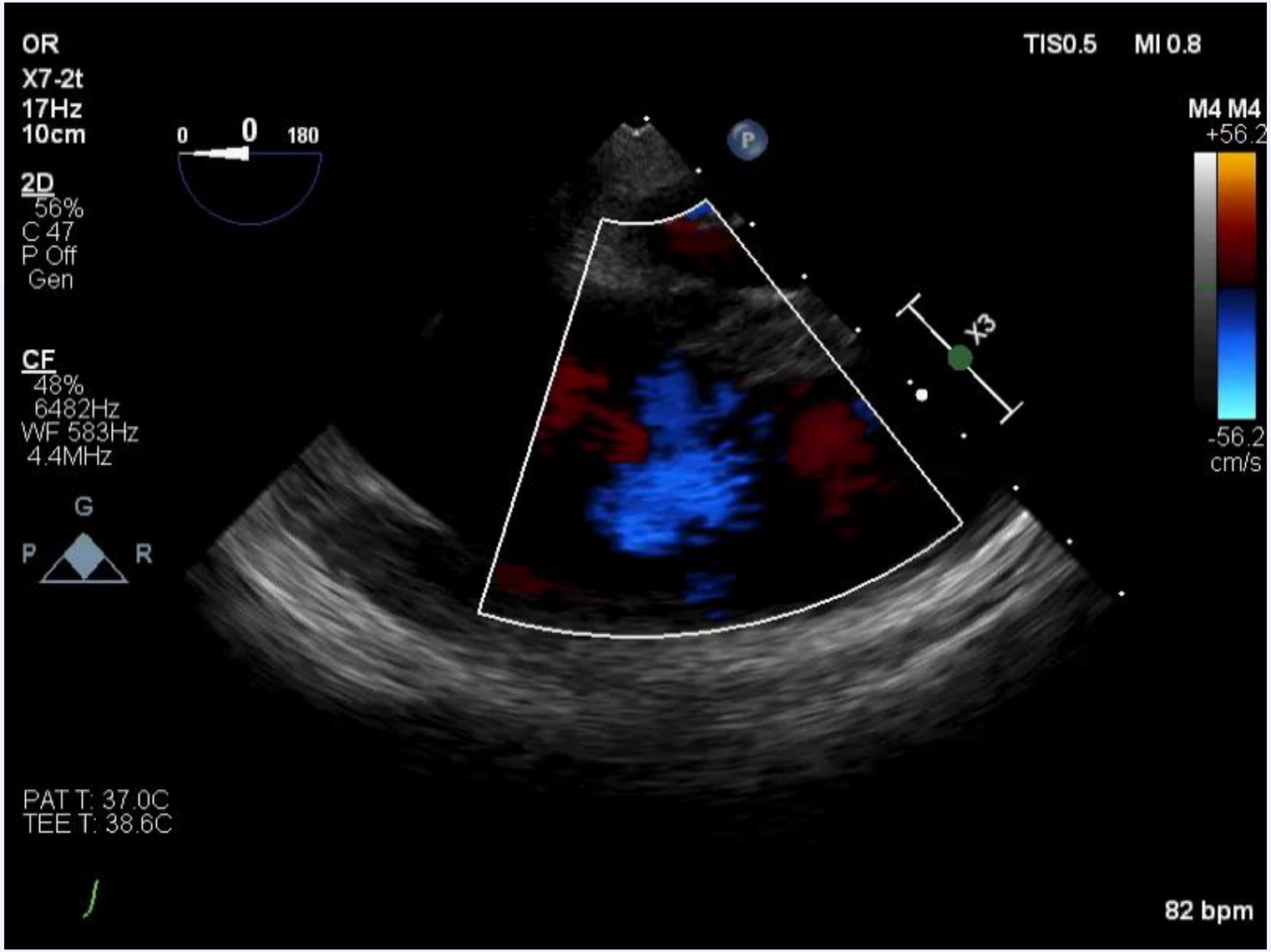
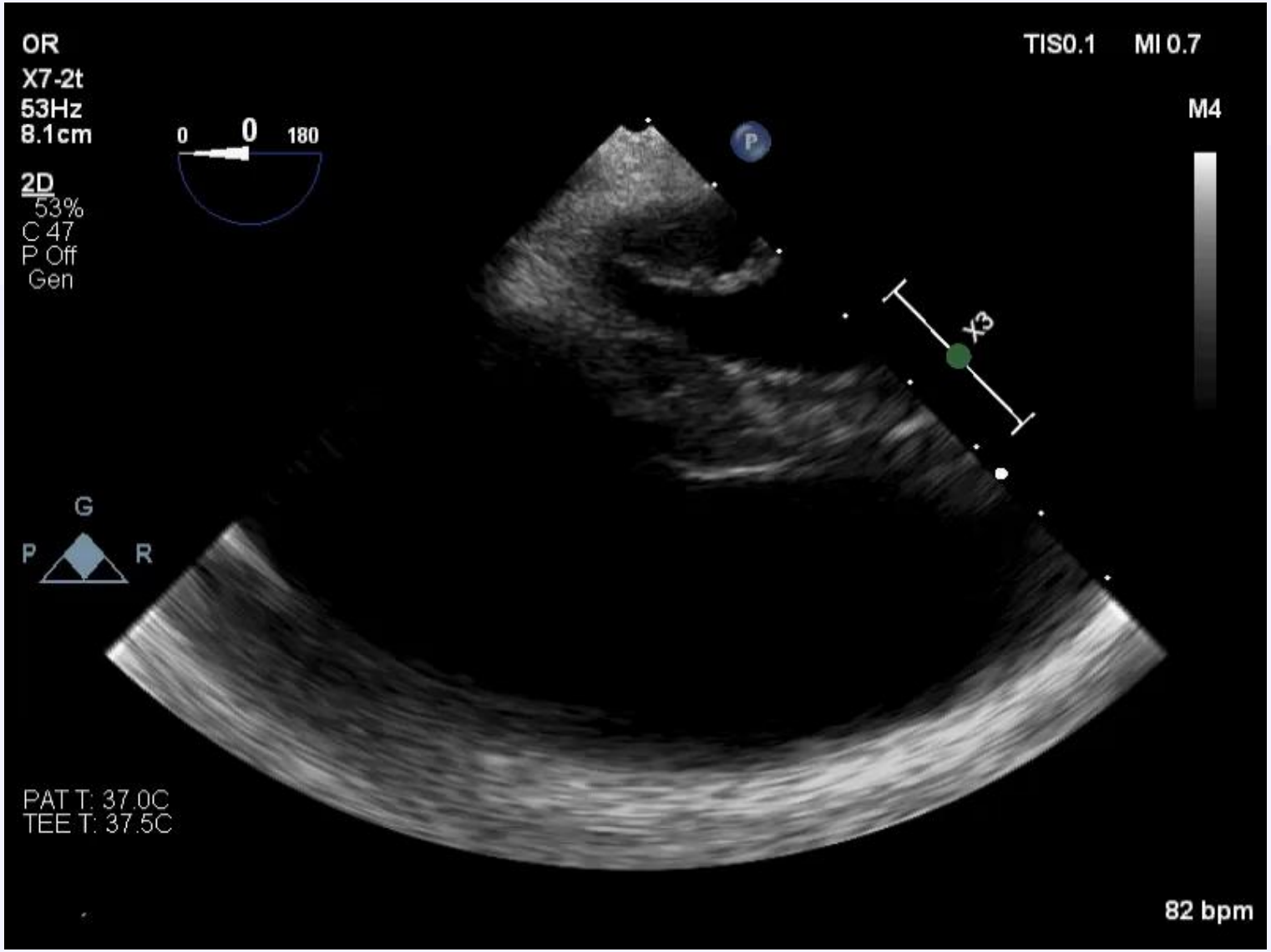
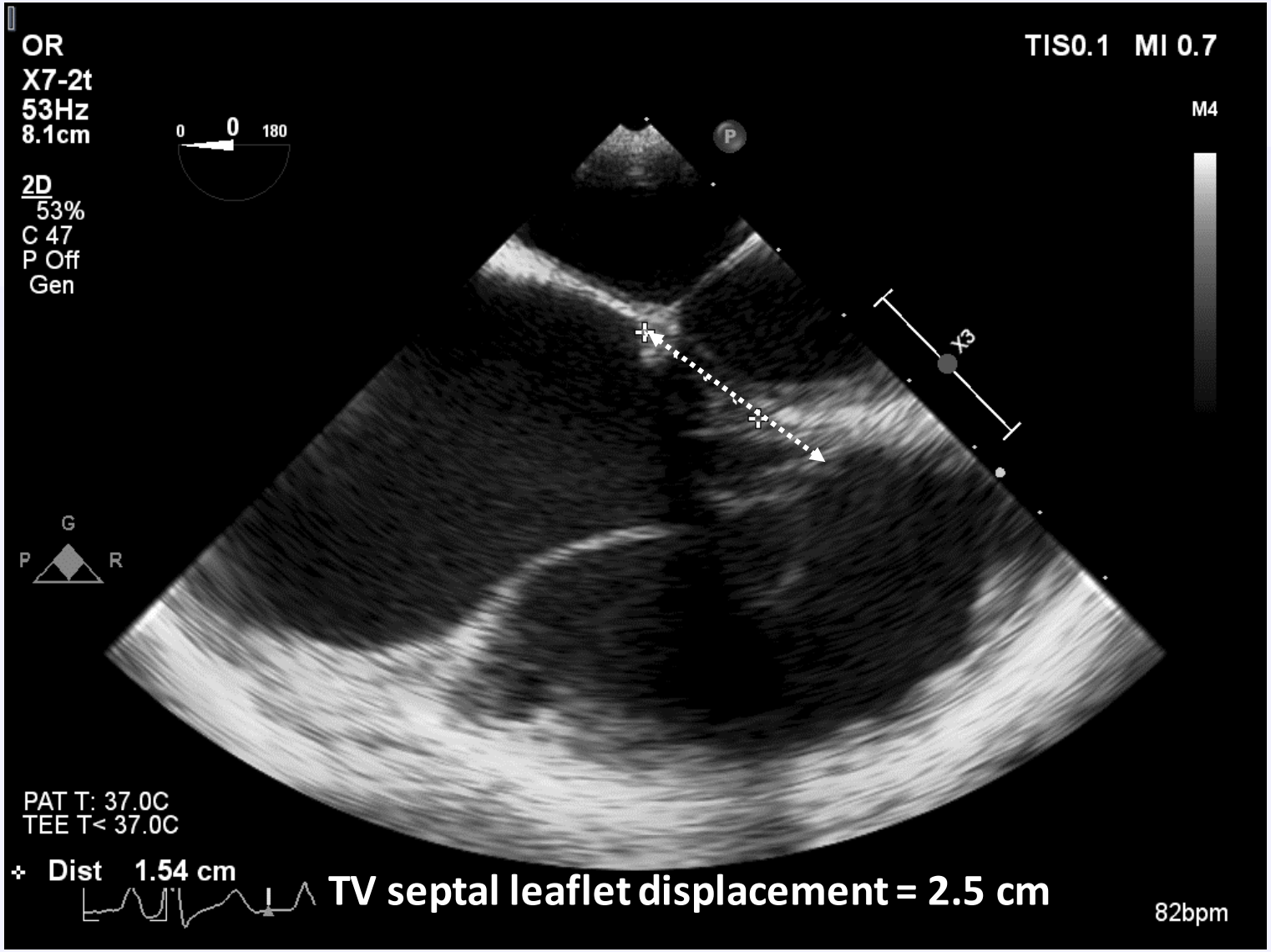
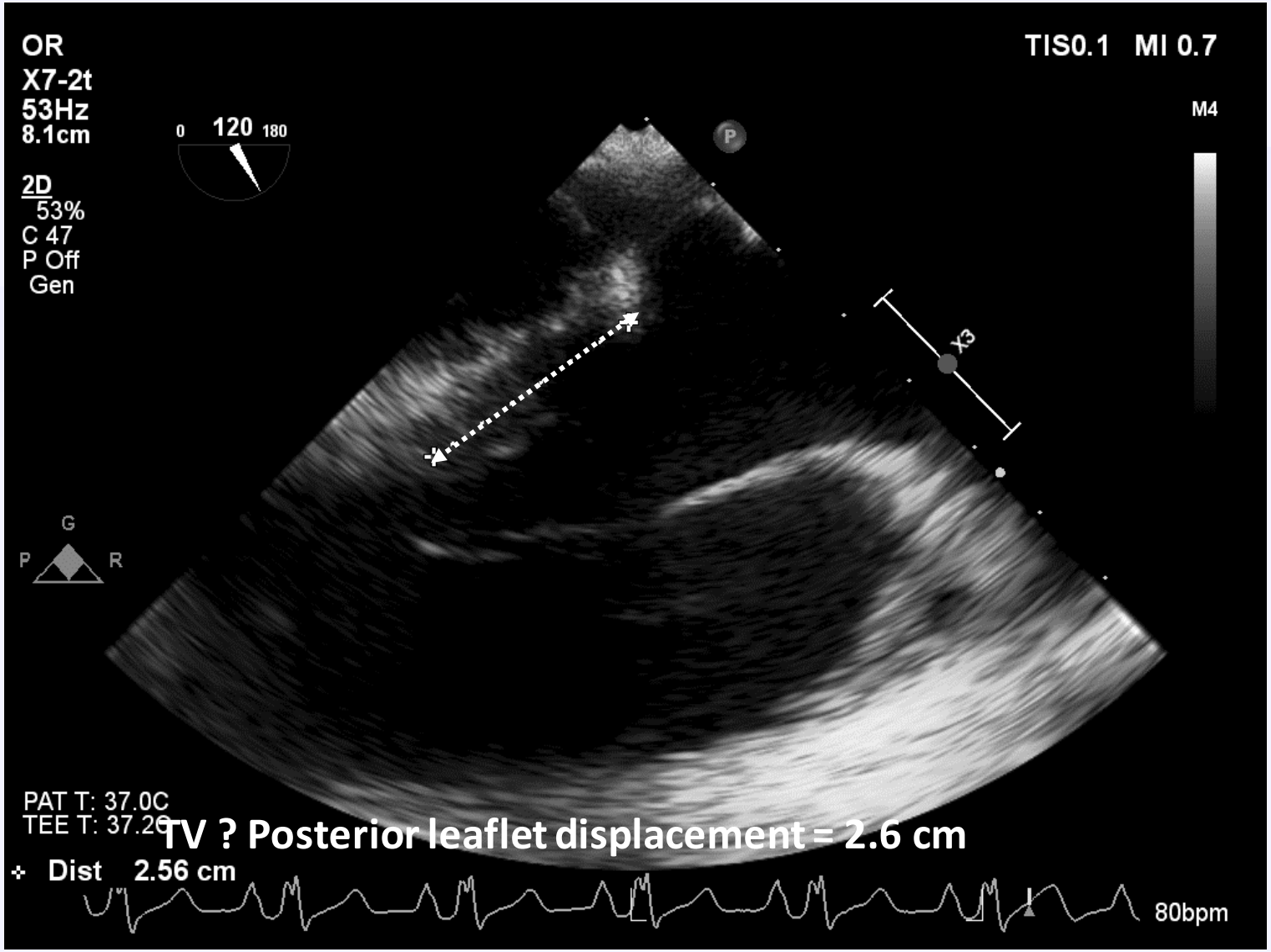
X7-2t
53Hz
10cm
2D
50%
C 47
P Off
Gen
0
0
180
TIS0.2
MI 0.5
M4
P
X3
G
P
R
PAT T: 37.0C
TEE T: 38.6C
88 bpm

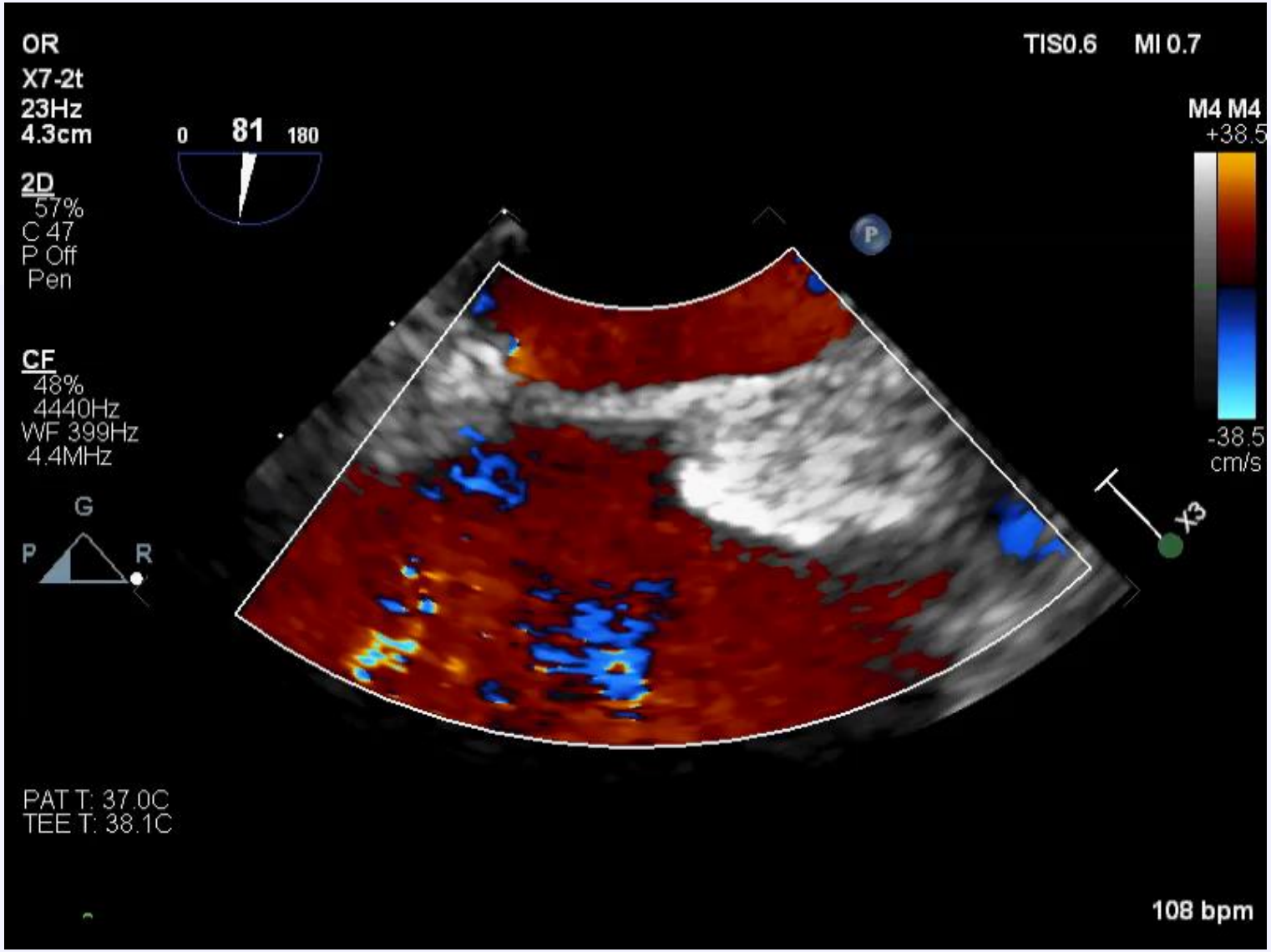

OR
X7-2t
17Hz
10cm
0 0 180
2D
56%
C 47
P Off
Gen
CF
48%
6482Hz
WF 583Hz
4.4MHz
G
P
R
TIS0.5 MI 0.8
M4 M4
+56.2
-56.2
cm/s
X3
PAT T: 37.0C
TEE T: 38.6C
82 bpm

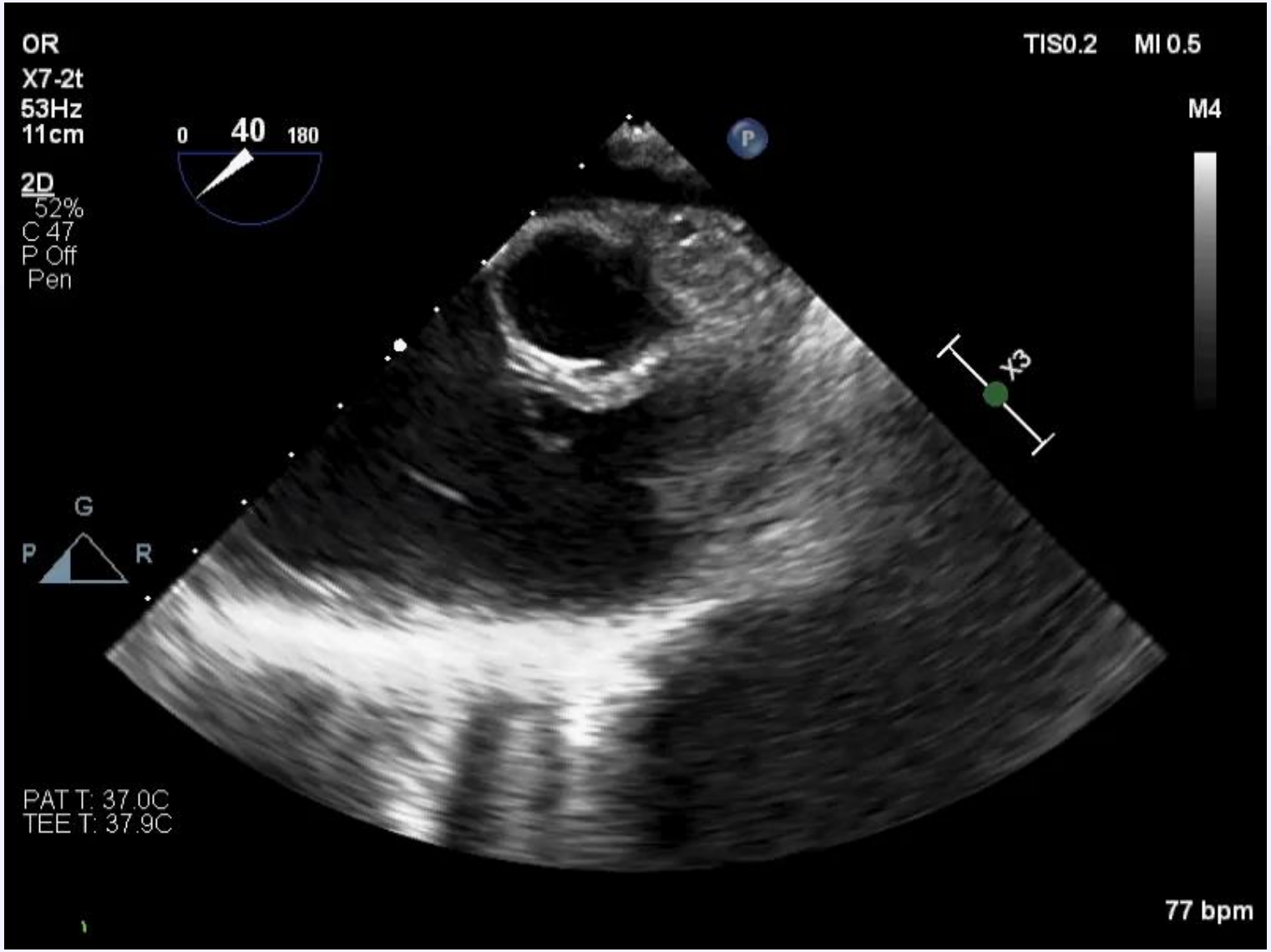

OR
X7-2t
53Hz
8.1cm
2D
53%
C 47
P Off
Gen
0
0
180
TIS0.1
MI 0.7
M4
X3
G
P
R
PAT T: 37.0C
TEE T: 37.5C
82 bpm

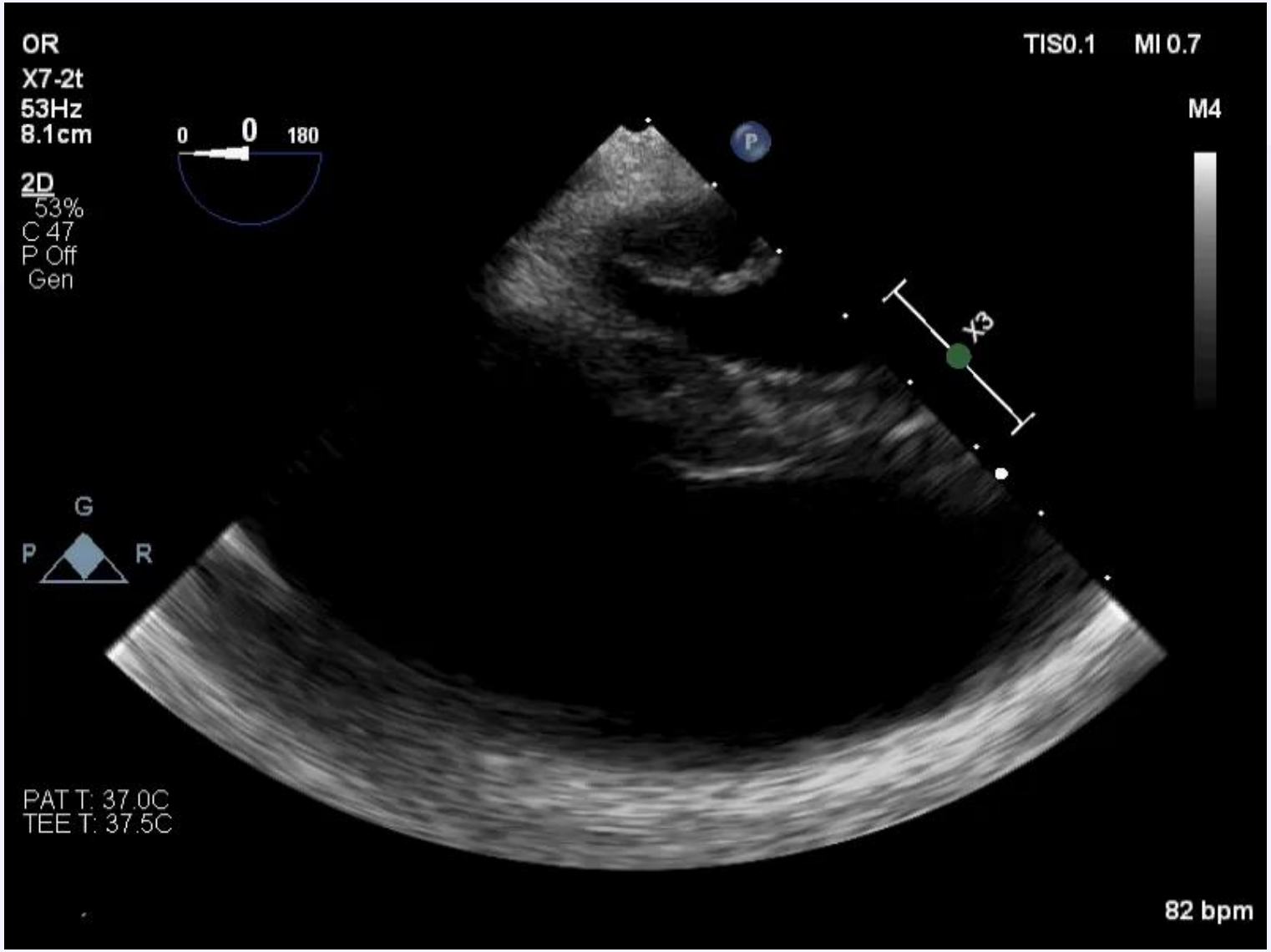

OR
X7-2t
53Hz
8.1cm
2D
53%
C 47
P Off
Gen
TIS0.1 MI 0.7
M4
X3
PAT T: 37.0C
TEE T< 37.0C
Dist 1.54 cm
TV septal leaflet displacement = 2.5 cm
82bpm

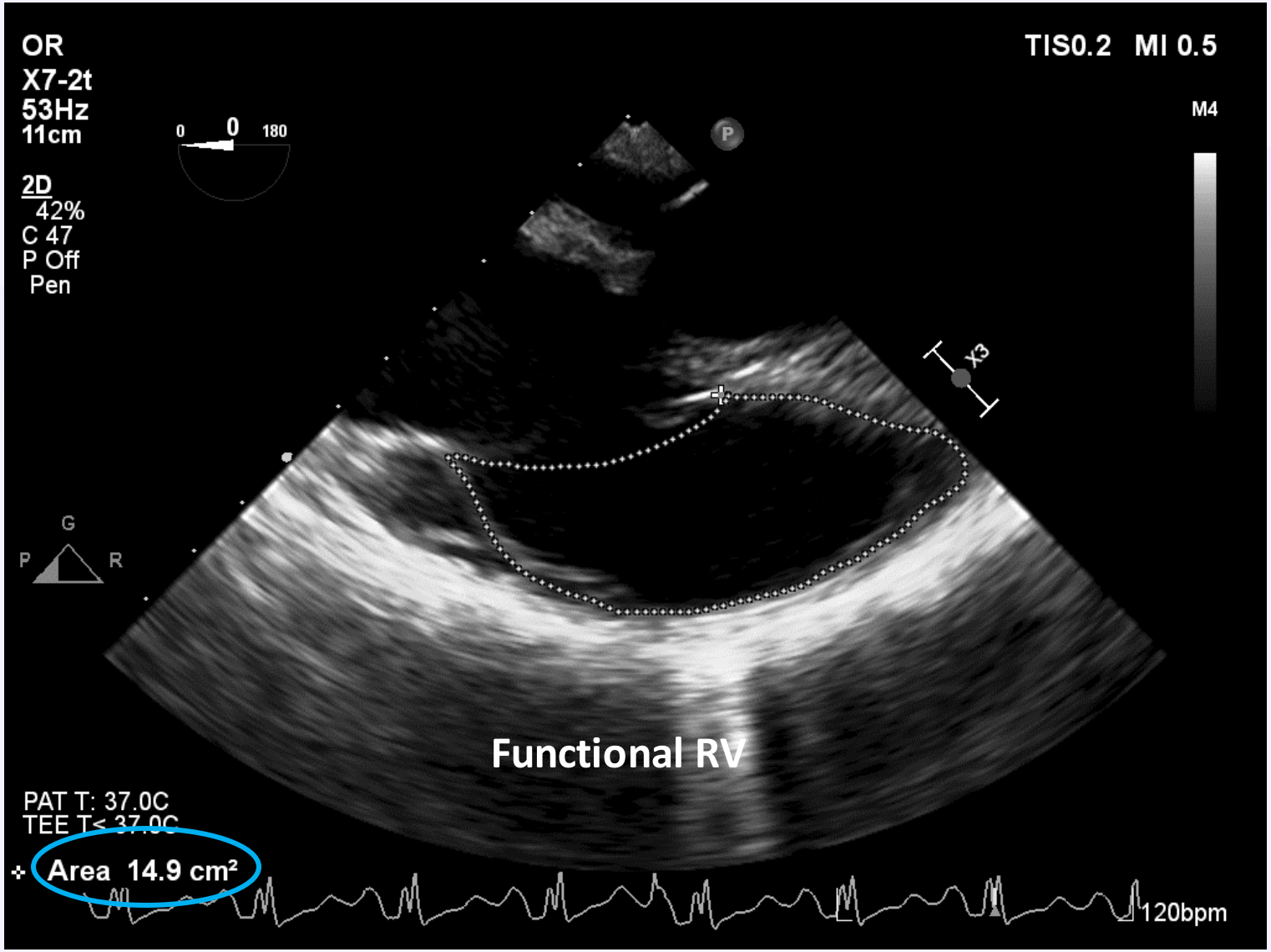


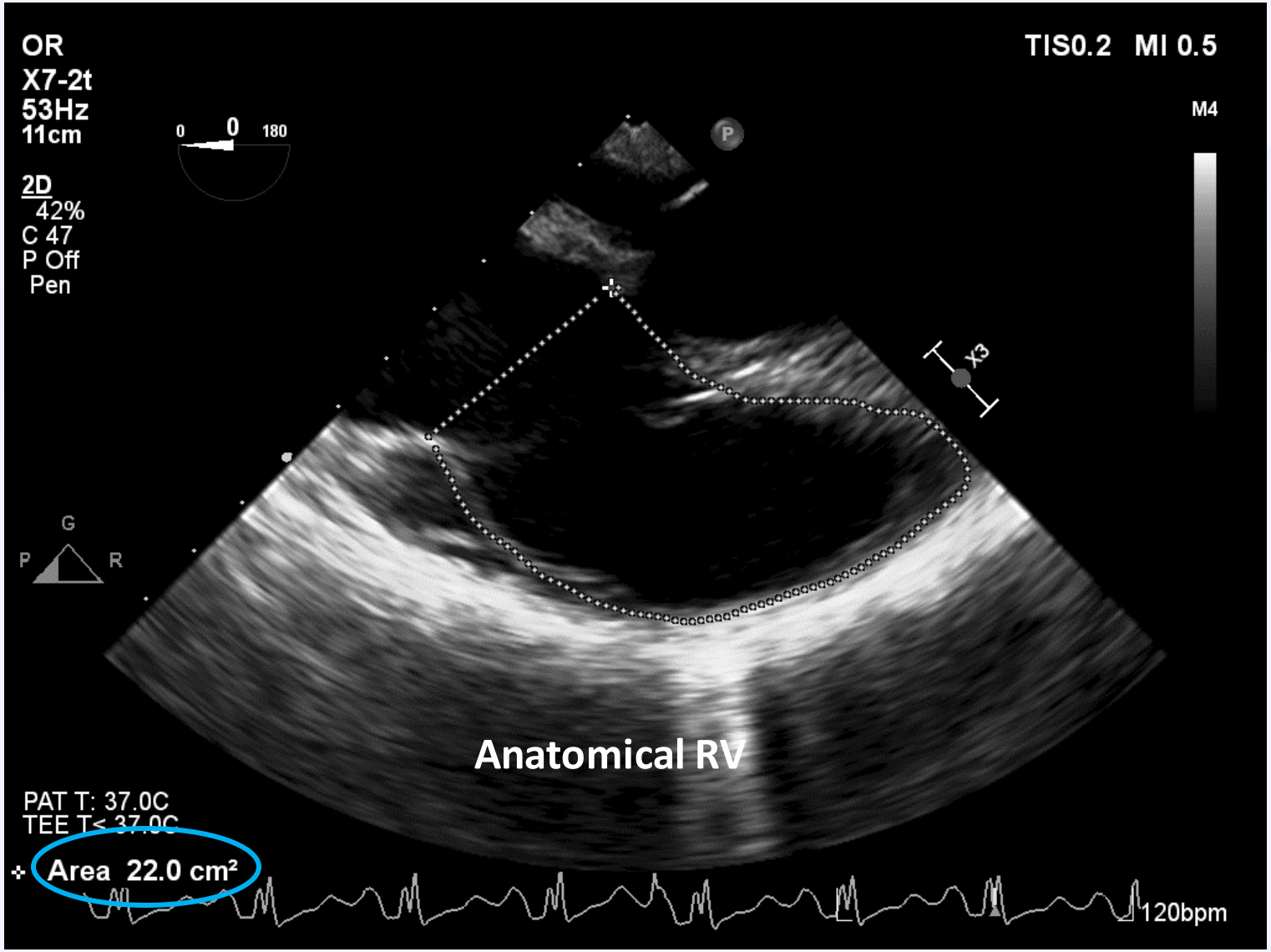
TV ? Posterior leaflet displacement = 2.6 cm

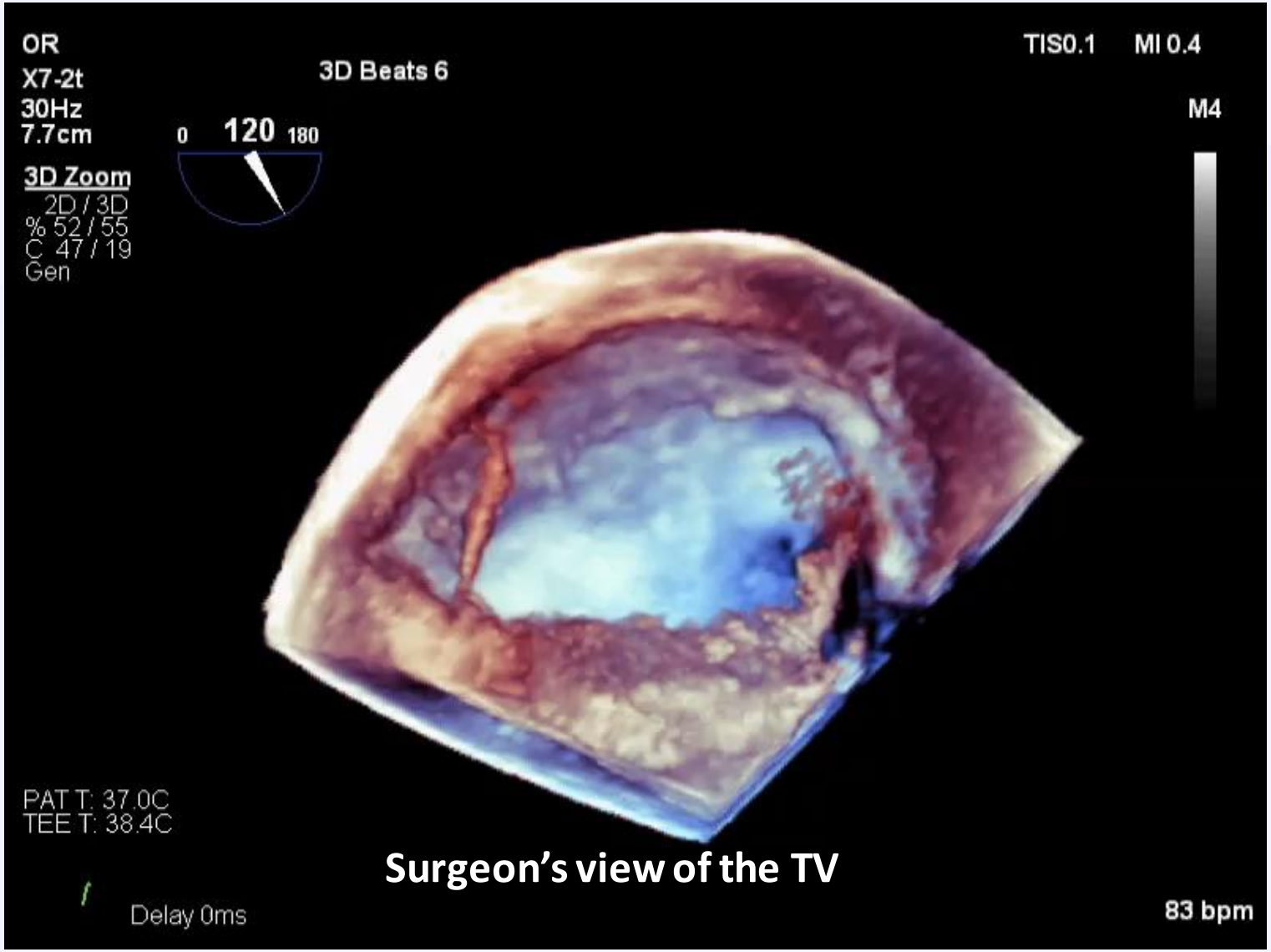

OR
X7-2t
23Hz
4.3cm
0
81
180
2D
57%
C 47
P Off
Pen
CF
48%
4440Hz
WF 399Hz
4.4MHz
G
P
R
TIS0.6
MI 0.7
M4 M4
+38.5
-38.5
cm/s
X3
PAT T: 37.0C
TEE T: 38.1C
108 bpm


OR
X7-2t
53Hz
11cm
2D
52%
C 47
P Off
Pen
0
40
180
TIS0.2
MI 0.5
M4
X3
G
P
R
PAT T: 37.0C
TEE T: 37.9C
77 bpm

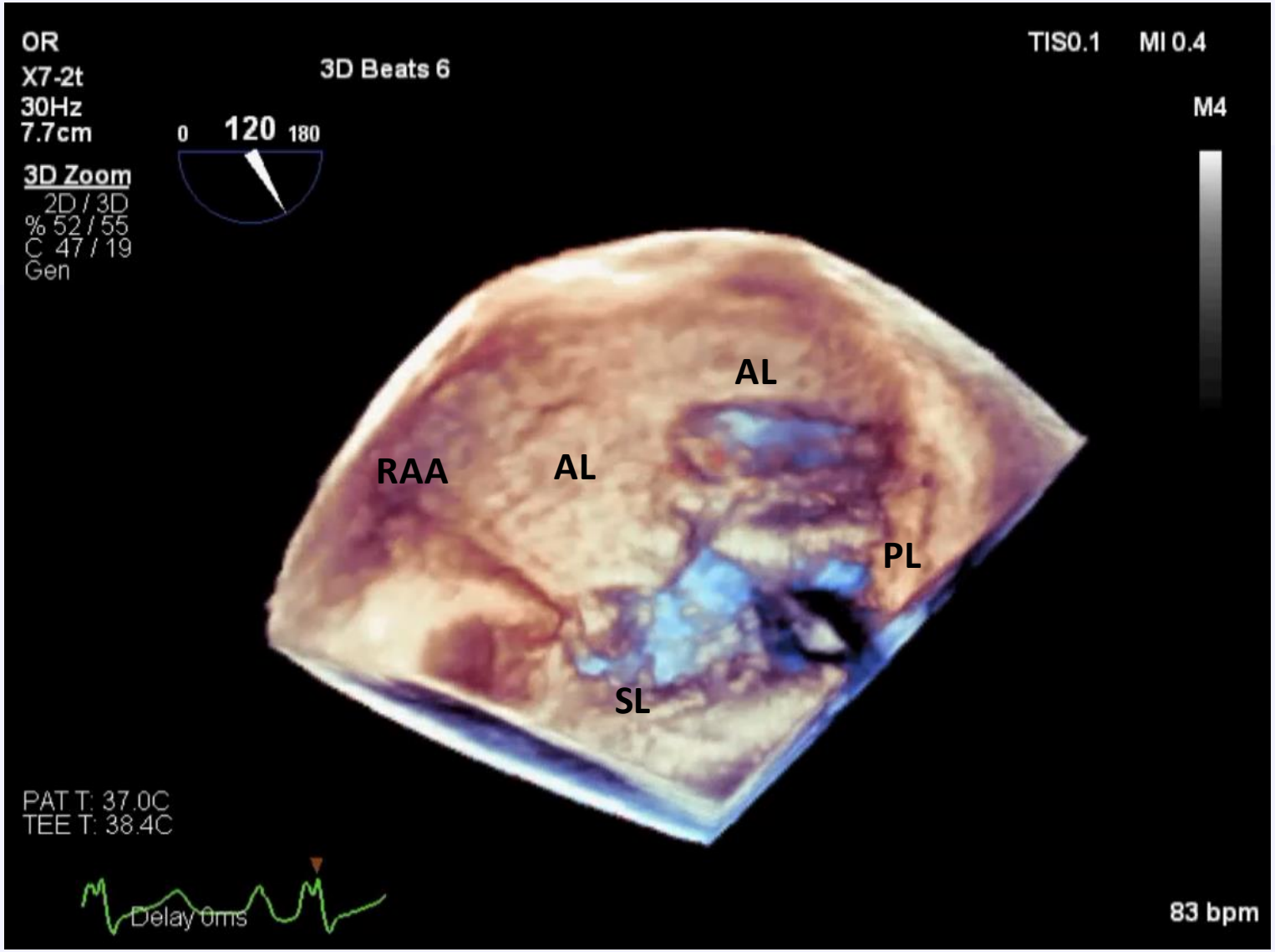

OR
X7-2t
53Hz
8.1cm
2D
53%
C 47
P Off
Gen
0
0
180
TIS0.1
MI 0.7
M4
X3
G
P
R
PAT T: 37.0C
TEE T: 37.5C
82 bpm

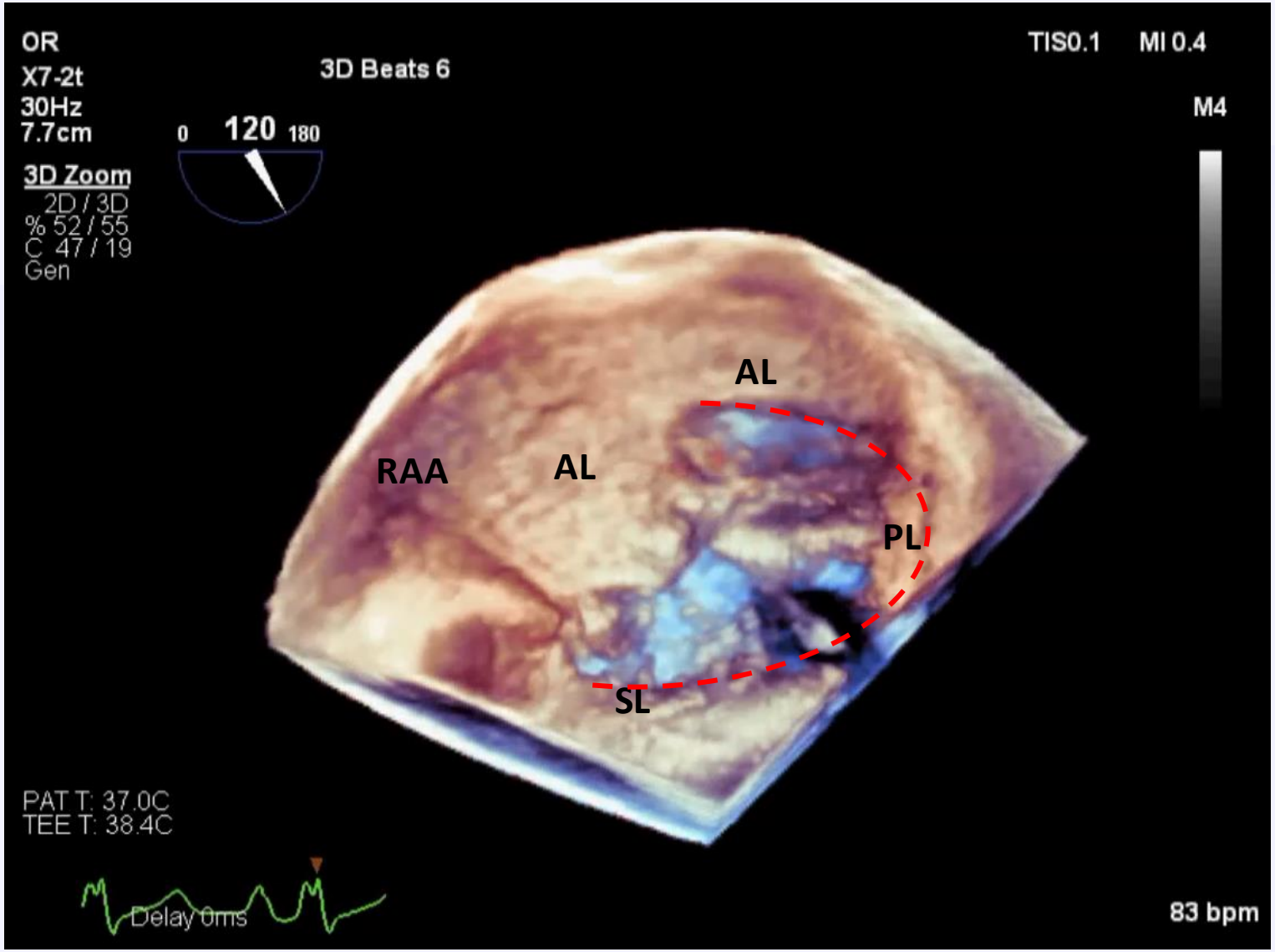

OR
X7-2t
53Hz
11cm
2D
42%
C 47
P Off
Pen
TIS0.2 MI 0.5
M4
Functional RV
PAT T: 37.0C
Area 14.9 cm²
120bpm


OR
X7-2t
53Hz
11cm
2D
42%
C 47
P Off
Pen
TIS0.2 MI 0.5
M4
Anatomical RV
PAT T: 37.0C
Area 22.0 cm²
120bpm

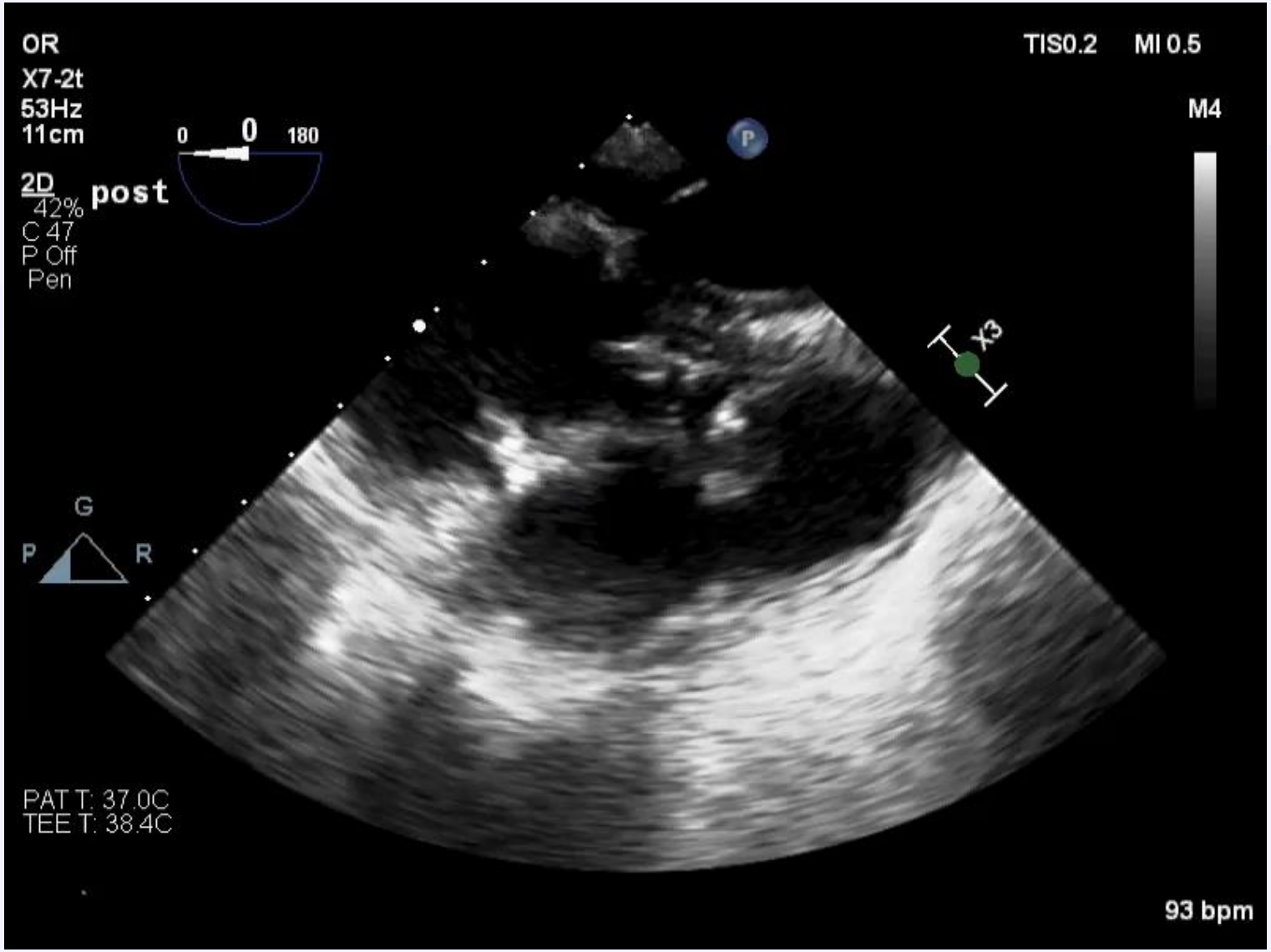


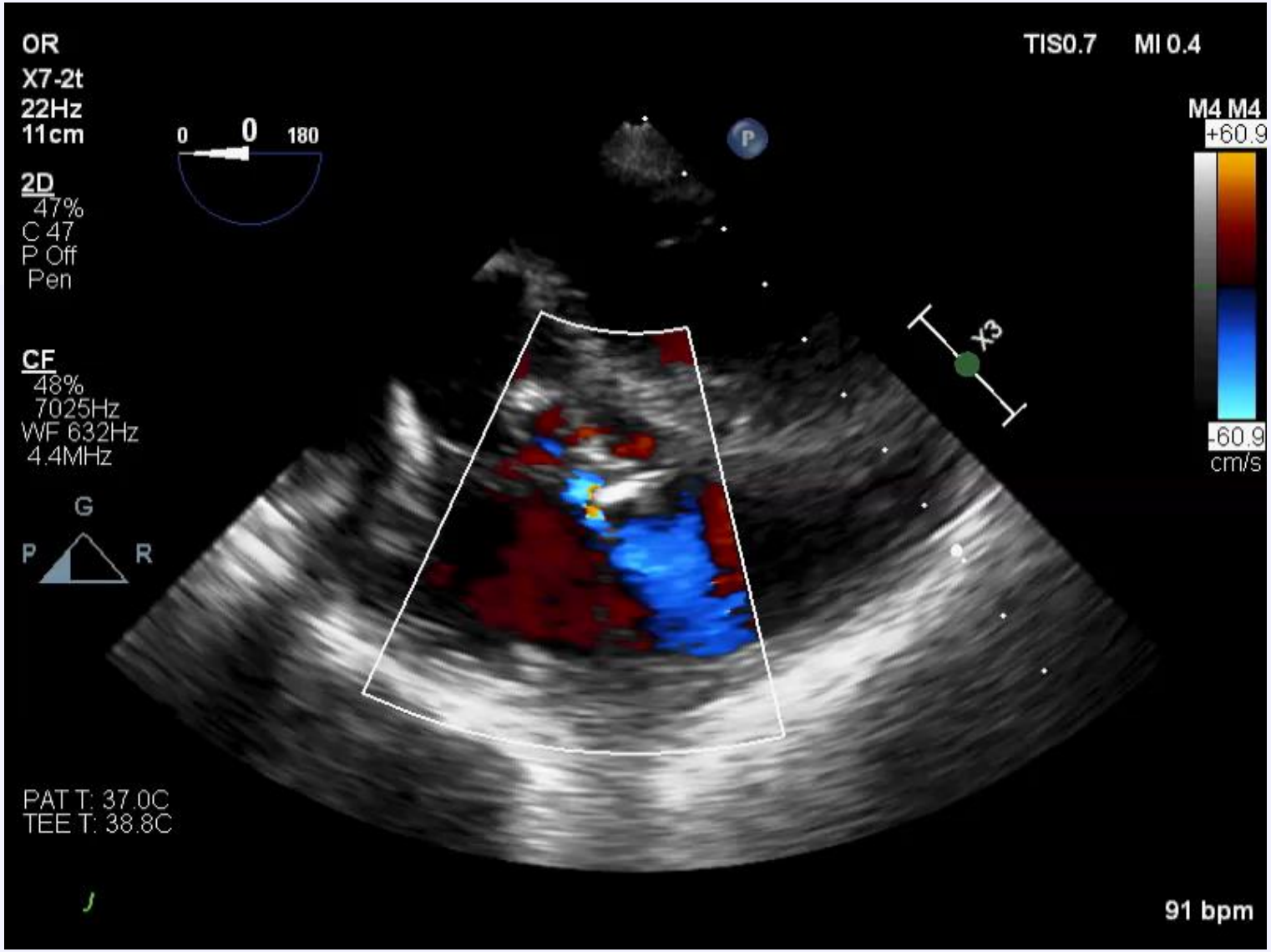
Surgeon's view of the TV

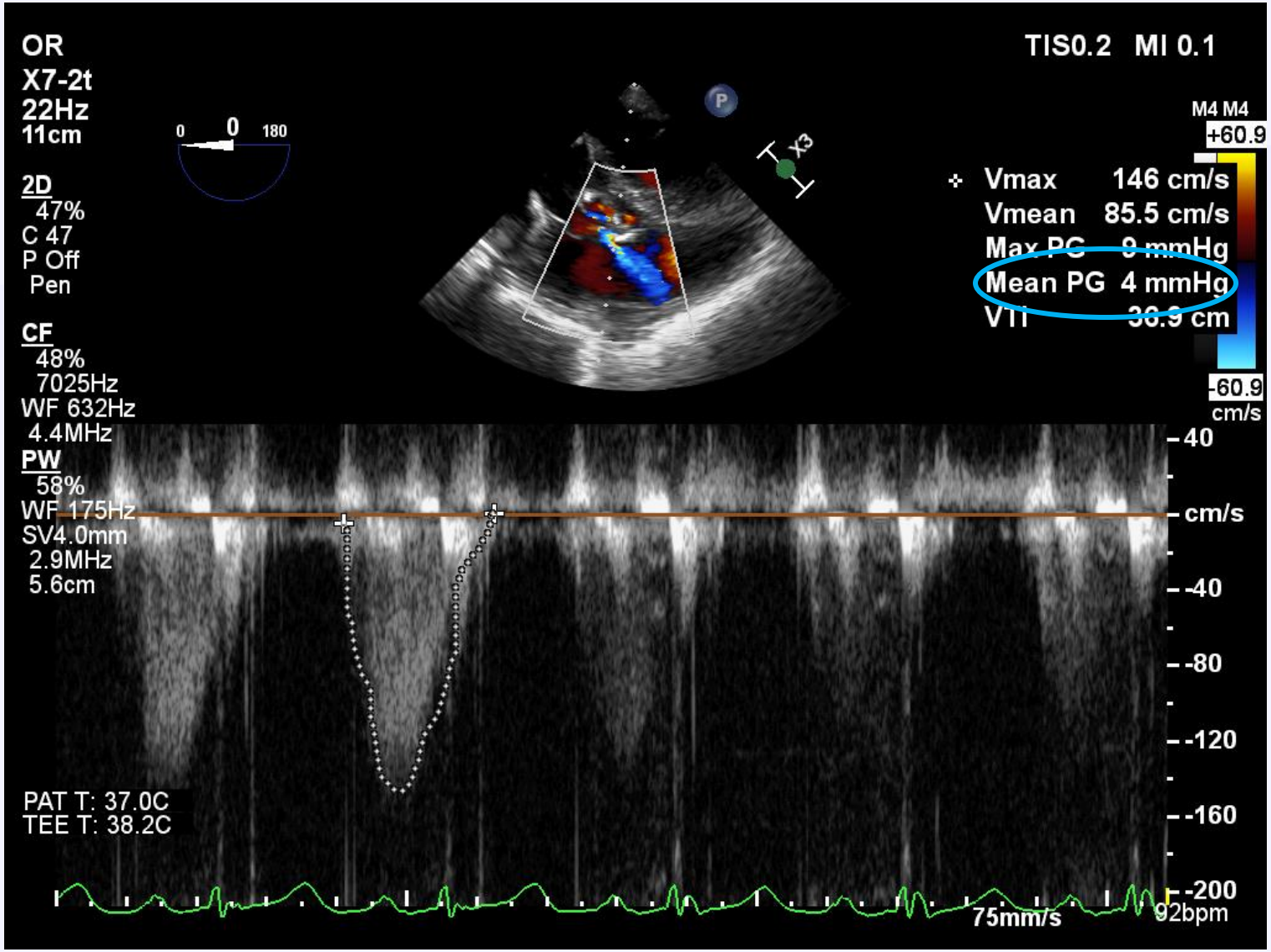

OR
X7-2t
30Hz
7.7cm
3D Zoom
2D / 3D
% 52 / 55
C 47 / 19
Gen
3D Beats 6
0
120
180
TIS0.1
MI 0.4
M4
AL
RAA
AL
PL
SL
PAT T: 37.0C
TEE T: 38.4C
Delay 0ms
83 bpm

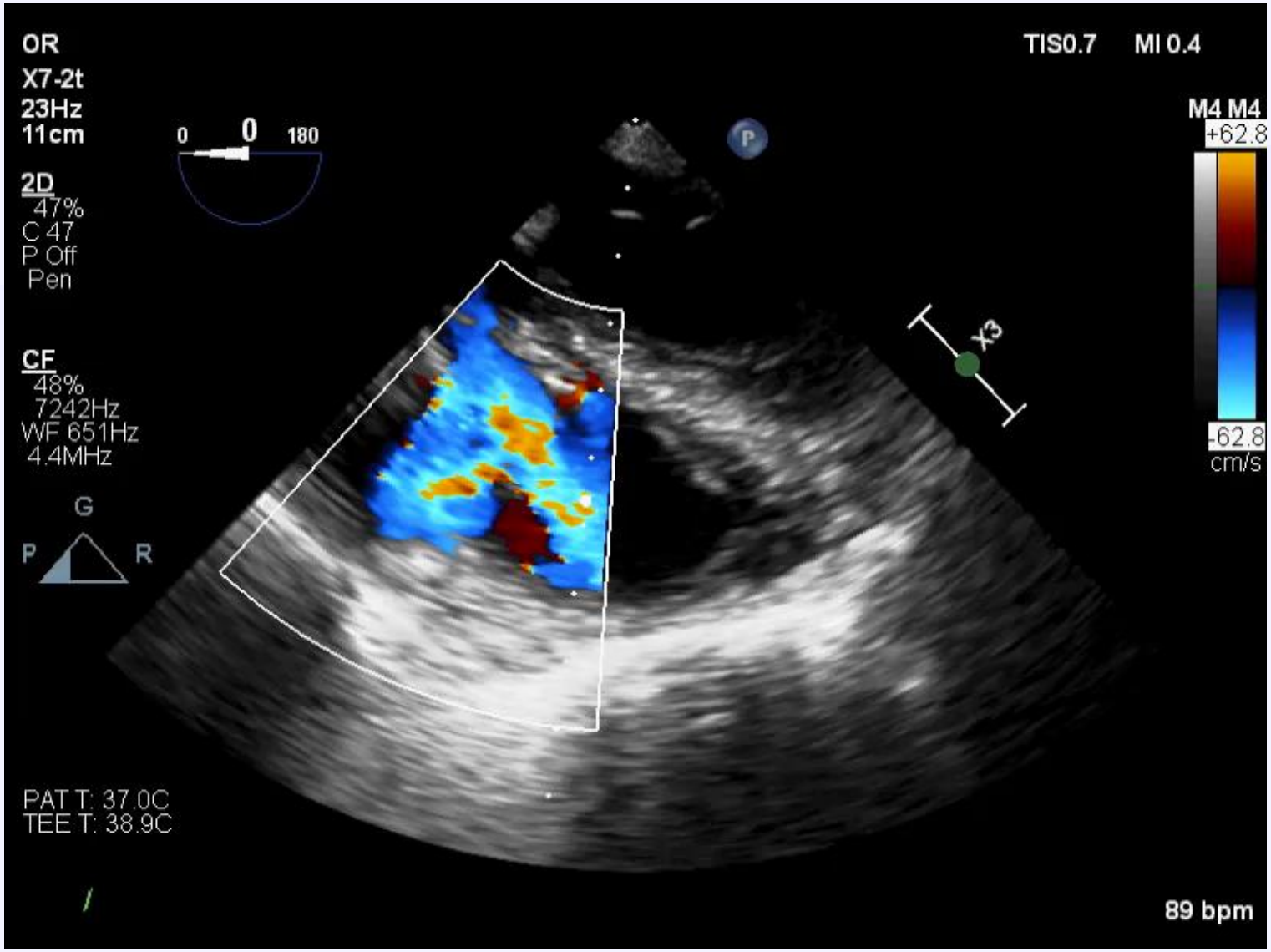

OR
X7-2t
30Hz
7.7cm
3D Zoom
2D / 3D
% 52 / 55
C 47 / 19
Gen
3D Beats 6
0
120
180
TIS0.1
MI 0.4
M4
AL
RAA
AL
PL
SL
PAT T: 37.0C
TEE T: 38.4C
Delay 0ms
83 bpm

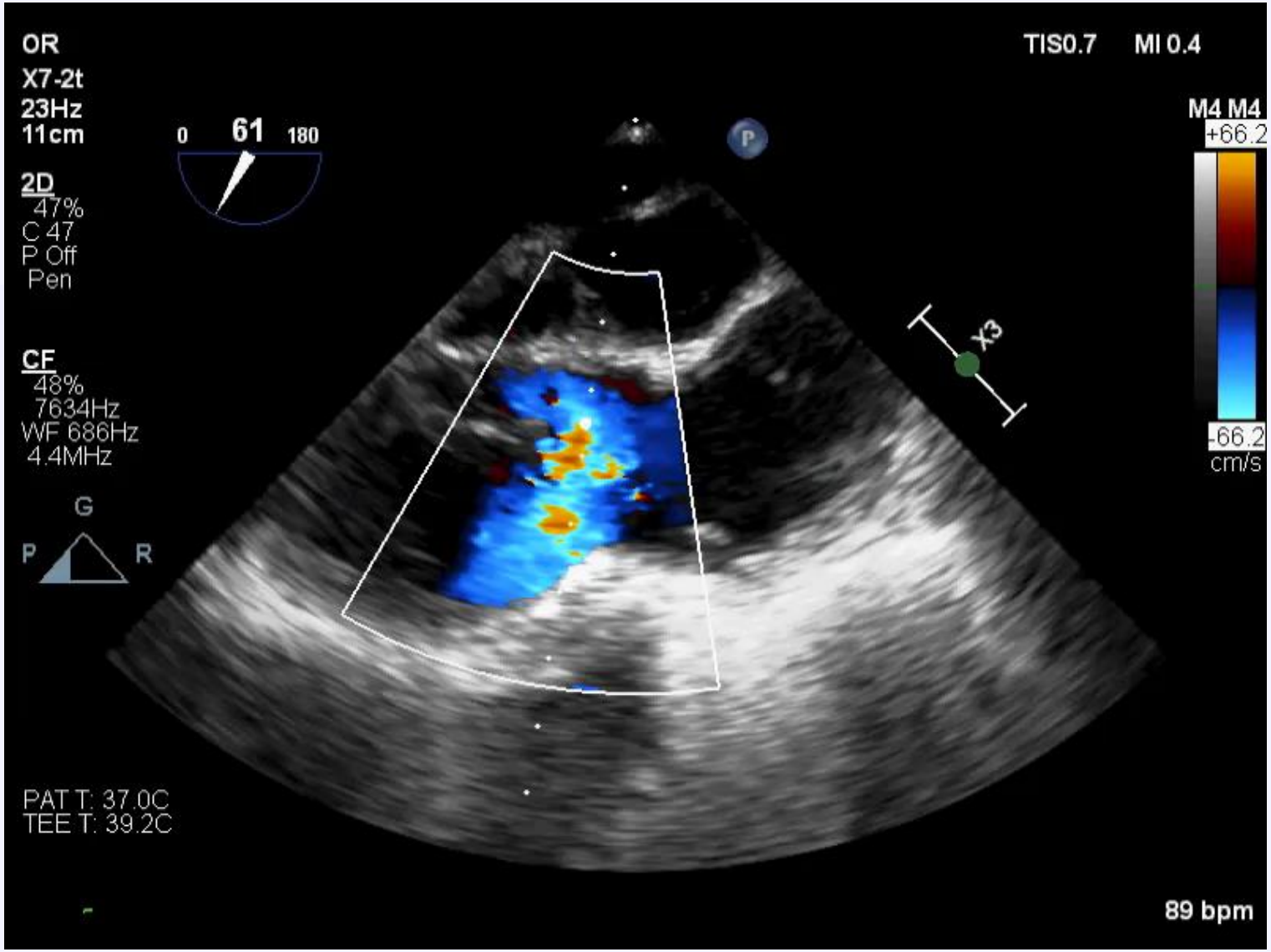
Patient underwent TV repair

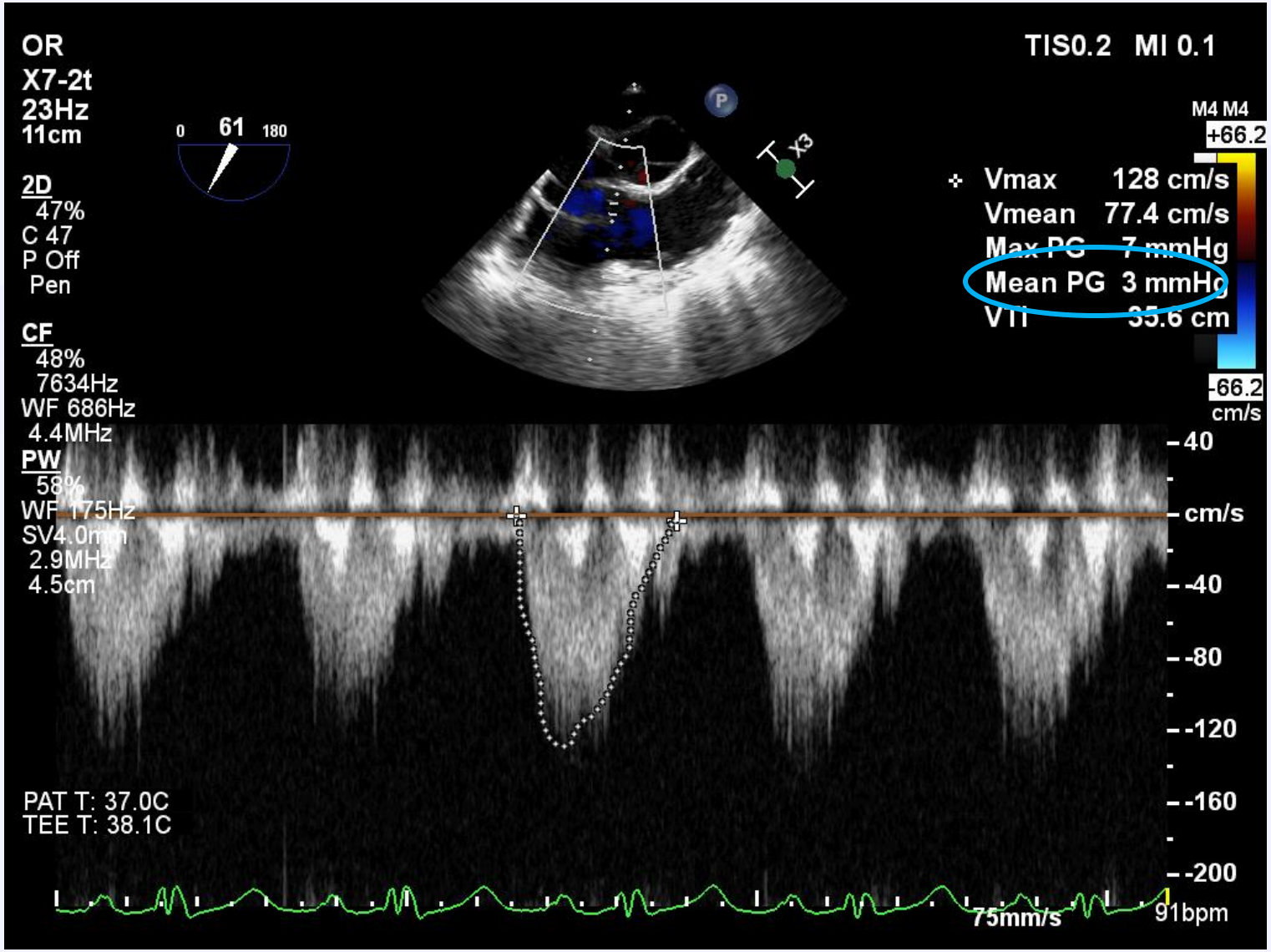

OR
X7-2t
53Hz
11cm
0
0
180
2D
42%
post
C 47
P Off
Pen
TIS0.2
MI 0.5
M4
X3
G
P
R
PAT T: 37.0C
TEE T: 38.4C
93 bpm


OR
X7-2t
22Hz
11cm
0 0 180
2D
47%
C 47
P Off
Pen
CF
48%
7025Hz
WF 632Hz
4.4MHz
G
P R
TIS0.7 MI 0.4
M4 M4
+60.9
-60.9
cm/s
X3
PAT T: 37.0C
TEE T: 38.8C
91 bpm

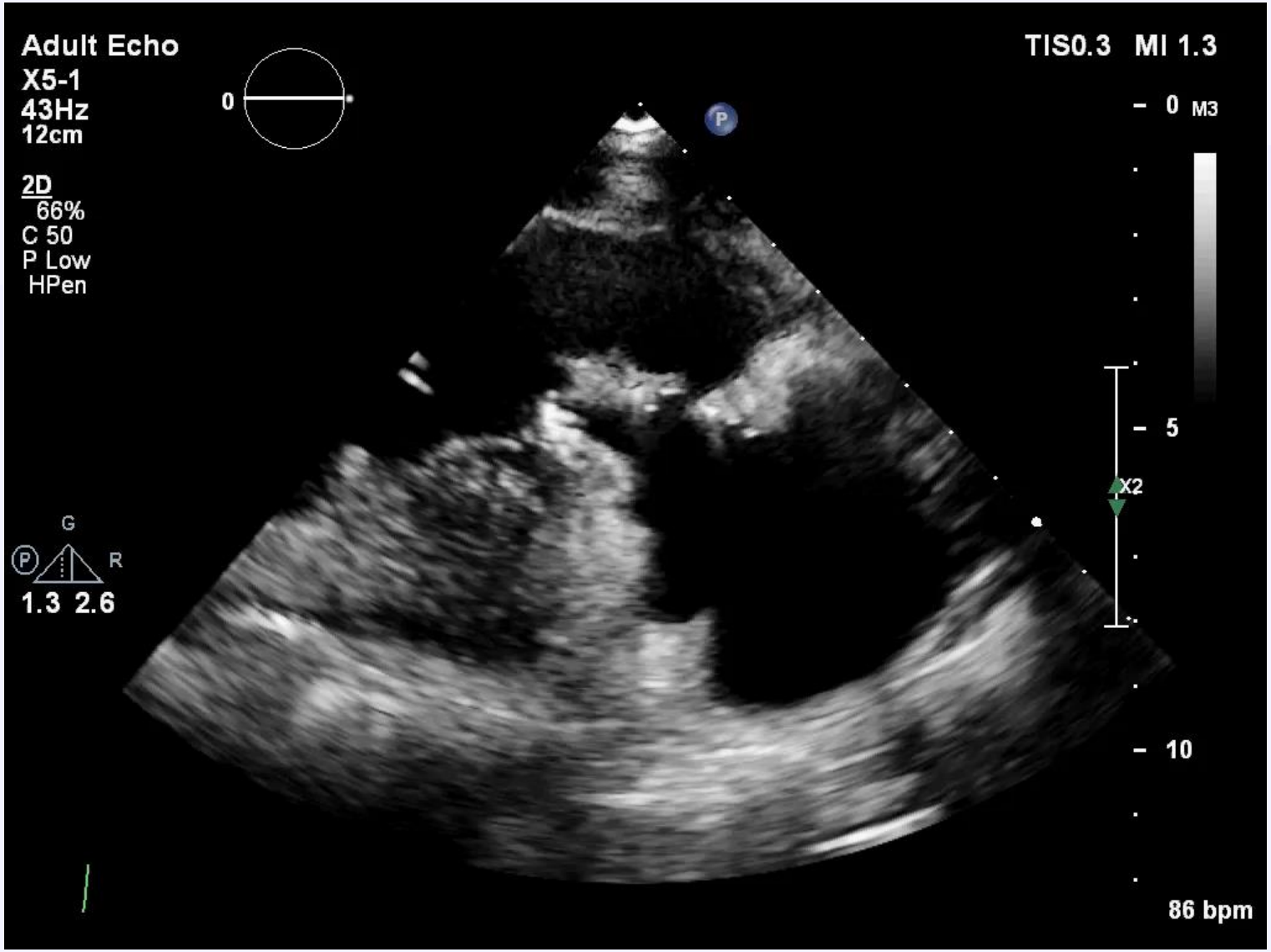

OR
X7-2t
22Hz
11cm
2D
47%
C 47
P Off
Pen
CF
48%
7025Hz
WF 632Hz
4.4MHz
PW
58%
WF 175Hz
SV4.0mm
2.9MHz
5.6cm
TIS0.2 MI 0.1
M4 M4
+60.9
-60.9
cm/s
Vmax 146 cm/s
Vmean 85.5 cm/s
Max PG 9 mmHg
Mean PG 4 mmHg
VTI 36.9 cm
40
cm/s
-40
-80
-120
-160
-200
PAT T: 37.0C
TEE T: 38.2C
75mm/s
92bpm

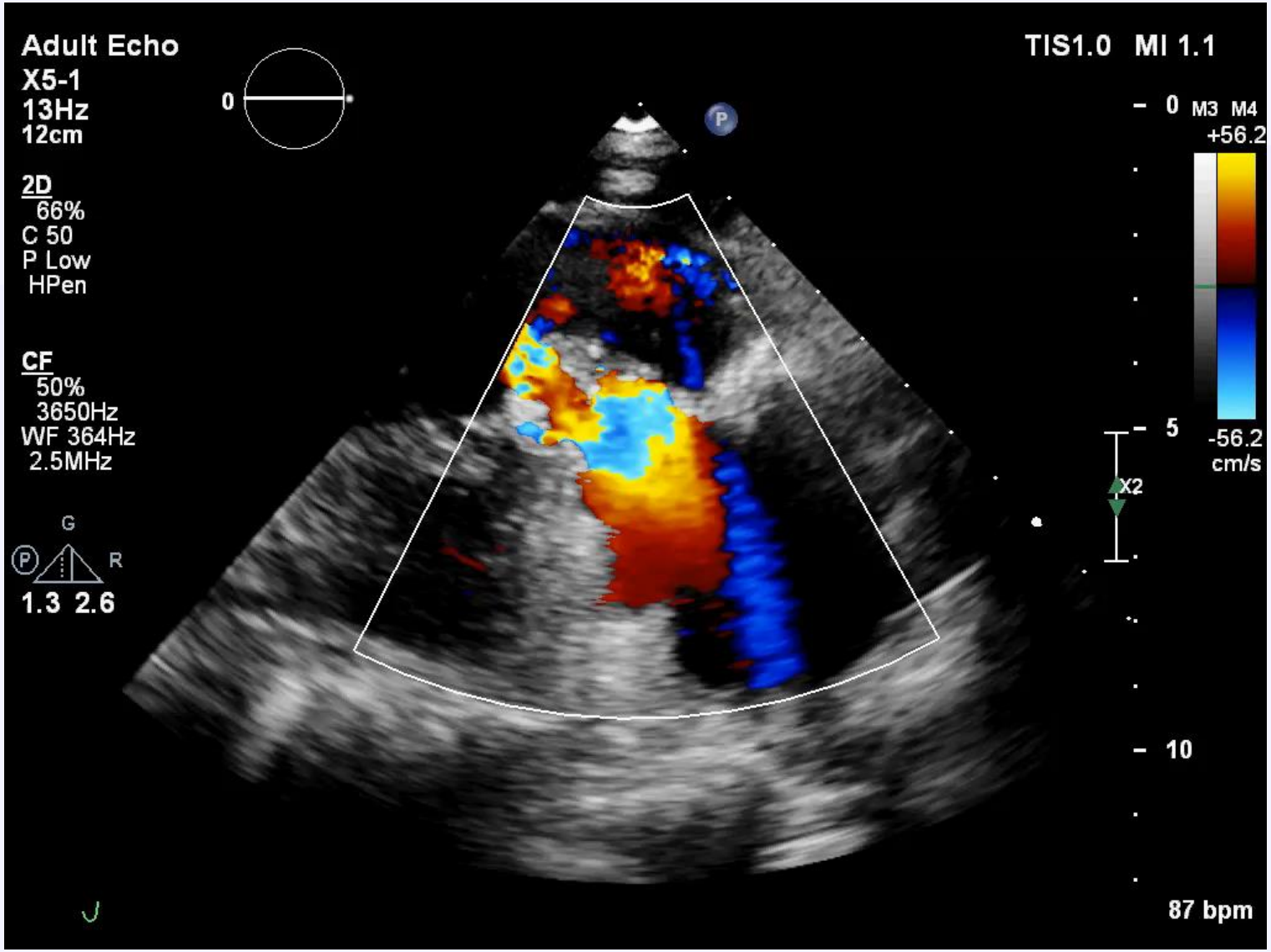

OR
X7-2t
23Hz
11cm
0 0 180
2D
47%
C 47
P Off
Pen
CF
48%
7242Hz
WF 651Hz
4.4MHz
G
P
R
TIS0.7 MI 0.4
M4 M4
+62.8
-62.8
cm/s
X3
PAT T: 37.0C
TEE T: 38.9C
89 bpm

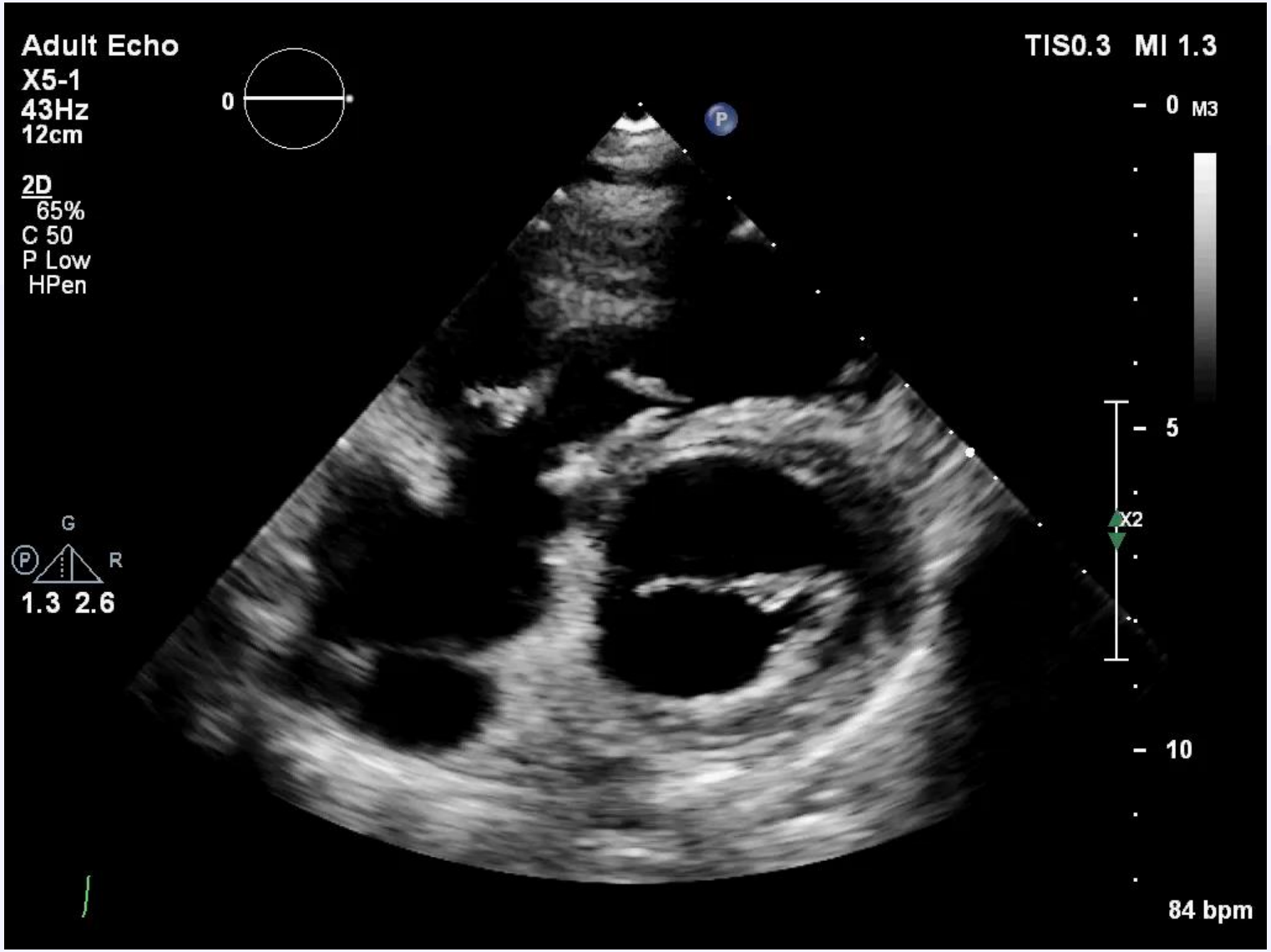

OR
X7-2t
23Hz
11cm
0
61
180
2D
47%
C 47
P Off
Pen
CF
48%
7634Hz
WF 686Hz
4.4MHz
G
P
R
TIS0.7
MI 0.4
M4 M4
+66.2
-66.2
cm/s
X3
PAT T: 37.0C
TEE T: 39.2C
89 bpm

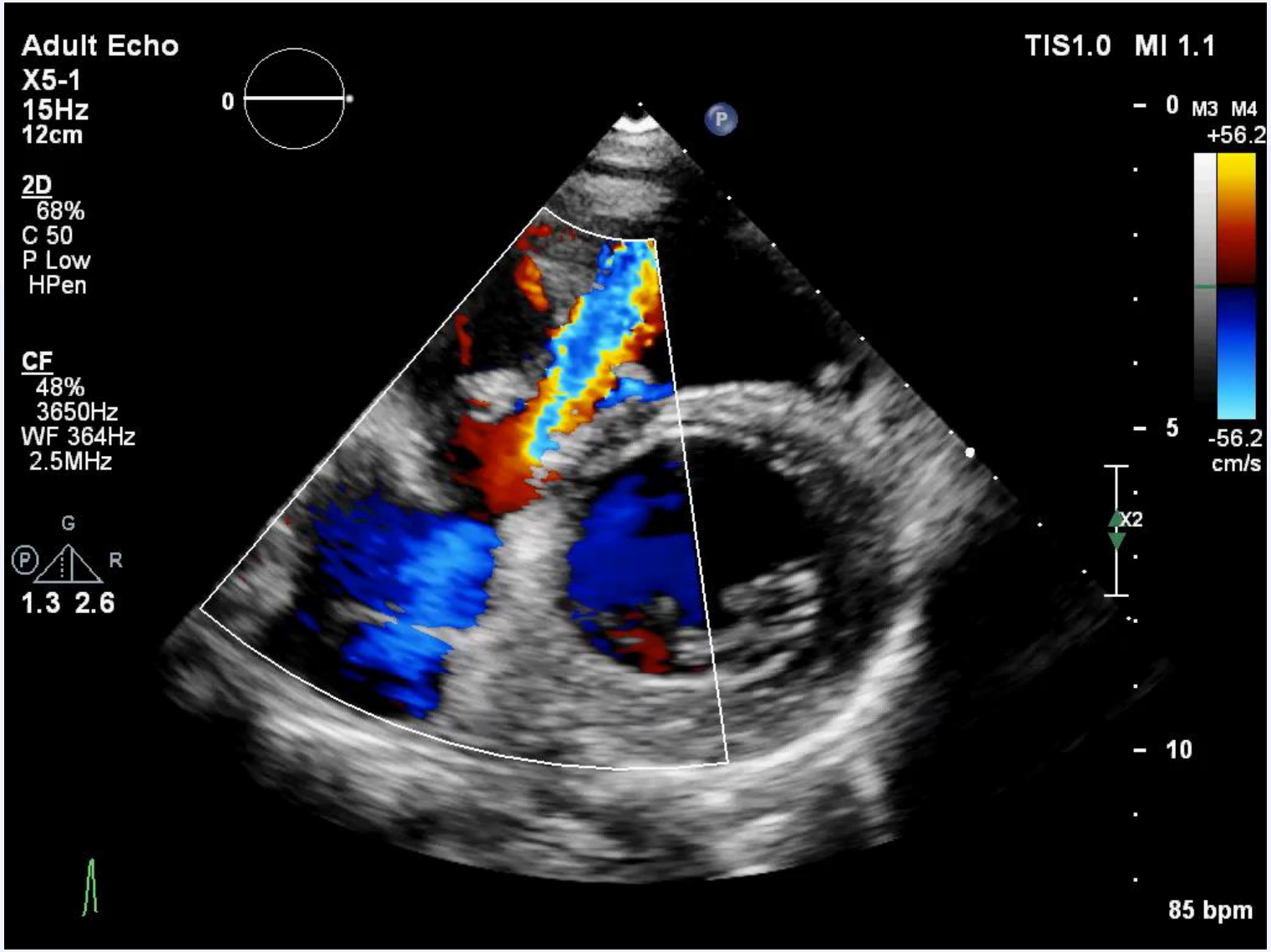

OR
X7-2t
23Hz
11cm
0 61 180
2D
47%
C 47
P Off
Pen
CF
48%
7634Hz
WF 686Hz
4.4MHz
PW
58%
WF 175Hz
SV4.0mm
2.9MHz
4.5cm
TIS0.2 MI 0.1
M4 M4
+66.2
Vmax 128 cm/s
Vmean 77.4 cm/s
Max PG 7 mmHg
Mean PG 3 mmHg
VTI 35.6 cm
-66.2
cm/s
40
cm/s
-40
-80
-120
-160
-200
PAT T: 37.0C
TEE T: 38.1C
75mm/s
91bpm

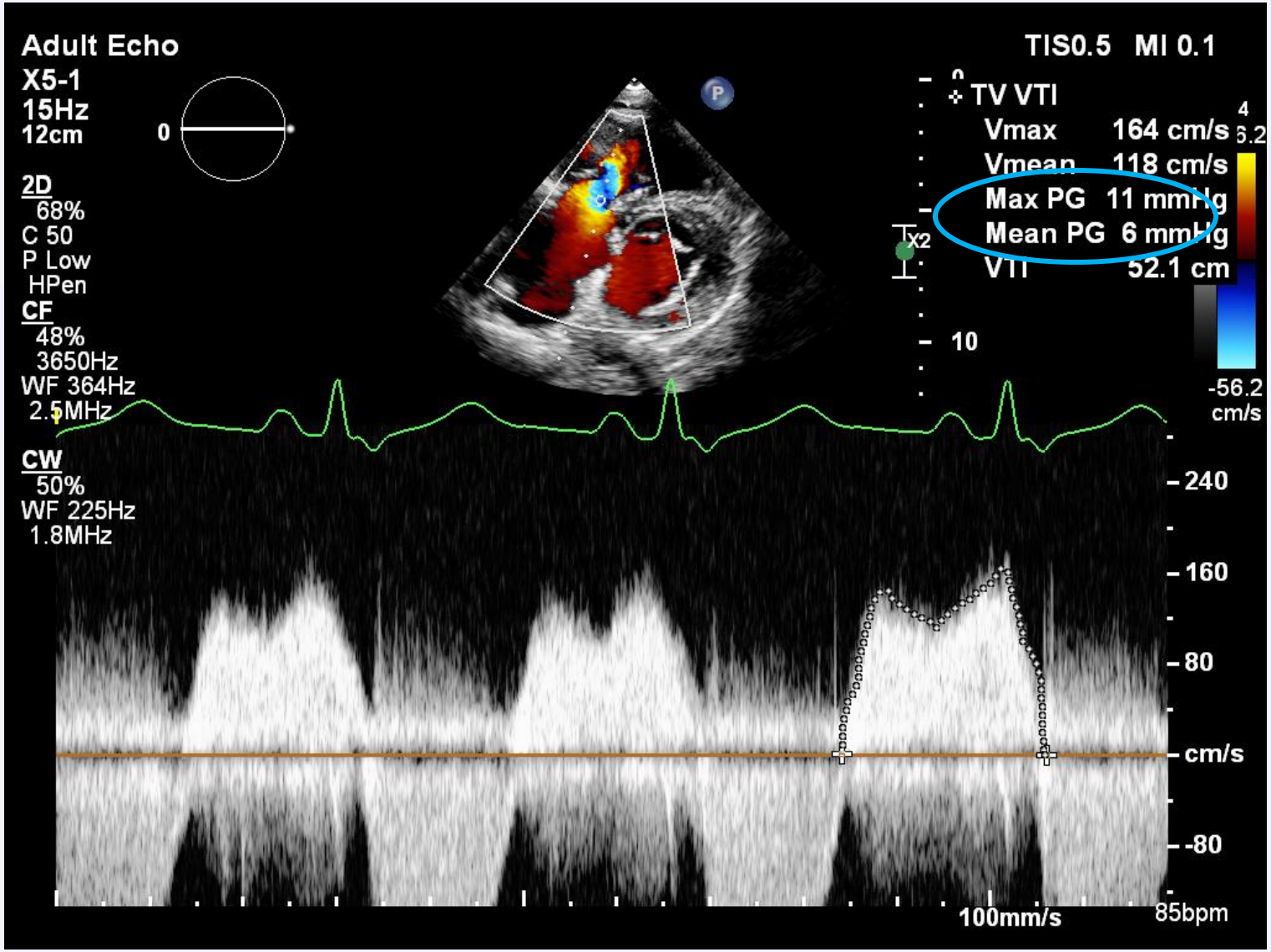
F/U echo in 6 weeks

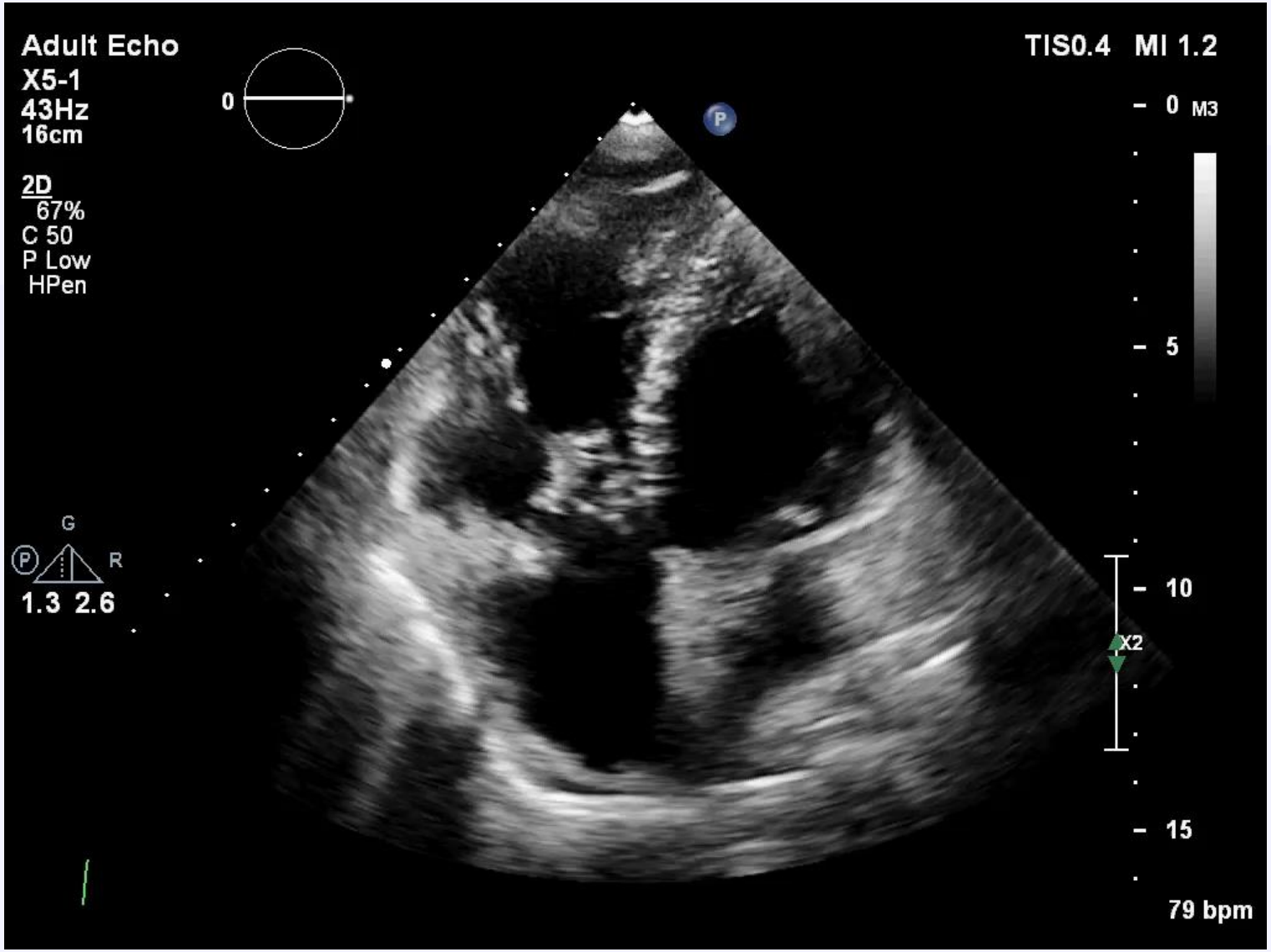

Adult Echo
X5-1
43Hz
12cm
2D
66%
C 50
P Low
HPen
TIS0.3 MI 1.3
0
M3
5
10
X2
G
R
1.3 2.6
86 bpm

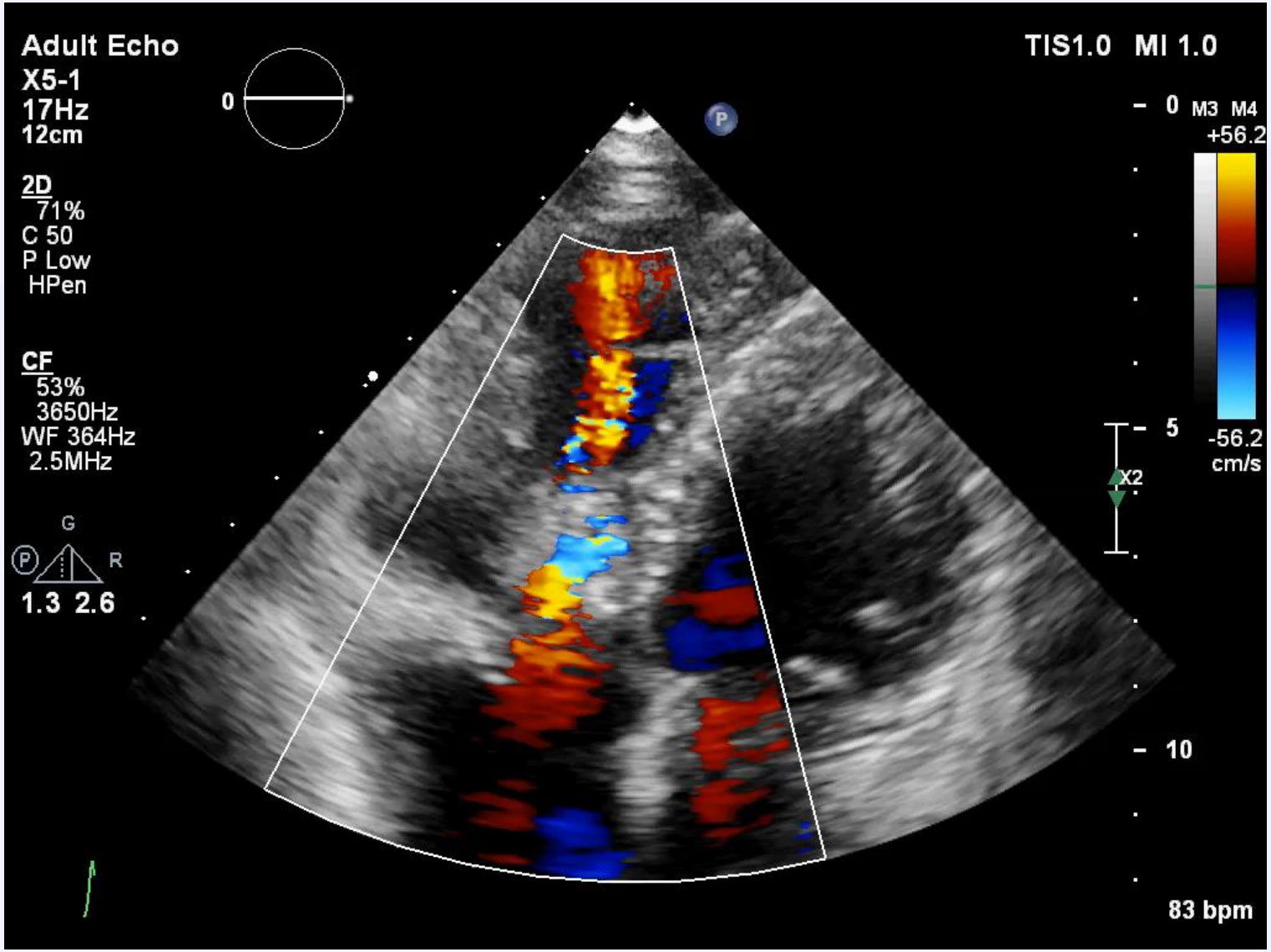

Adult Echo
X5-1
13Hz
12cm
2D
66%
C 50
P Low
HPen
CF
50%
3650Hz
WF 364Hz
2.5MHz
G
P
R
1.3 2.6
TIS1.0 MI 1.1
0
M3 M4
+56.2
-56.2
cm/s
0
5
10
X2
87 bpm


Adult Echo
X5-1
43Hz
12cm
2D
65%
C 50
P Low
HPen
TIS0.3 MI 1.3
0
M3
5
10
X2
G
P
R
1.3 2.6
84 bpm


Adult Echo
X5-1
15Hz
12cm
2D
68%
C 50
P Low
HPen
CF
48%
3650Hz
WF 364Hz
2.5MHz
G
P
R
1.3 2.6
TIS1.0 MI 1.1
0
M3 M4
+56.2
-56.2
cm/s
0
5
10
X2
85 bpm


Adult Echo
X5-1
15Hz
12cm
2D
68%
C 50
P Low
HPen
CF
48%
3650Hz
WF 364Hz
2.5MHz
CW
50%
WF 225Hz
1.8MHz
TIS0.5 MI 0.1
TV VTI
Vmax 164 cm/s
Vmean 118 cm/s
Max PG 11 mmHg
Mean PG 6 mmHg
VTI 52.1 cm
-56.2
cm/s
240
160
80
cm/s
-80
100mm/s
85bpm


Adult Echo
X5-1
43Hz
16cm
2D
67%
C 50
P Low
HPen
TIS0.4 MI 1.2
0
M3
5
10
15
X2
G
R
1.3 2.6
79 bpm


Adult Echo
X5-1
17Hz
12cm
2D
71%
C 50
P Low
HPen
CF
53%
3650Hz
WF 364Hz
2.5MHz
G
P
R
1.3 2.6
TIS1.0 MI 1.0
0
M3 M4
+56.2
-56.2
cm/s
5
10
X2
83 bpm

The cone reconstruction of the tricuspid valve in Ebstein's anomaly. The operation: early and midterm results

José Pedro da Silva, MD,[a] José Francisco Baumgratz, MD,[b] Luciana da Fonseca, MD,[b] Sônia Meiken Franchi, MD,[a] Lilian Maria Lopes, MD[b], Gláucia Maria P. Tavares, MD,[a] Andressa Mussi Soares, MD,[a] Luiz Felipe Moreira, MD,[a] and Miguel Barbero-Marcial, MD[a]

J Thorac Cardiovasc Surg 2007

Dr da Silva

Objectives: We sought to describe a new technique for tricuspid valve repair in Ebstein's anomaly and to report early echocardiographic results, as well as early and midterm clinical outcomes.

Methods: From November 1993 through August 2005, 40 consecutive patients with Ebstein's anomaly (mean age, 16.8 ± 12.3 years) underwent a new surgical repair modified from Carpentier's procedure, the principal details of which are as follows. The anterior and posterior tricuspid valve leaflets are mobilized from their anomalous attachments in the right ventricle, and the free edge of this complex is rotated clockwise to be sutured to the septal border of the anterior leaflet, thus creating a cone the vertex of which remains fixed at the right ventricular apex and the base of which is sutured to the true tricuspid valve annulus level. Additionally, the septal leaflet is incorporated into the cone wall whenever possible, and the atrial septal defect is closed in a valved fashion.

Results: There was 1 (2.5%) hospital death and 1 late death. Early postoperative

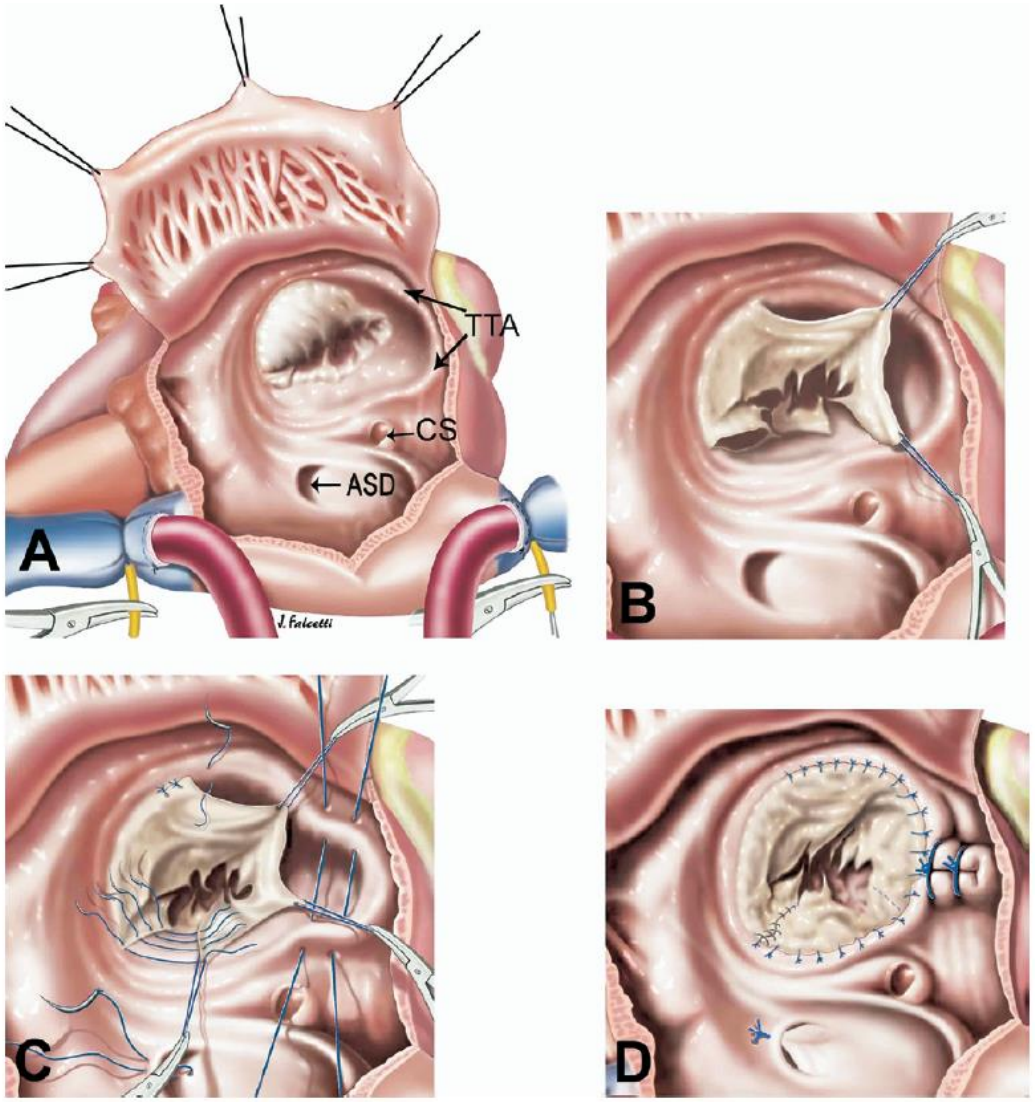
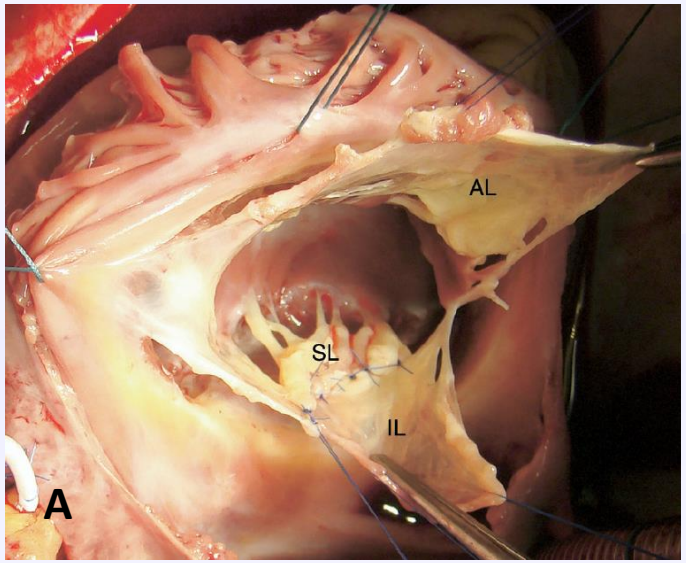
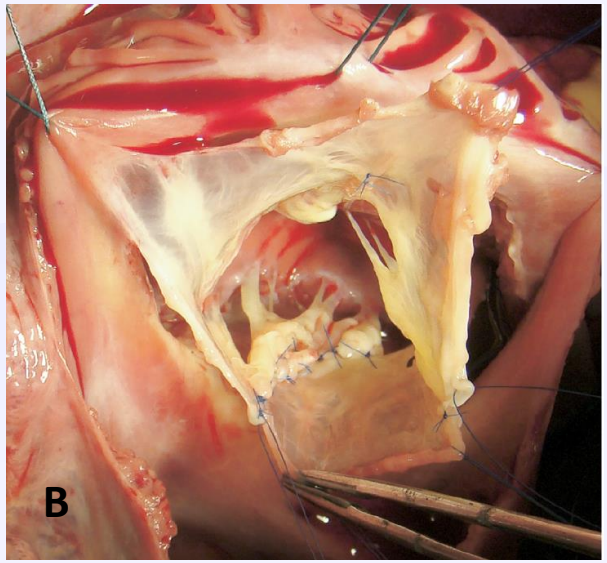
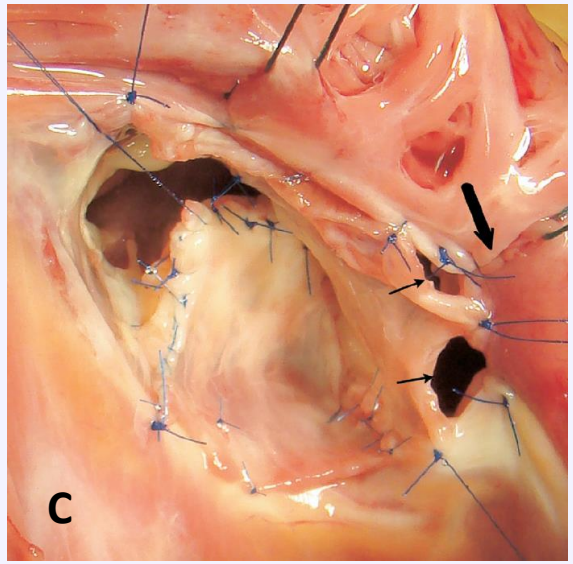
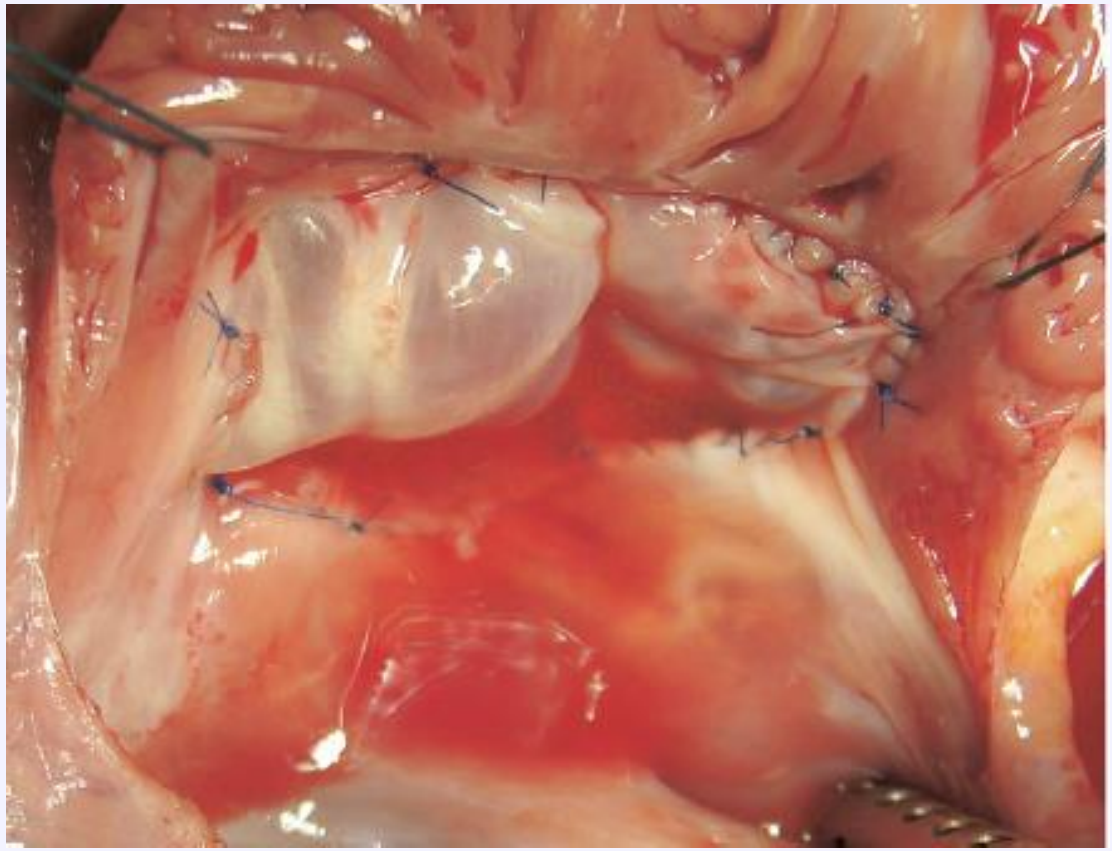


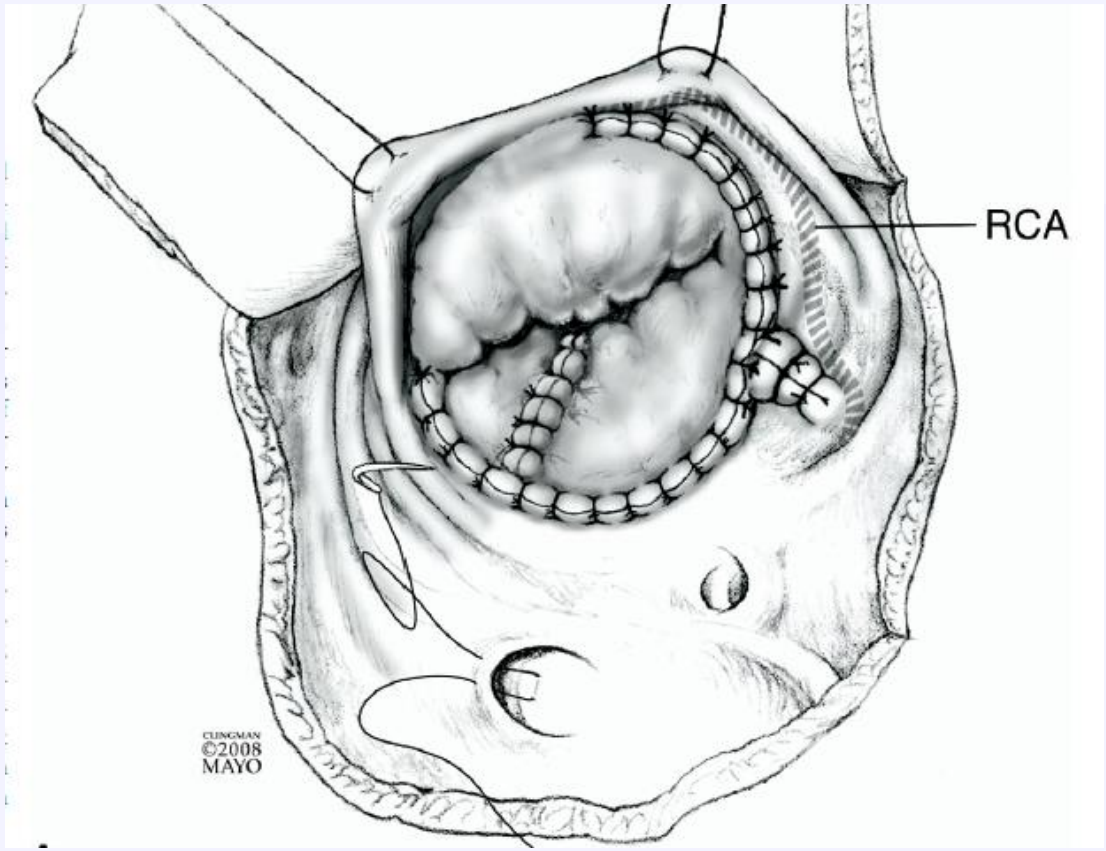
Figure 1. Operative steps for Ebstein's anomaly repair. A, Opened right atrium showing displacement of the tricuspid valve. *TTA*, True tricuspid annulus; *ASD*, atrial septal defect; *CS*, coronary sinus. B, Detached part of the anterior and posterior leaflet forming a single piece. C, Clockwise rotation of the posterior leaflet edge to be sutured to the anterior leaflet septal edge and plication of the true tricuspid annulus. D, Complete valve attachment to the true tricuspid annulus and valved closure of the atrial septal defect.


AL
SL
IL
A


B


C





Completed cone reconstruction of the tricuspid valve+ longitudinal plication of the tricuspid annulus and atrialized right ventricle. No annuloplasty ring was used.

Pulmonic (pulmonary) valve disease

Table 11 Grading of pulmonary stenosis

	Mild	Moderate	Severe
Peak velocity (m/s)	<3	3–4	>4
Peak gradient (mmHg)	<36	36–64	>64

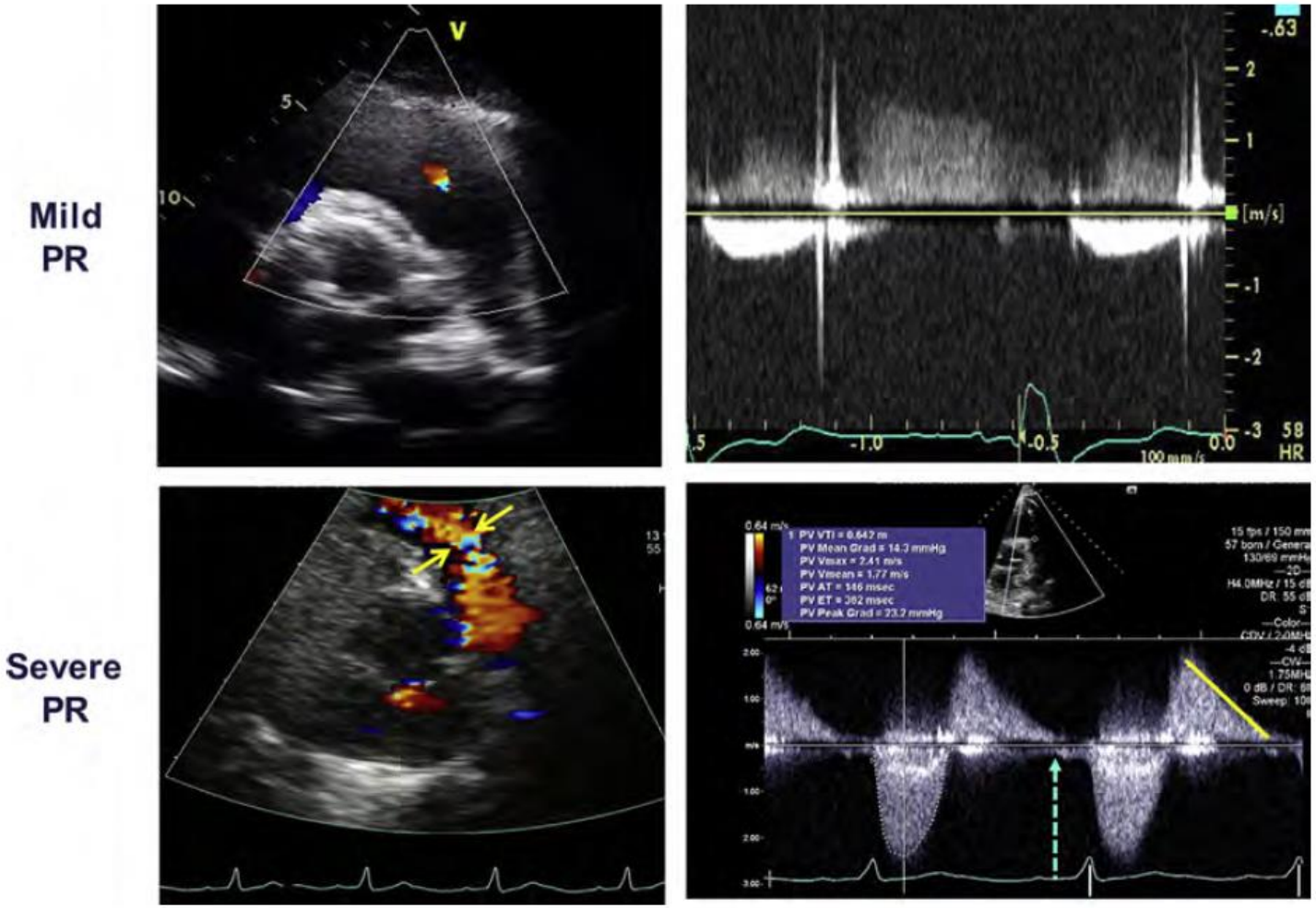


Figure 32 Examples of mild and severe PR depicting the difference in color jet, jet height (*between arrows*), and spectral density and deceleration of the PR jet by CWD. In severe PR, there is frequently early termination of the diastolic regurgitant flow (*green arrow*) with early equalization of RV and PA diastolic pressures.

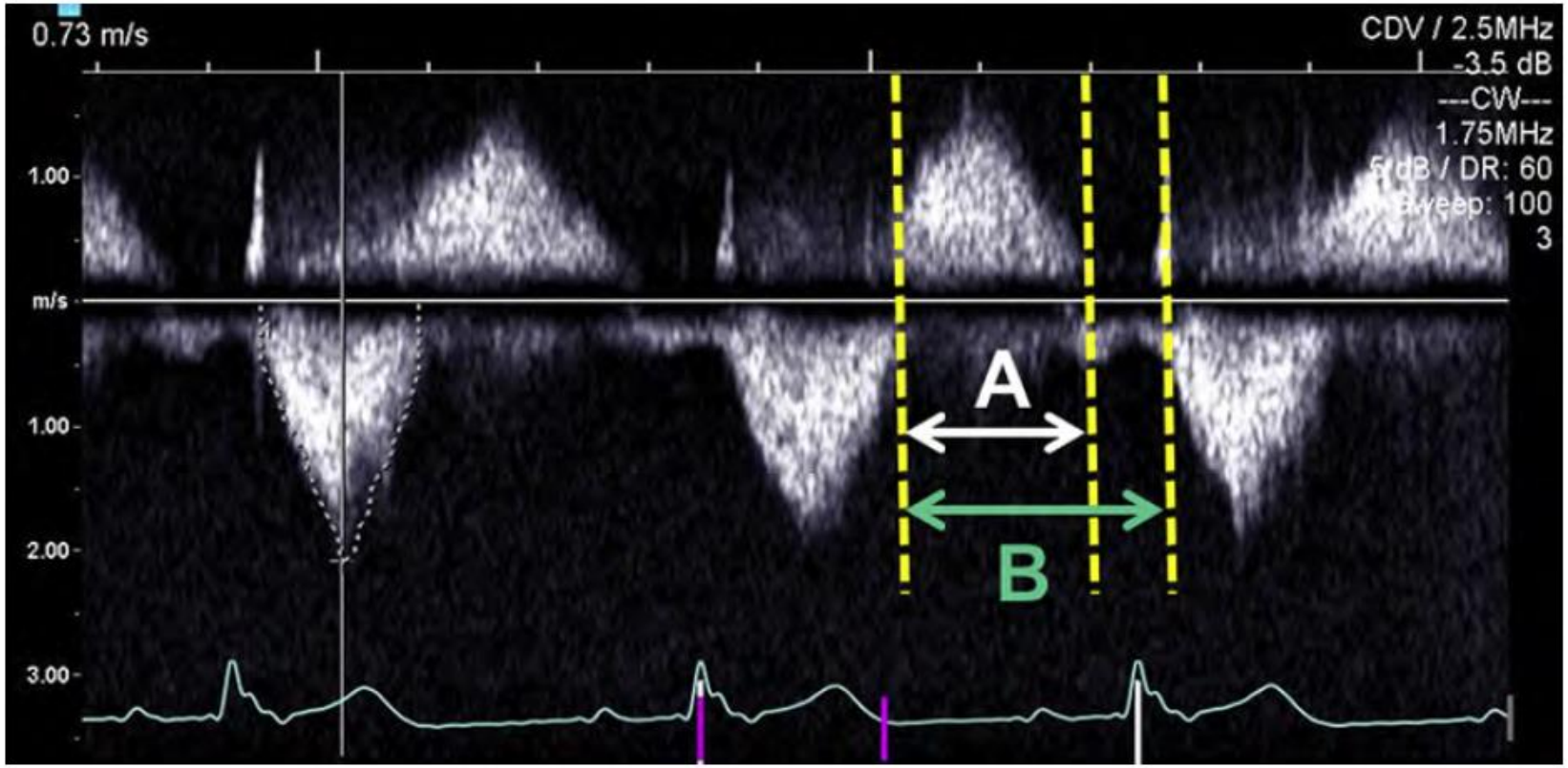


Figure 33 CWD of pulmonic flow. Calculation of pulmonic regurgitation index (PR index = A/B) is shown, an index of PR severity, quantitating early termination of diastolic regurgitant flow.

Table 16 Echocardiographic and Doppler parameters useful in grading PR severity

Parameter	Mild	Moderate	Severe
Pulmonic valve	Normal	Normal or abnormal	Abnormal and may not be visible
RV size	Normal*	Normal or dilated	Dilated†
Jet size, color Doppler‡	Thin (usually <10 mm in length) with a narrow origin	Intermediate	Broad origin; variable depth of penetration
Ratio of PR jet width/pulmonary annulus			>0.7§
Jet density and contour (CW)	Soft	Dense	Dense; early termination of diastolic flow
Deceleration time of the PR spectral Doppler signal			Short, <260 msec
Pressure half-time of PR jet			<100 msec‖
PR index¶		<0.77	<0.77
Diastolic flow reversal in the main or branch PAs (PW)			Prominent
Pulmonic systolic flow (VTI) compared to systemic flow (LVOT VTI) by PW#	Slightly increased	Intermediate	Greatly increased
RF**	<20%	20%-40%	>40%

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Table 16 Echocardiographic and Doppler parameters useful in grading PR severity

Parameter	Mild	Moderate	Severe
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Jet density and contour (CW)	Soft	Dense	Dense; early termination of diastolic flow
Deceleration time of the PR spectral Doppler signal			Short, <260 msec
Pressure half-time of PR jet			<100 msec‖
PR index¶		<0.77	<0.77
Diastolic flow reversal in the main or branch PAs (PW)			Prominent
Pulmonic systolic flow (VTI) compared to systemic flow (LVOT VTI) by PW#	Slightly increased	Intermediate	Greatly increased
RF**	<20%	20%-40%	>40%

2017 ASE guideline

Suggested reading materials

1. Echocardiographic Assessment of Valve Stenosis: EAE/ ASE Recommendations for Clinical Practice. JASE 2009.
2. 2017 AHA/ ACC Focused Update of the 2014 AHA/ ACC Guideline for the Management of Patients with Valvular Heart Disease.
3. Recommendations for Noninvasive Evaluation of Native Valvular Regurgitation. A Report from the American Society of Echocardiography Developed in Collaboration with the Society for Cardiovascular Magnetic Resonance.

Questions

Question 1

Which of the following statements about tricuspid valve anatomy is CORRECT?

A. Anterior tricuspid leaflet is adjacent to the coronary sinus
B. Anterior tricuspid leaflet is adjacent to the IVC
C. Tricuspid septal leaflet is adjacent to the IVC
D. A-V node is adjacent to the commissure between anterior and posterior leaflets

Question 2

All of the following statements about severe of TR are correct EXCEPT

A. There is a flow reversal in hepatic vein Doppler
B. CW Doppler is parabolic shape
C. Tricuspid inflow Doppler E velocity is more than 1.0 m/s
D. Regurgitant volume by PISA method is more than 45 ml/beat

Question 3

Which of the following statements about etiology of TR is CORRECT?

A. Right side endocarditis is the most common cause of TR in North America
B. Carcinoid heart is the most common cause of the TR
C. Atrial fibrillation is common in idiopathic TR
D. In Ebstein's anomaly of the tricuspid valve, most of the time anterior leaflet is displaced

Question 4

All of the following statements about tricuspid stenosis (TS) are correct EXCEPT

A. Carcinoid heart is the most common cause of the isolated TS
B. Rheumatic TS is associated with rheumatic mitral valve in most of the cases
C. Pacemaker lead can cause severe TS
D. RV dilatation is an echo sign of isolated TS

Question 5

All of the following statements about pulmonary regurgitation are correct EXCEPT

A. PR index in CW Doppler is less than 0.77
B. There is diastolic flow reversal in pulmonary branches
C. Regurgitant fraction is more than 40%
D. Pressure half-time of PR jet is less than 250 ms

Correct Answers

1- C
2- B
3- C
4- A
5- D


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Thank you.