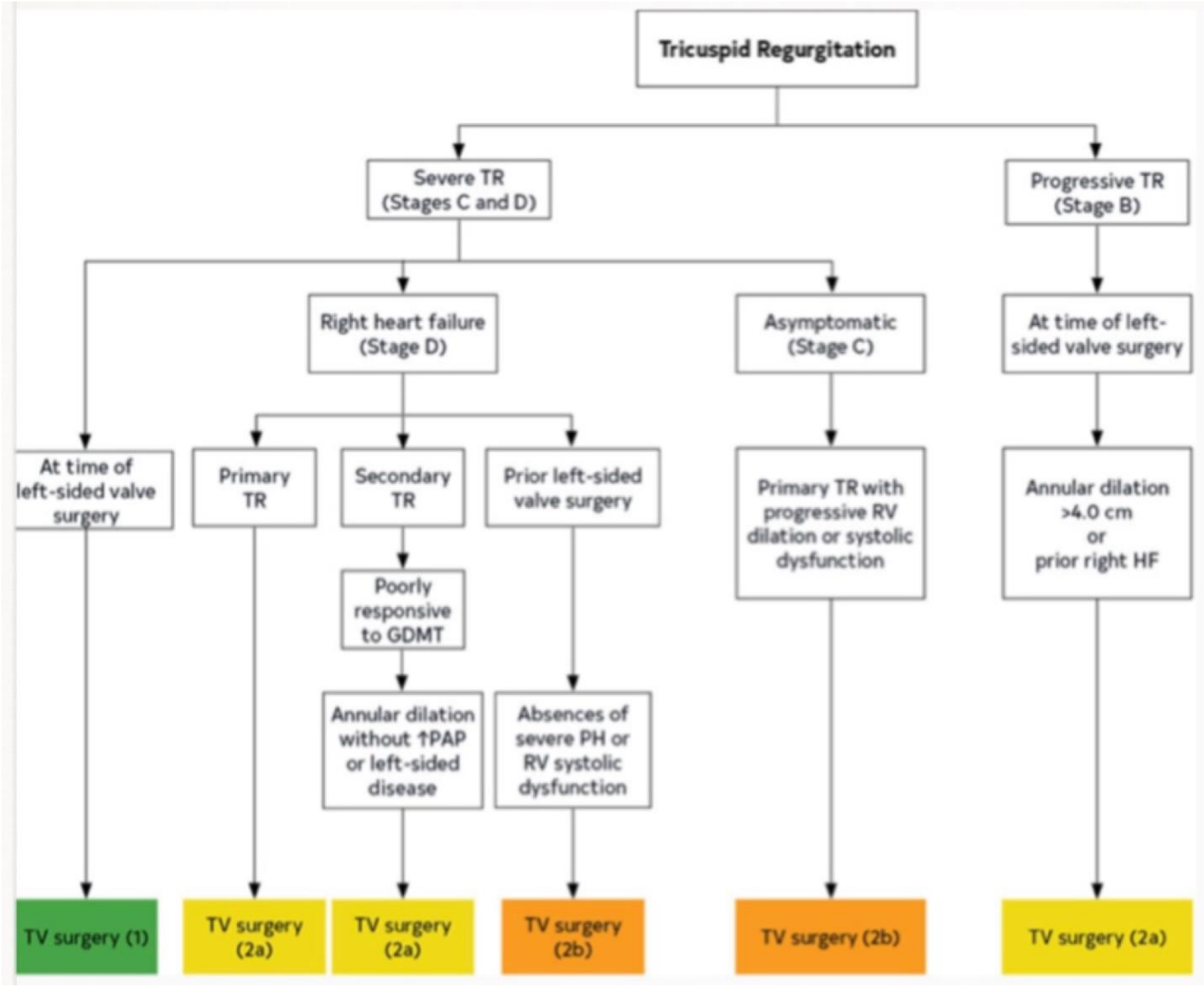
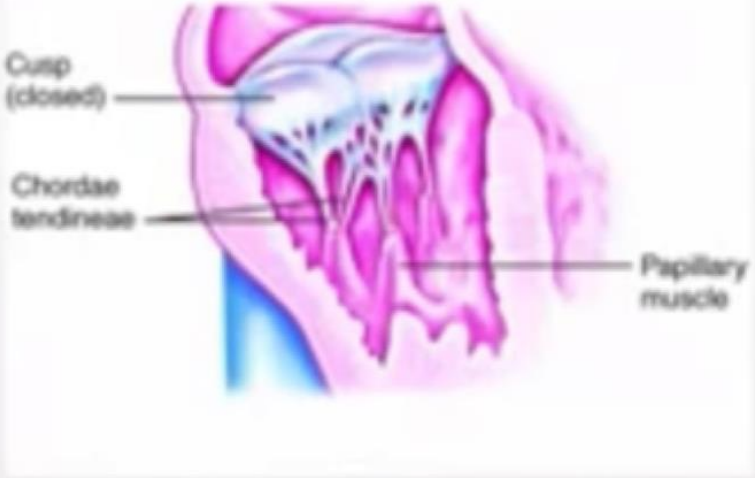
1. The guideline continues to recommend the use of disease stages among patients with valvular heart disease, consisting of Stage A (at risk), Stage B (progressive), Stage C (asymptomatic severe; with ventricular compensation [Stage C1] or with ventricular decompensation [Stage C2]), and Stage D (symptomatic severe). Disease stages should be assigned based on valve anatomy, the severity of valve dysfunction, the ventricular and pulmonary circulation response to valve dysfunction, and symptoms.

8. Tricuspid regurgitation (TR) is most often secondary, due to annular dilation in the setting of right ventricular (RV) dilation and/or dysfunction, as seen in pulmonary hypertension, or in right atrial dilation in the setting of atrial fibrillation. Medical treatment for TR consists of diuresis and treatment of underlying causes of heart failure and pulmonary hypertension.
9. In severe primary TR with symptoms of right heart failure, isolated tricuspid valve surgery can improve symptoms and reduce hospitalizations (Class 2a). In asymptomatic patients with severe primary TR, tricuspid valve surgery may be considered if RV dilation or dysfunction develop (Class 2b). With respect to secondary TR, patients undergoing left-sided valve surgery should be considered for concomitant tricuspid valve surgery if the TR is severe (Class 1), or if the tricuspid annulus is dilated (>4.0 cm) and/or if right heart failure symptoms have occurred (Class 2a). In symptomatic patients with severe, functional TR (particularly if related to atrial fibrillation and atrial dilation), surgical intervention is reasonable in the absence of severe RV dysfunction, pulmonary hypertension, and liver/kidney damage (Class 2a).

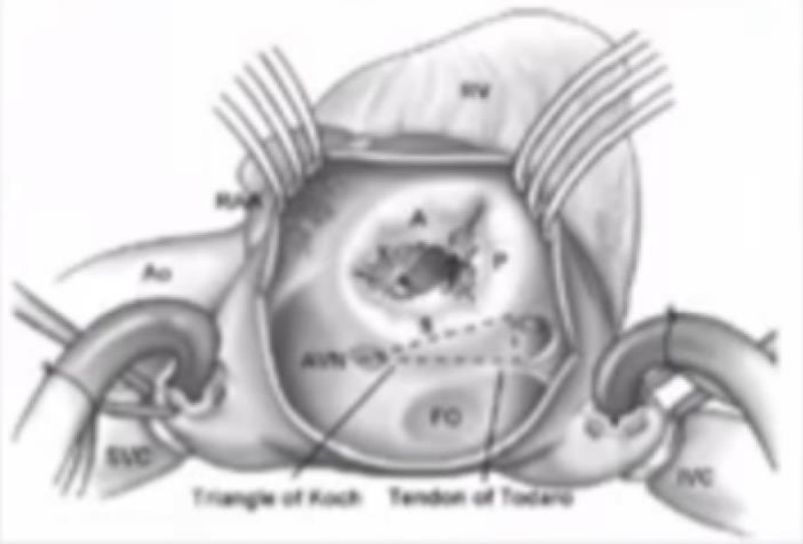

Tricuspid Regurgitation
Severe TR (Stages C and D)
Progressive TR (Stage B)
At time of left-sided valve surgery
Right heart failure (Stage D)
Asymptomatic (Stage C)
At time of left-sided valve surgery
Primary TR
Secondary TR
Prior left-sided valve surgery
Primary TR with progressive RV dilation or systolic dysfunction
Annular dilation >4.0 cm or prior right HF
Poorly responsive to GDMT
Annular dilation without ↑PAP or left-sided disease
Absences of severe PH or RV systolic dysfunction
TV surgery (1)
TV surgery (2a)
TV surgery (2a)
TV surgery (2b)
TV surgery (2b)
TV surgery (2a)

Tricuspid valve complex

- 3 leaflets:
  - Anterior
  - Posterior
  - Septal
- Chordae tendinae
- 2 papillary muscles
- Fibrous tricuspid annulus
- RA myocardium
- RV myocardium



Mosby's Medical Dictionary, 8th edition. © 2009, Elsevier



Tricuspid valve complex

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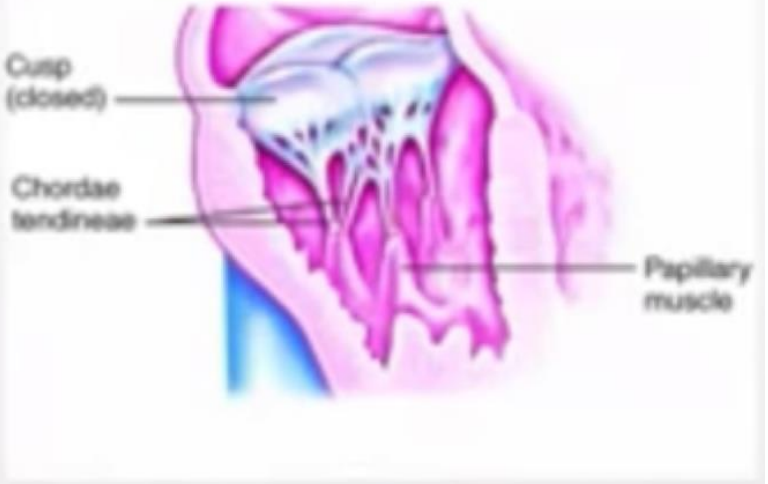

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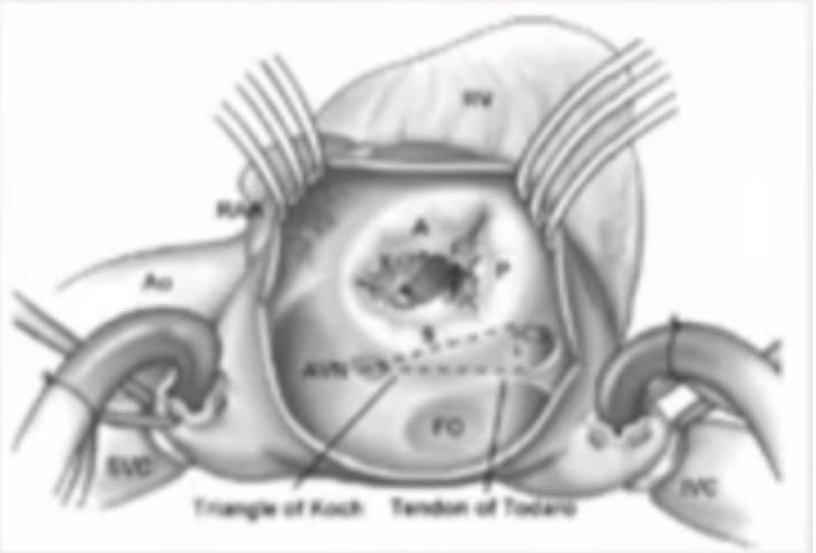
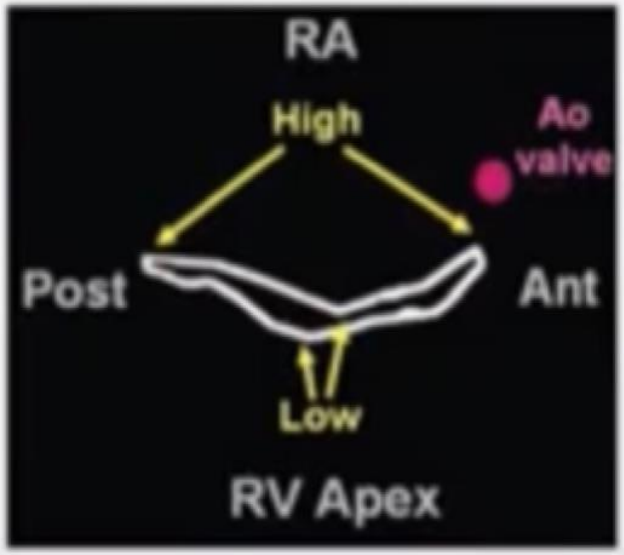


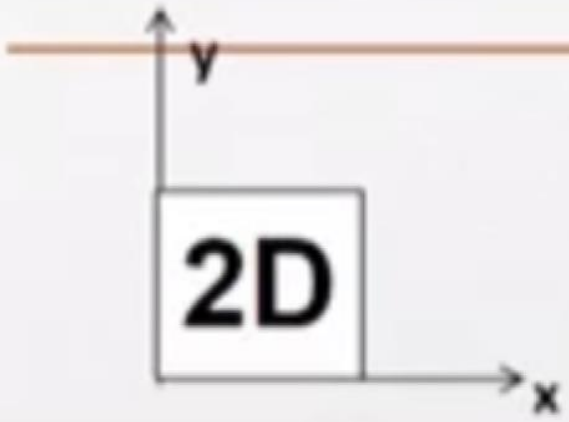
The Tricuspid Valve

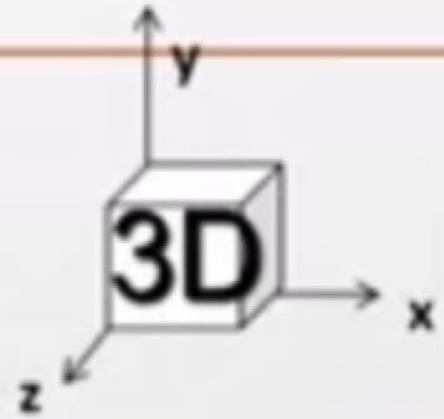


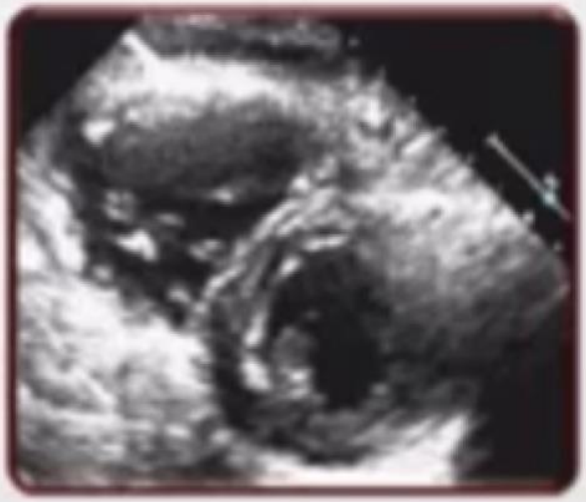
Ton-Nu Circulation. 2006

The Tricuspid Valve

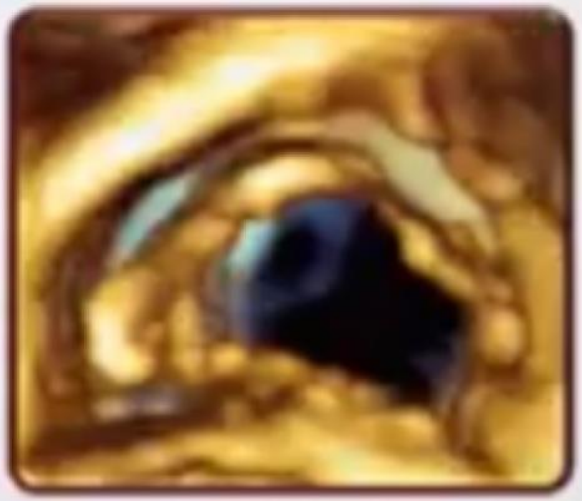
The added value of the 3rd dimension



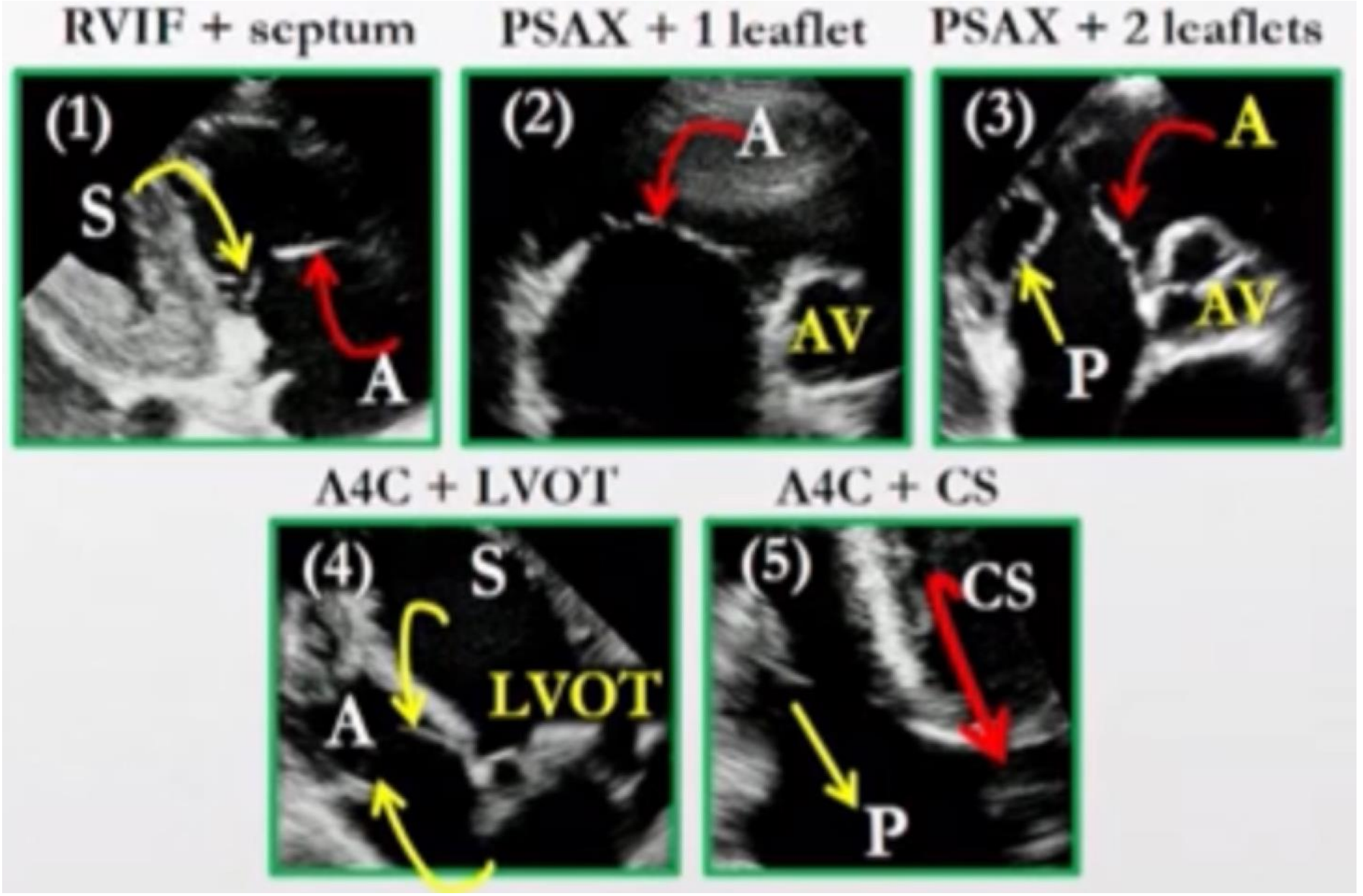




< 5% of pts



~ 85% of pts


RVIF + septum
PSAX + 1 leaflet
PSAX + 2 leaflets
(1)
S
A
(2)
A
AV
(3)
A
AV
P
A4C + LVOT
A4C + CS
(4)
S
LVOT
A
(5)
CS
P

Tricuspid Valve Disorders

Tricuspid Stenosis

1. Rheumatic #1
2. Tricuspid atresia
3. RA tumors
4. Carcinoid
5. RV inflow obstruction
6. Endomyocardial fibrosis
7. TV vegetations
8. Pacemaker
9. Extracardiac tumors

Tricuspid Regurgitation

Primary (or "Organic")

Intrinsic abnormality of the valve apparatus

15-30%* of TR

Secondary (or "Functional")

TR due to RV and/ or TV annular dilation

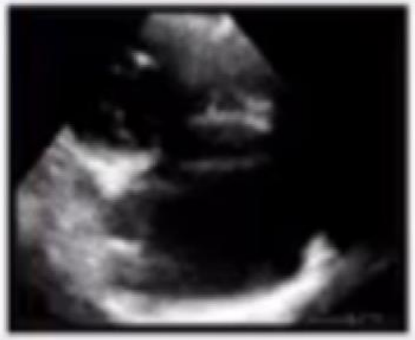
70-85%* of TR

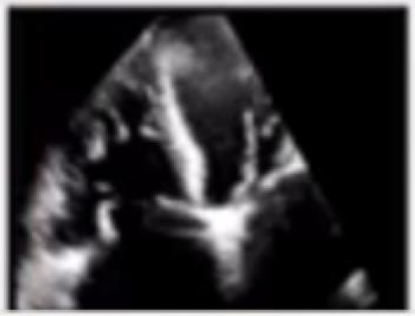
Antunes MJ, Barlow JB. Heart 2007

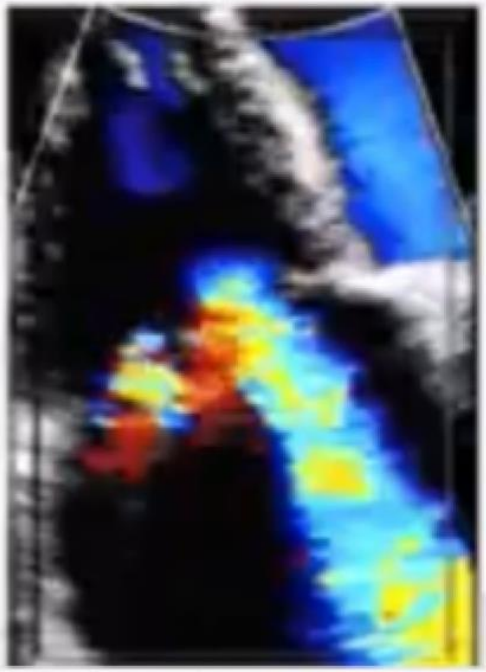
Primary TR due to PM/ICD

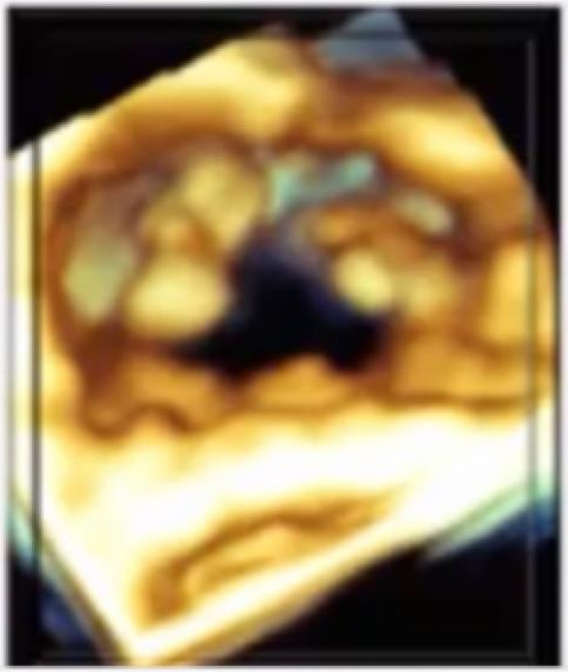
89 year-old man with right heart failure and ascites was sent for TTE

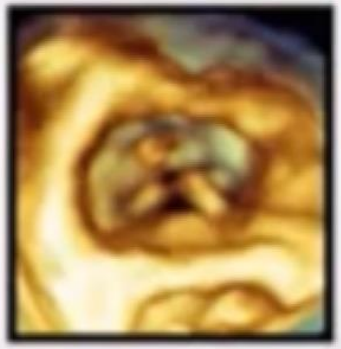
- Past medical history: CAD, MV repair, TAVI in 2009
- Permanent pacemaker implantation post TAVI for bradycardia

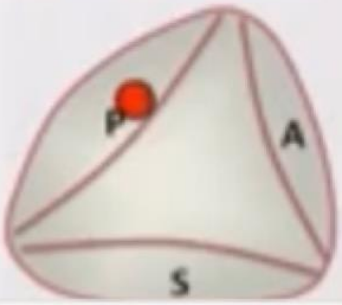


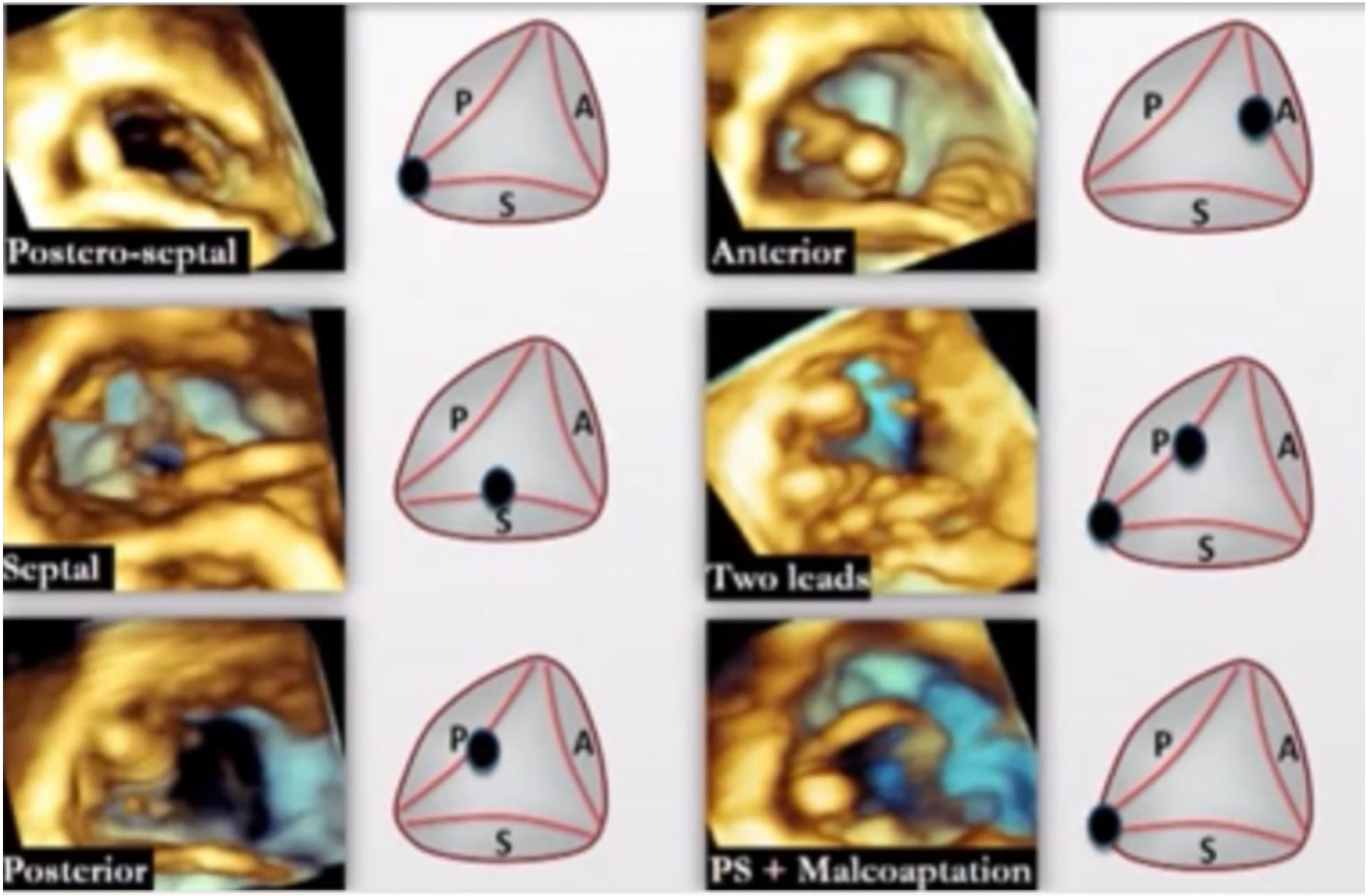


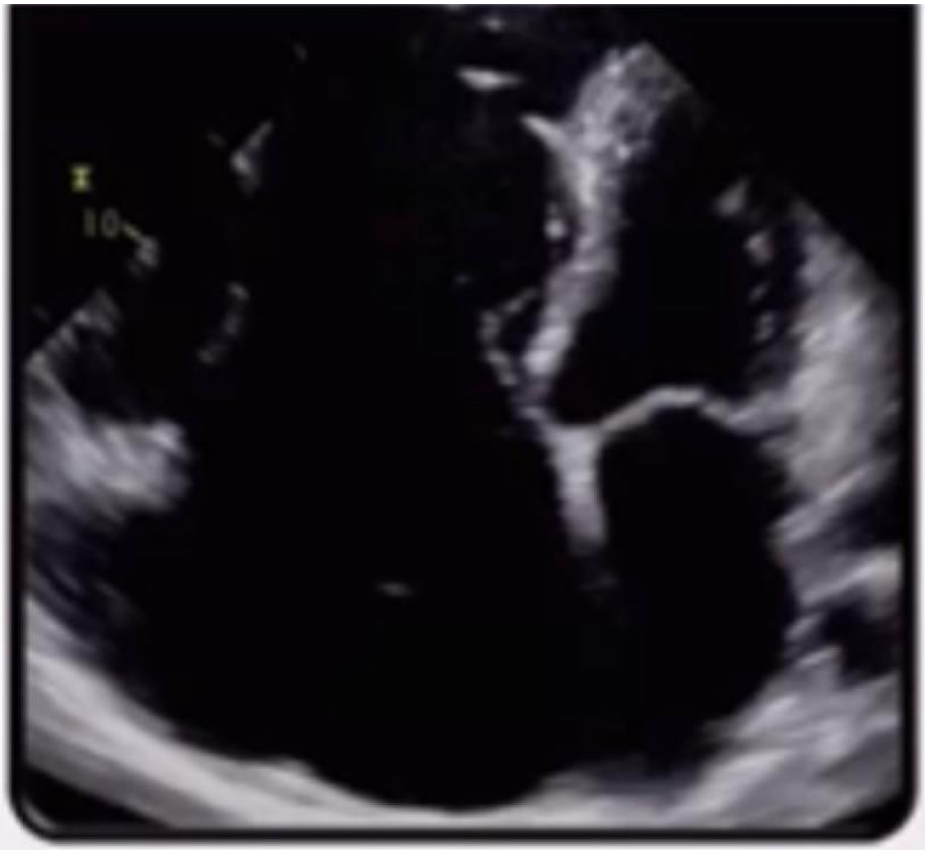


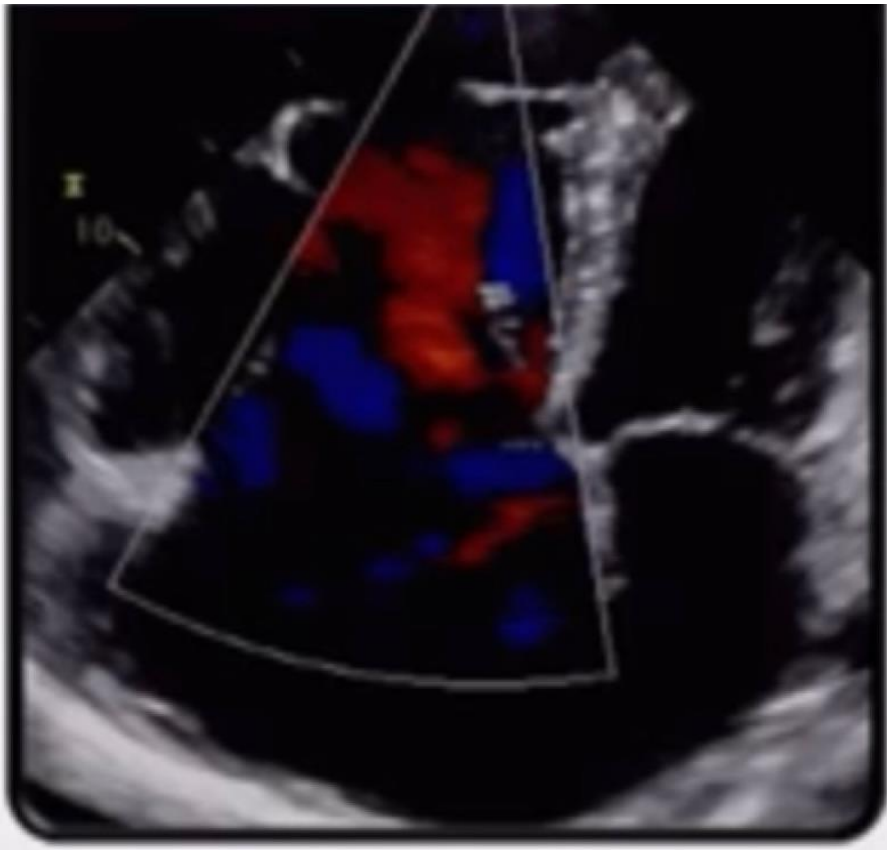







Postero-septal
P
A
S
Anterior
P
A
S
Septal
P
A
S
Two leads
P
A
S
Posterior
P
A
S
PS + Malcoaptation
P
A
S

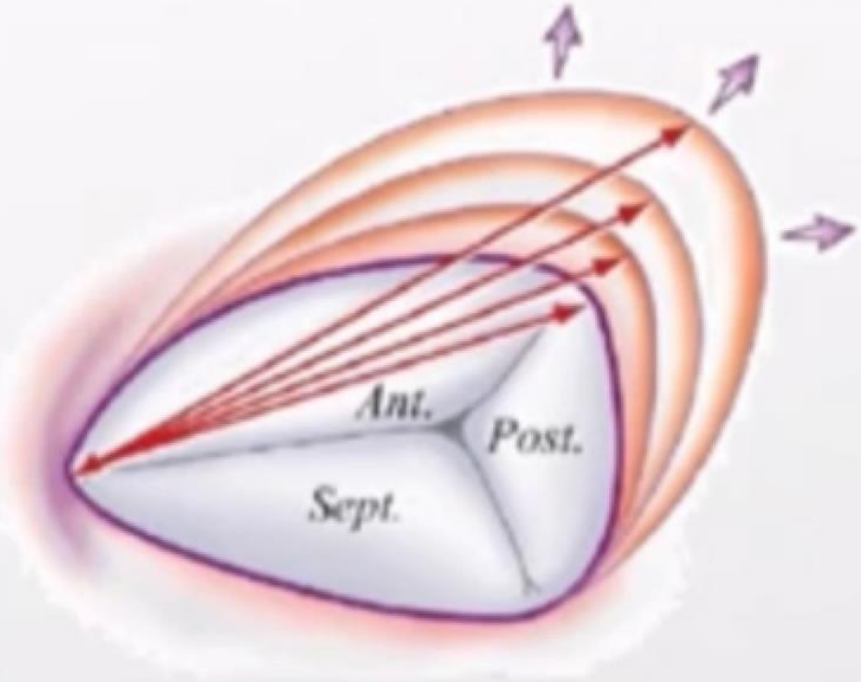


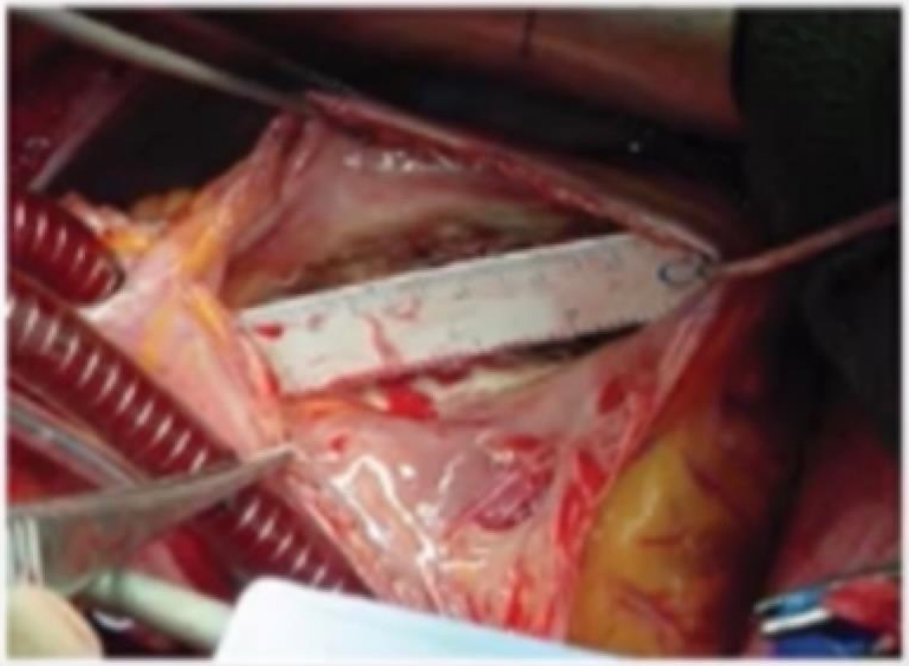


- RV dilatation
- TV annular dilatation
- TV leaflet tethering
- RV remodeling due to pressure/volume overload

- Left heart disease + PH
  - ↓LV function
  - Valve disease
- Any cause of PH
- RV dysfunction

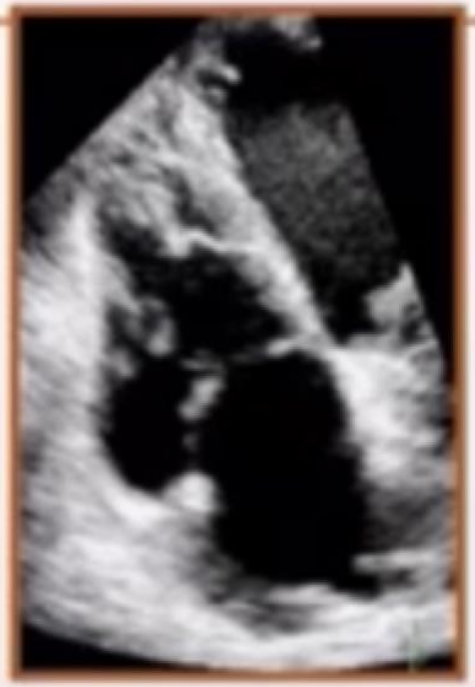
Anteroseptal to anteroposterior commissure with supple ruler intra-op

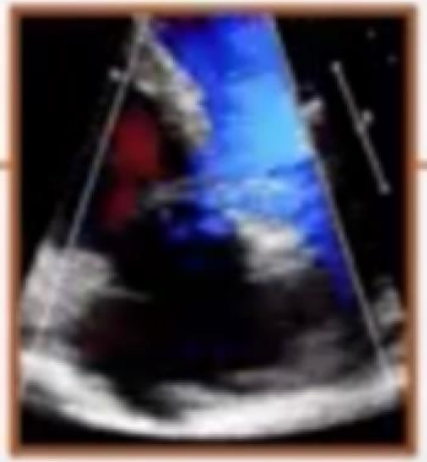


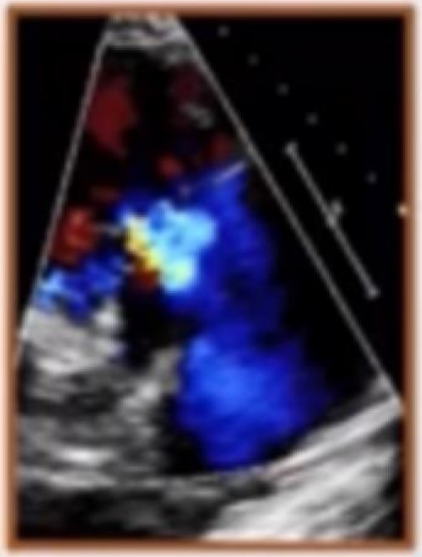


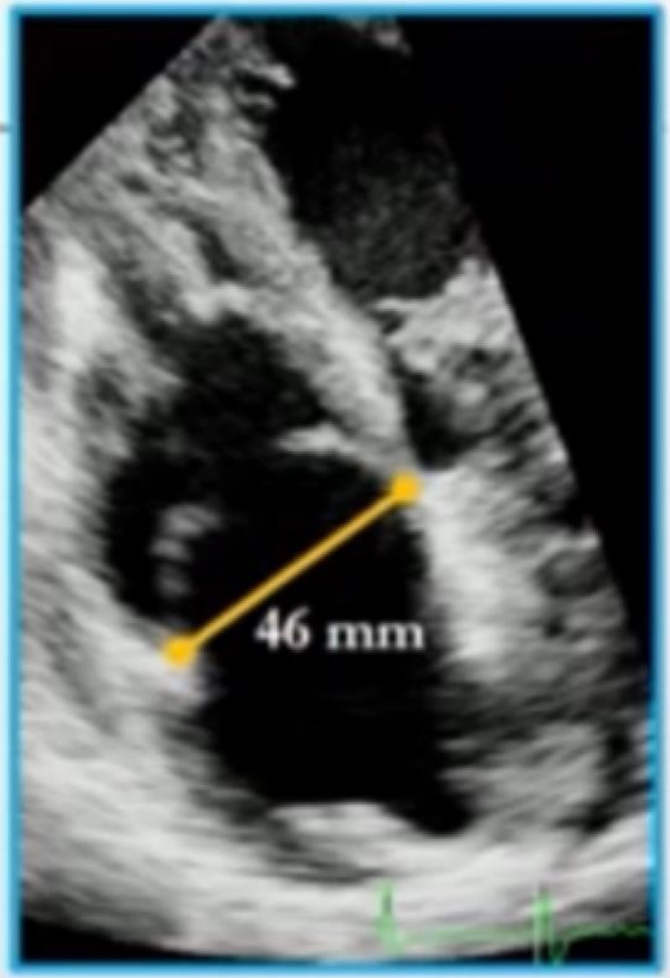
- TA dilatation mostly along septal-lateral dimension
- Septal portion of the tricuspid annulus relatively fixed

DILATED TA MILD TR









TR can vary depending on preload, afterload, RV function

But how should we measure TA dilatation?

Intra-op?

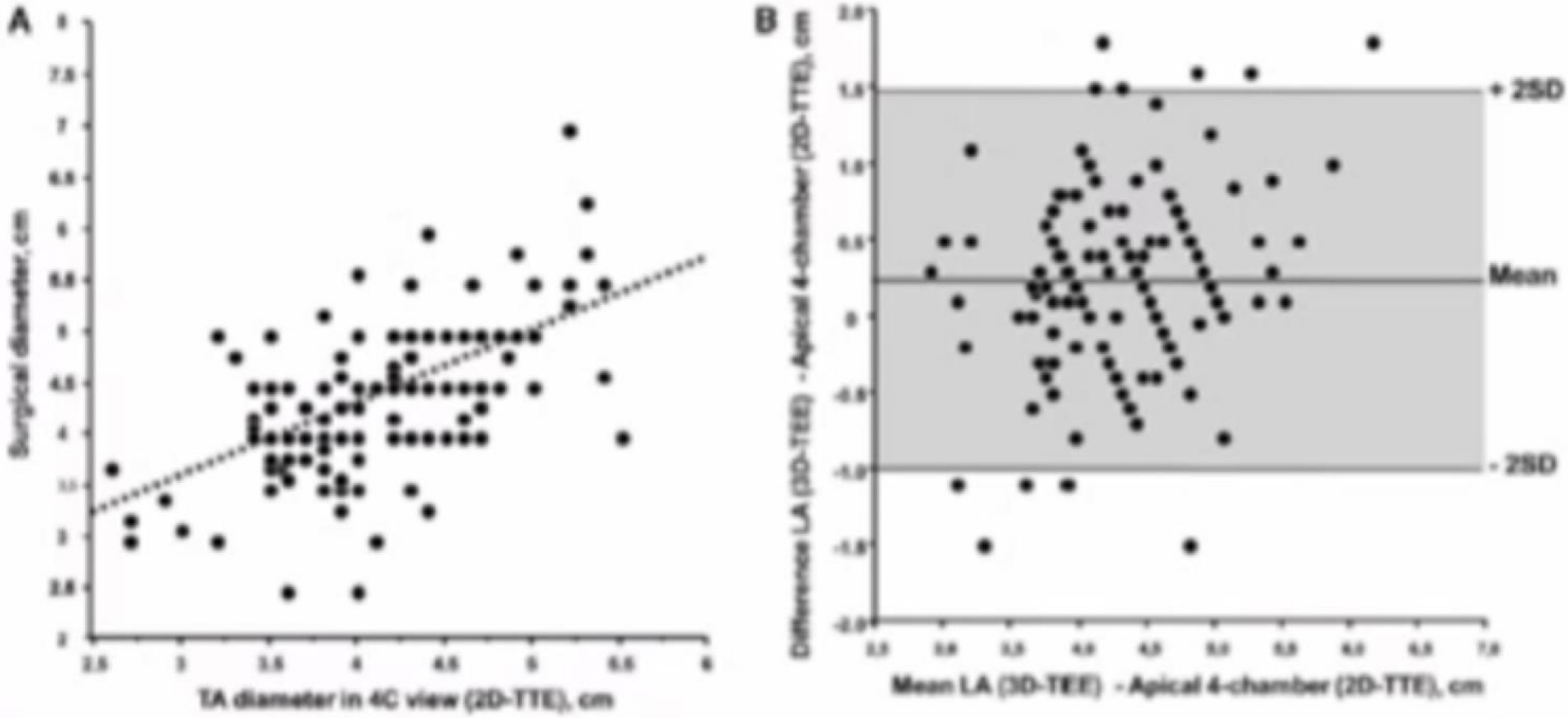
2D Echo?

3D Echo?

Intra-Op ? No

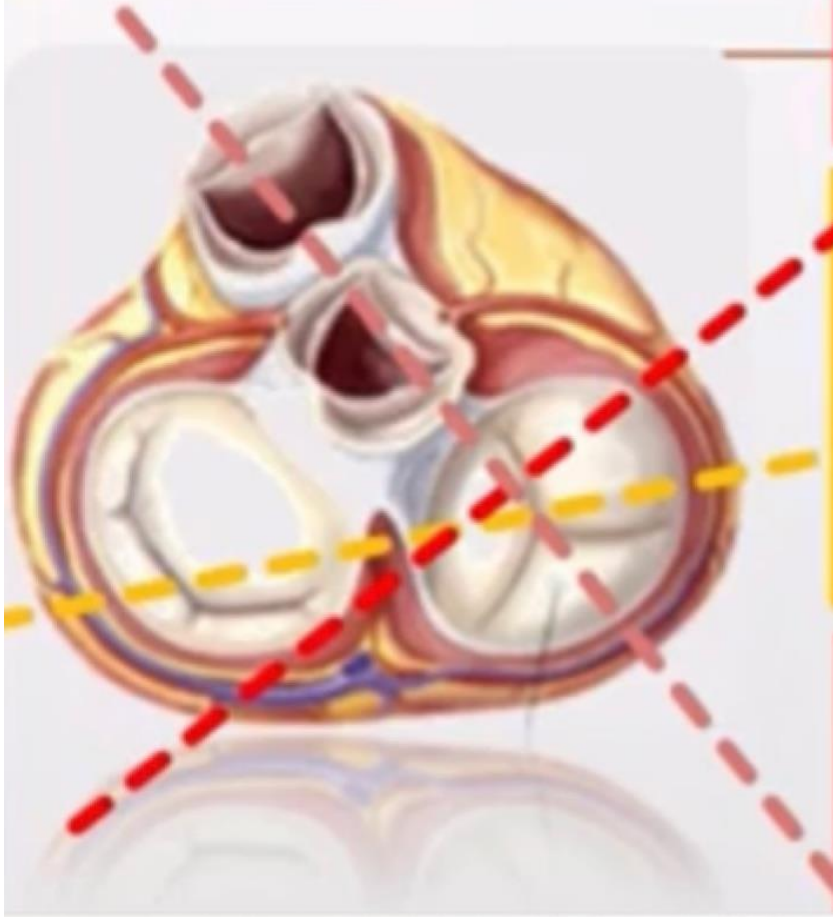
Circ Cardiovasc Imaging. 2015;8:e003241

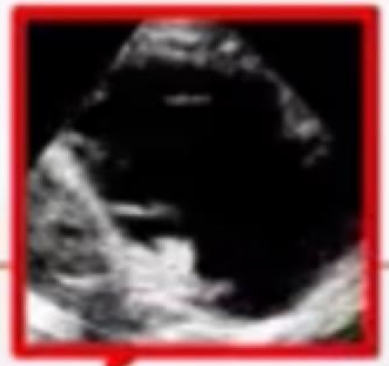
surgical and Echo (2D and 3D) was moderate and SD large

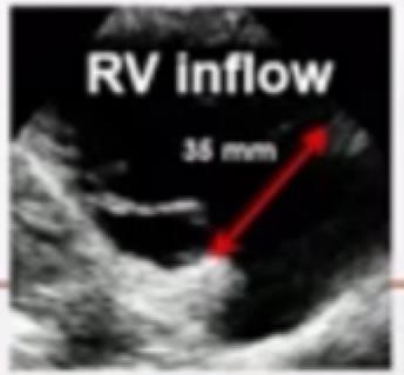


2D Echo?

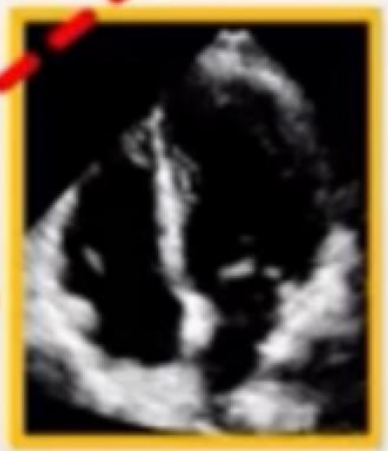
Feasibility of the measurement

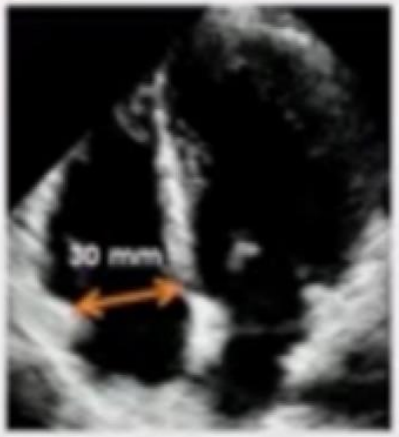




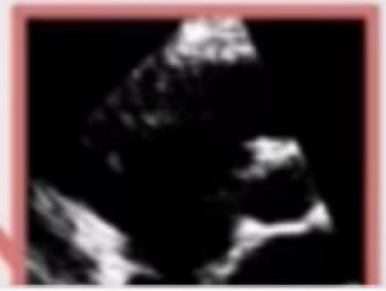


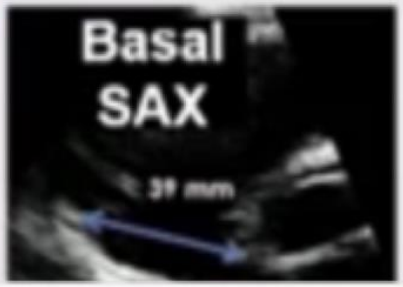
83.6%





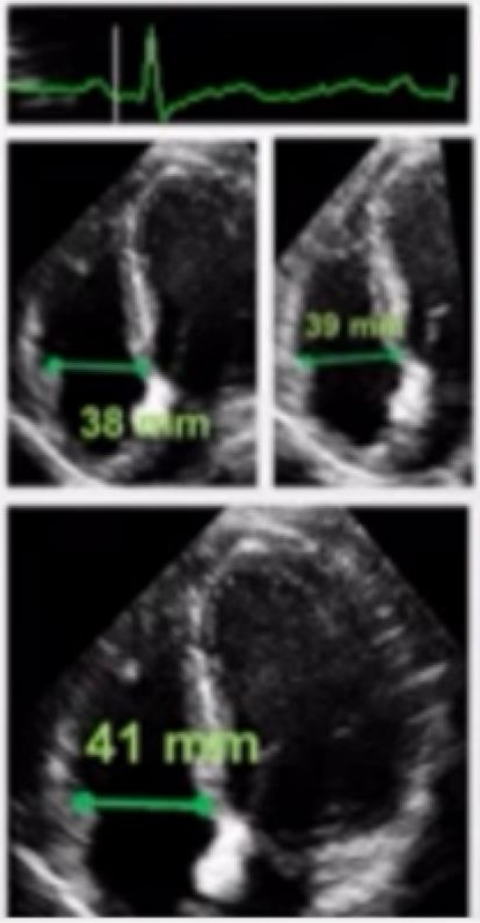
99.5%

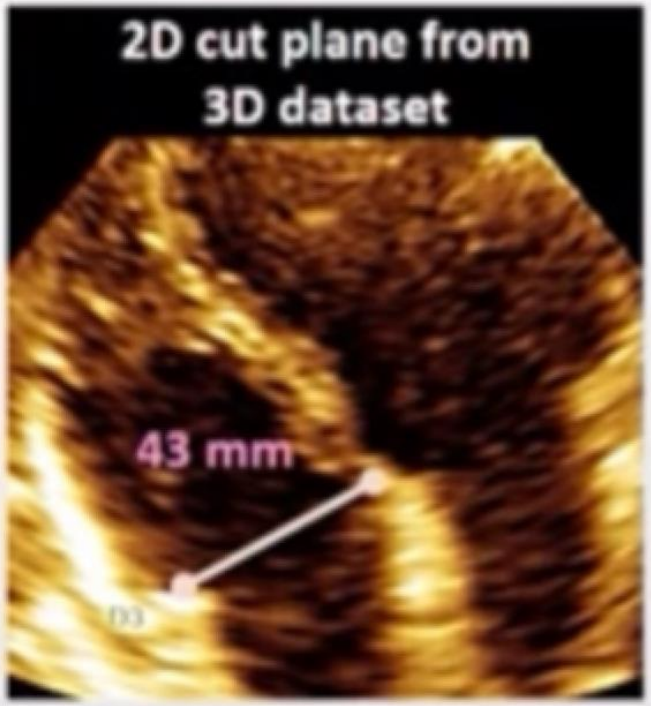




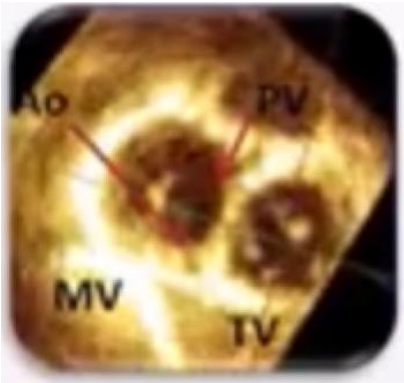
55%

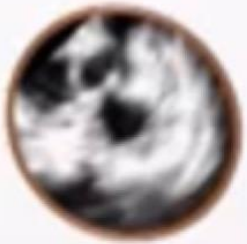
Role for 3D echocardiography: 2D underestimates TA diameter





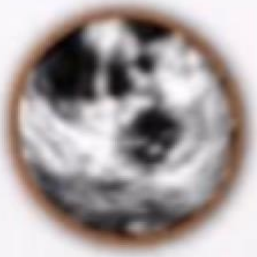
All from the
same patient





TV closure

Mid-systole

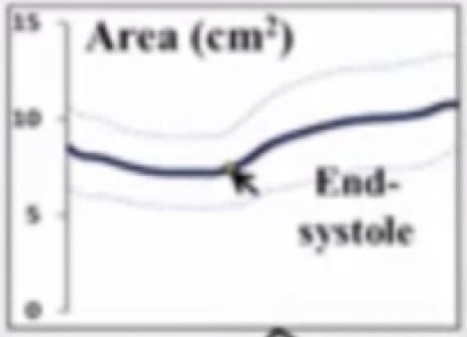


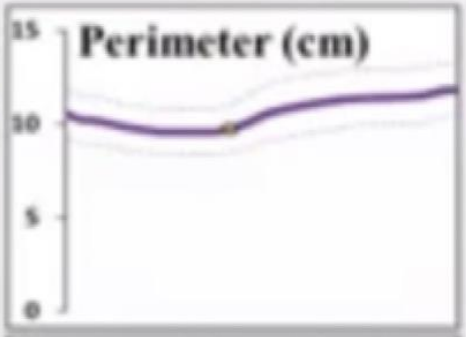
End-systole

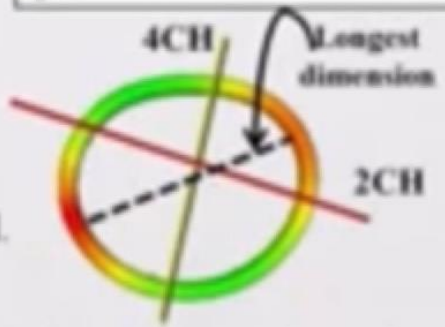
Early diastole

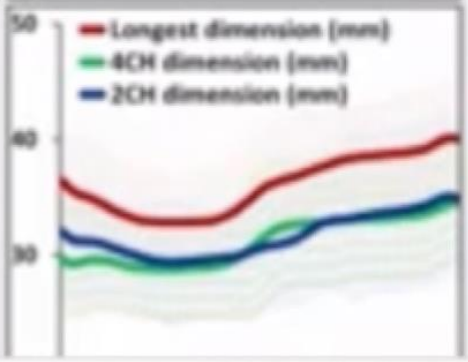
Late diastole

Muraru D…Addetia K…Lang RM, Badano LP et. al.







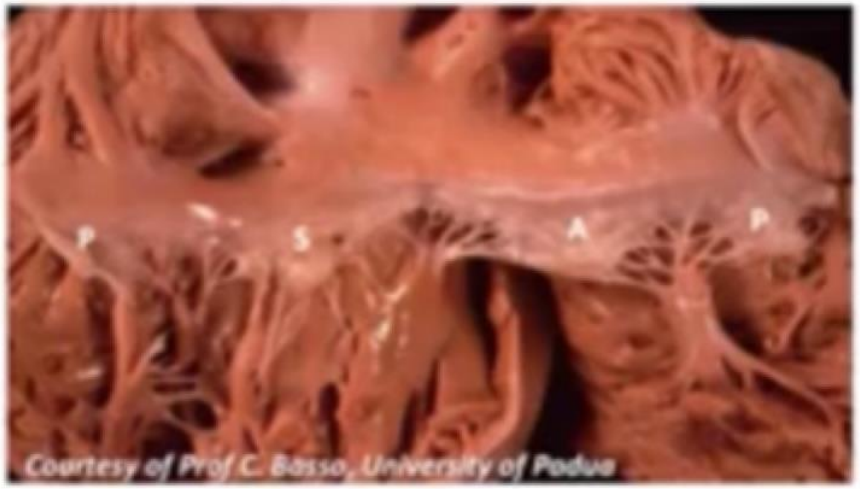


TRICUSPID VALVE ANATOMY AND FUNCTION

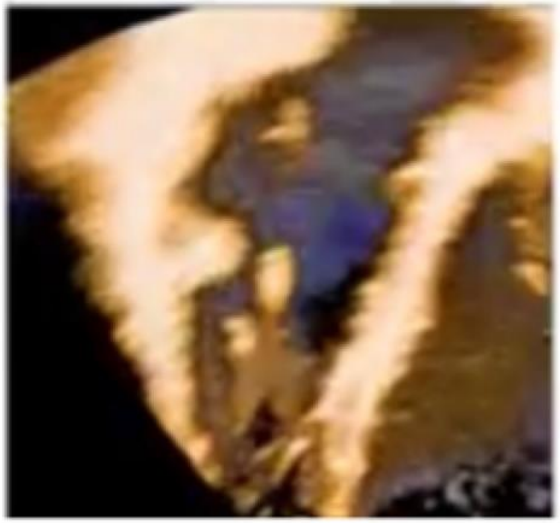
Tricuspid Valve Apparatus:

- Leaflets ☑
- Annulus ☑
- Chordae ☑
- Papillary muscles ☑
- Right ventricle ☑

Effective valve function depends on the **structural integrity** and **dynamic functional coordination** of all these components.

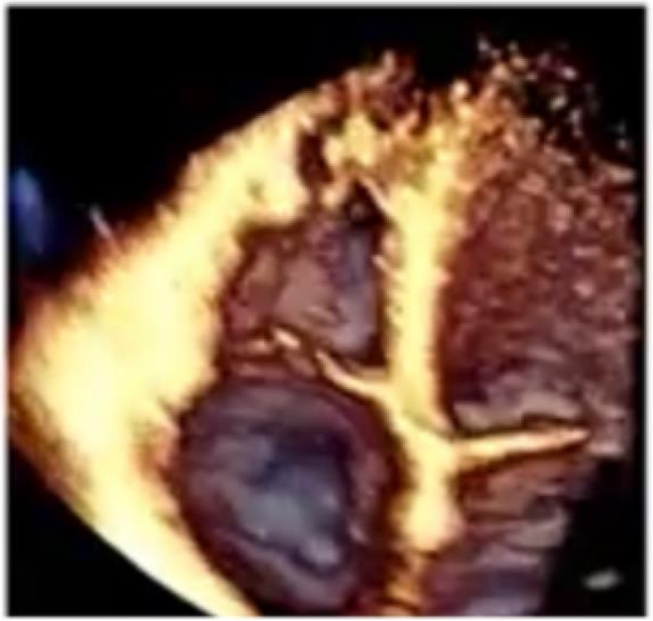


Courtesy of Prof C. Basso, University of Padua

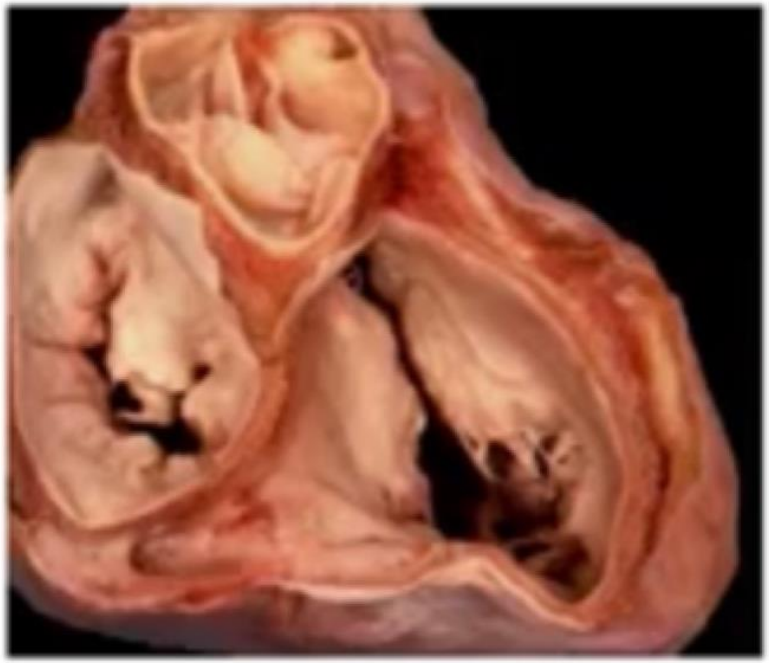


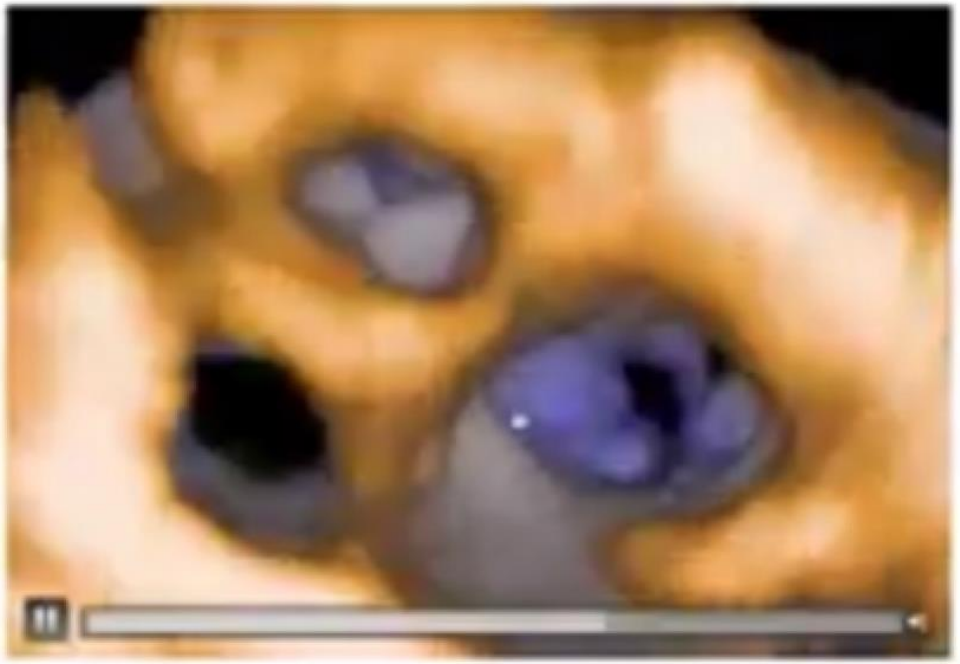
TRICUSPID VALVE ANATOMY AND FUNCTION

- TV is the largest and most caudally located among the four cardiac valves.
- Normal TV is thinner than the mitral valve due to lower right-sided pressures



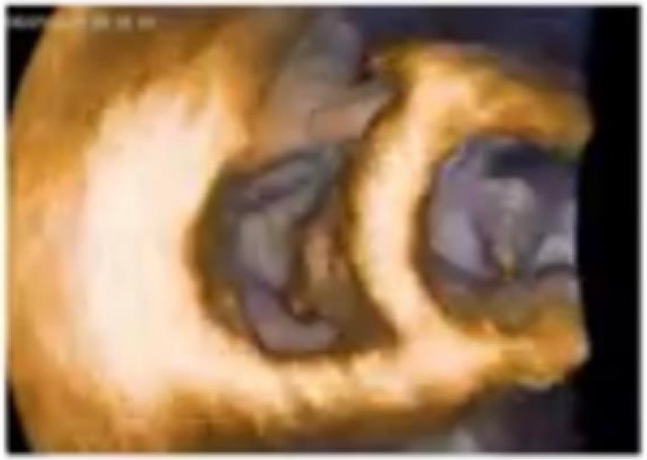
TV SPATIAL RELATIONSHIPS



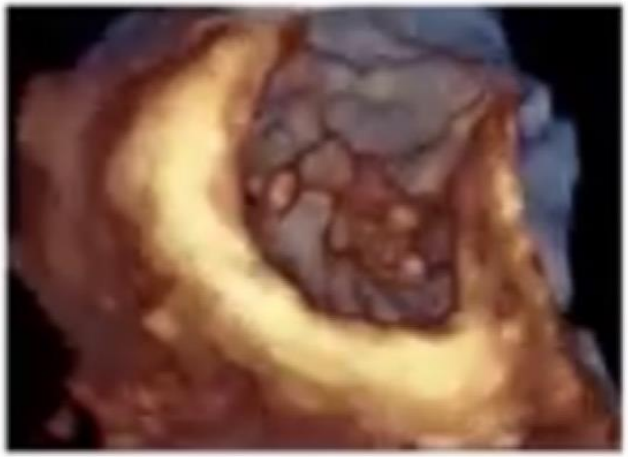


GREATER ANATOMIC VARIABILITY THAN MITRAL VALVE

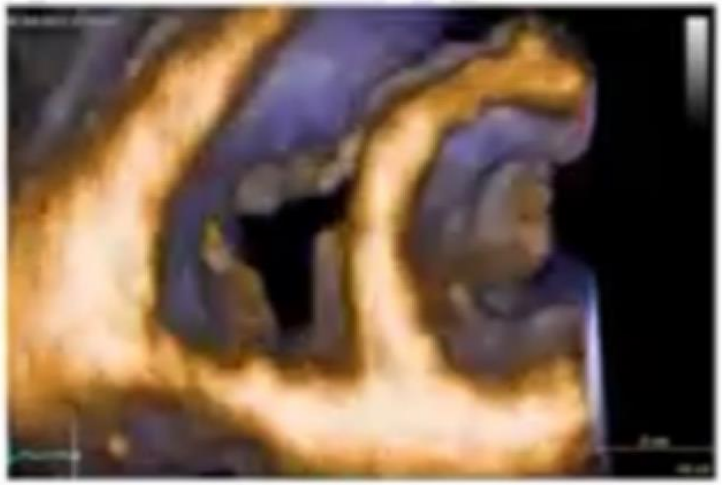
How many leaflet has the *tri*cuspid valve?



2...



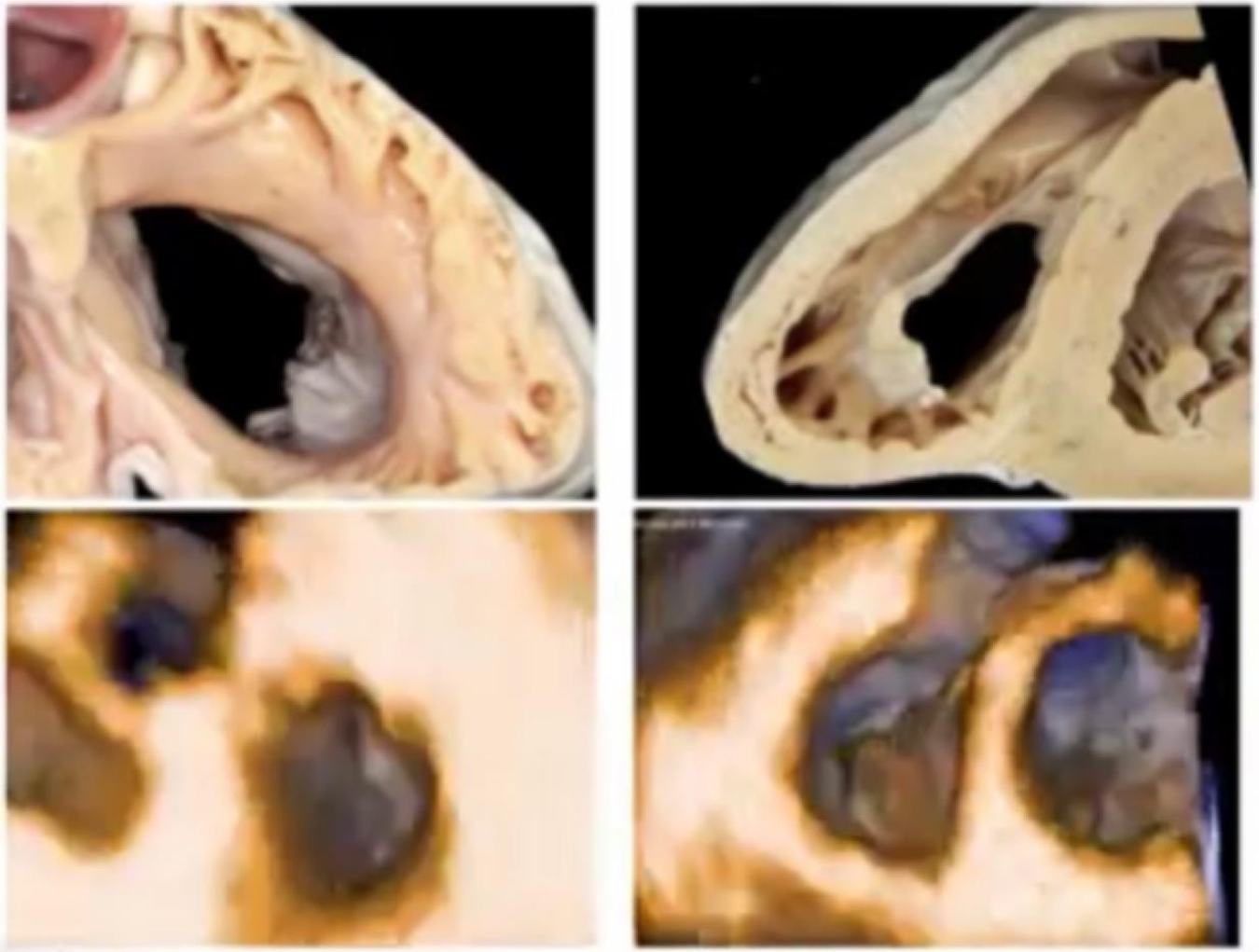
... or 4!



3...

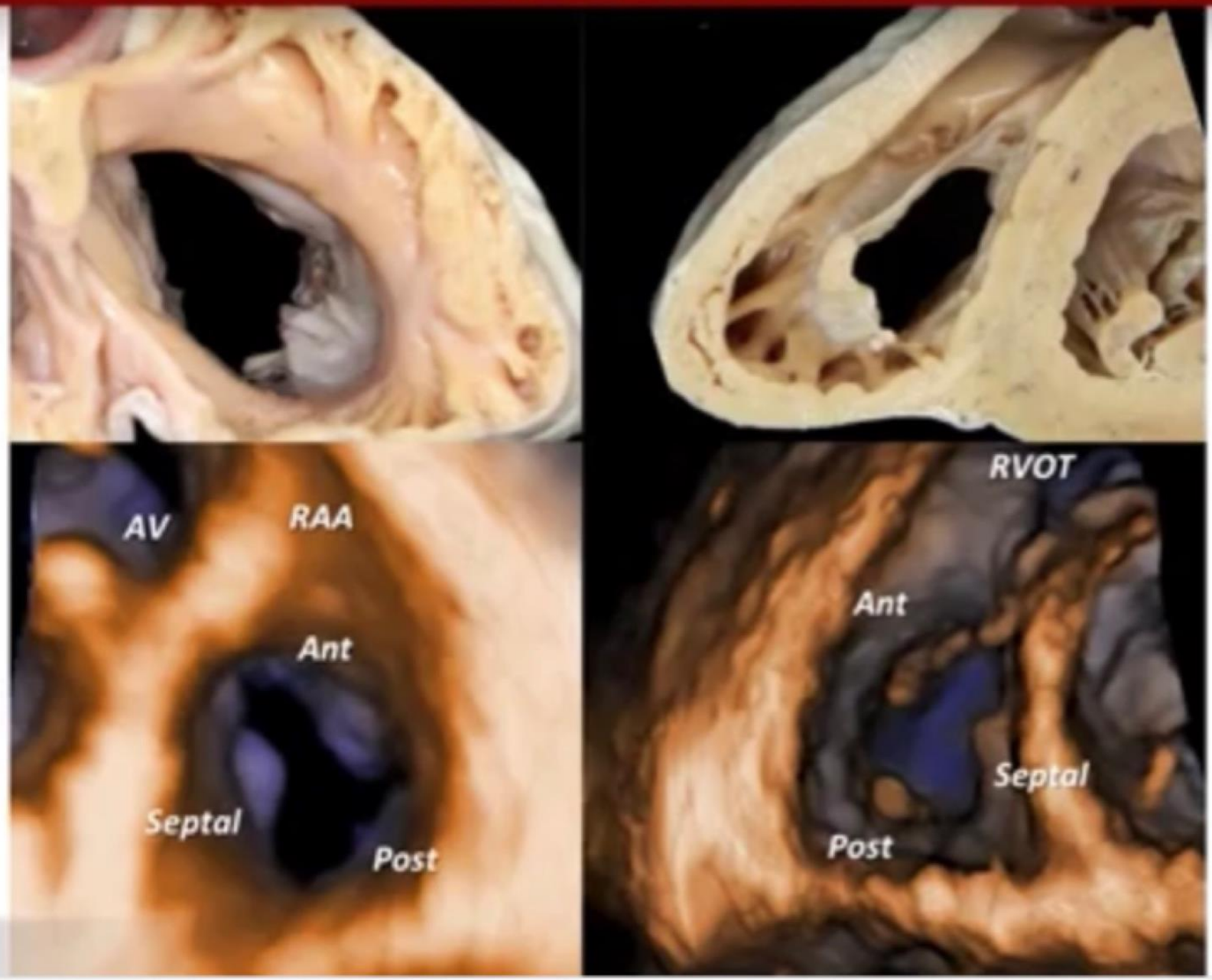
TRICUSPID VALVE ANATOMY AND FUNCTION

En face views of the tricuspid valve



Basso C, Muraru D, Badano LP, Thiene G.
In Rajamannan N ed. Cardiac valvular medicine 2012

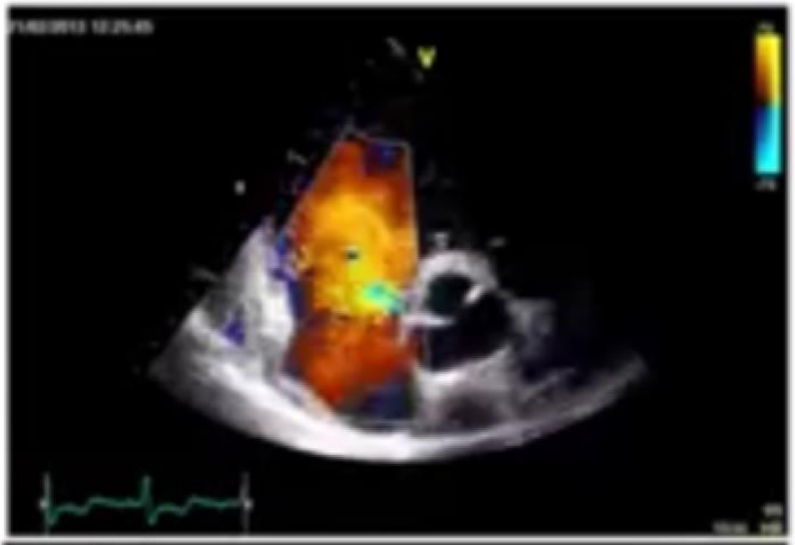
TRICUSPID VALVE ANATOMY AND FUNCTION

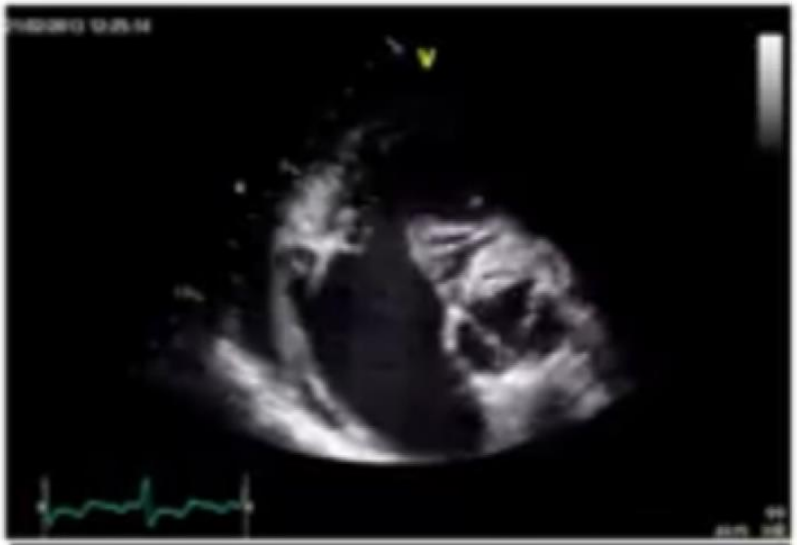


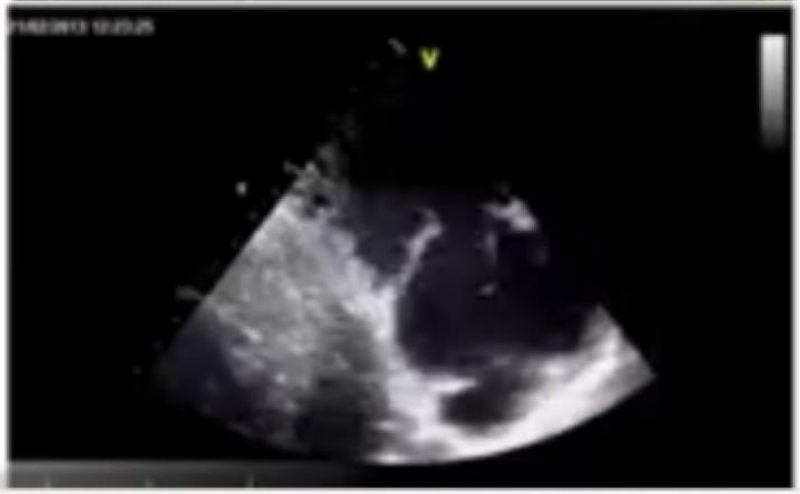
TRICUSPID LEAFLET IDENTIFICATION

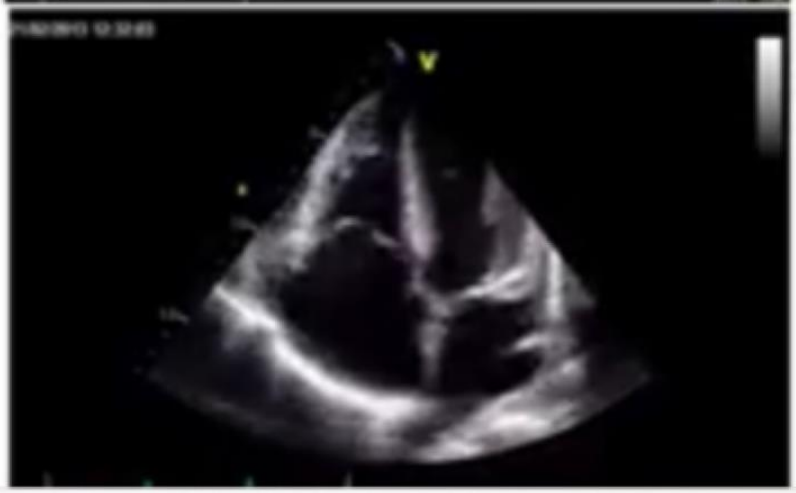
Clinical case

- 31-year-old woman, IVDA, fever

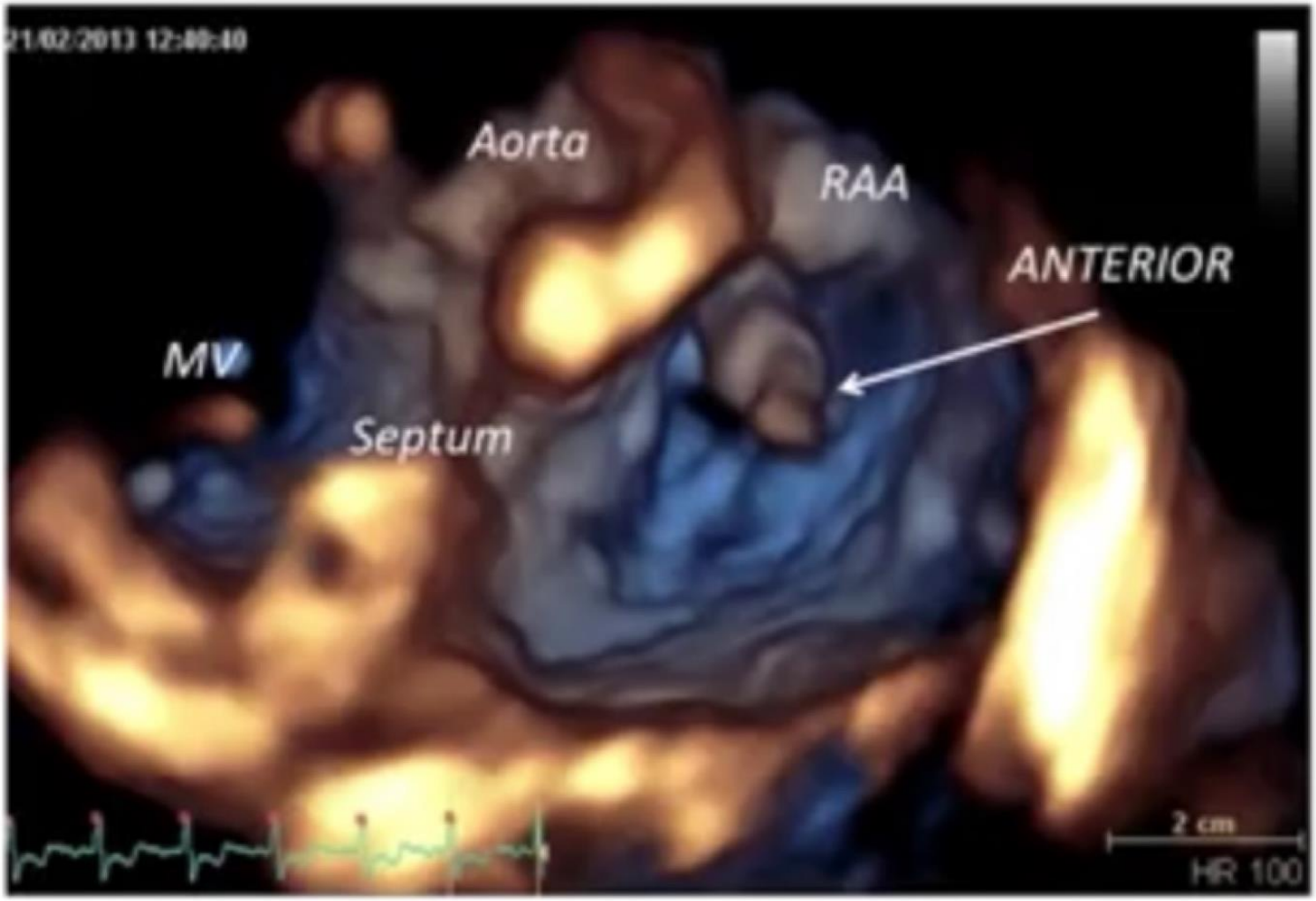






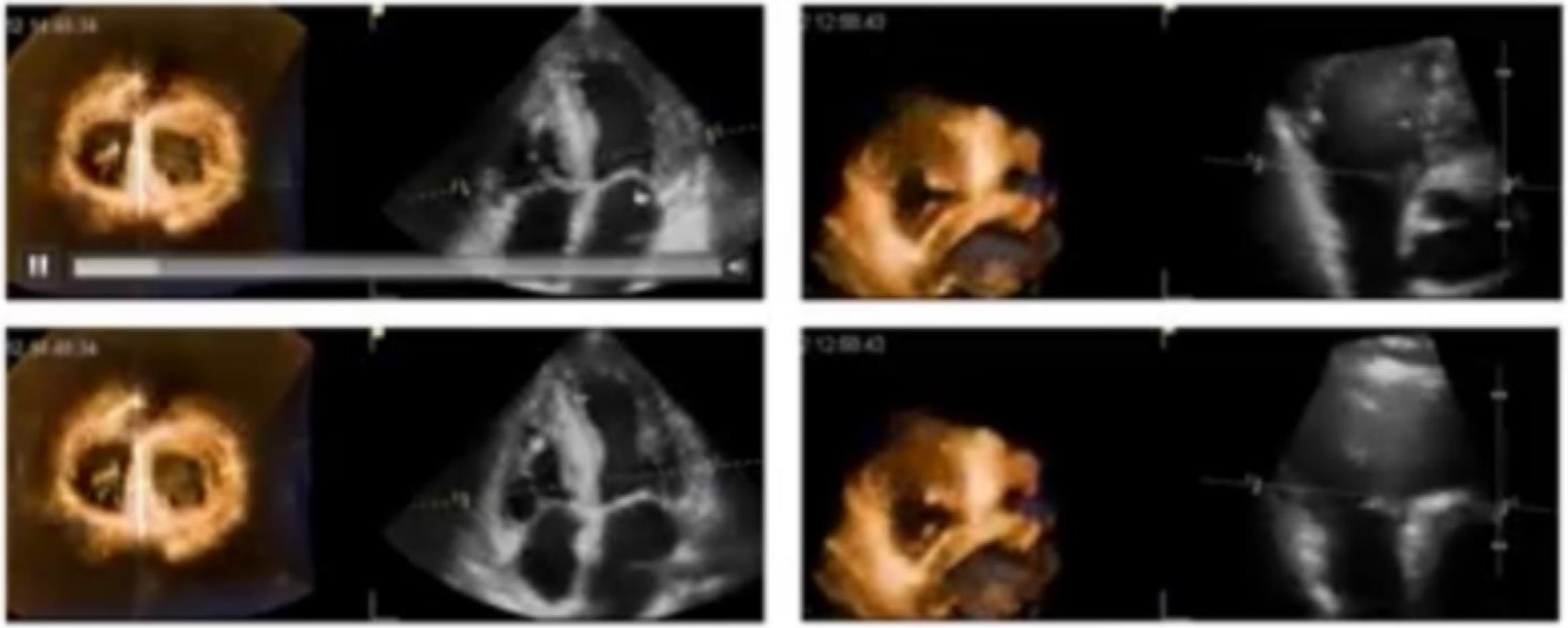


TRICUSPID LEAFLET IDENTIFICATION



TRICUSPID VALVE - LIMITATIONS OF 2D ECHO

- By 2DE, visible leaflets may vary in any standard echo view due to variability in leaflet morphology and imaging plane

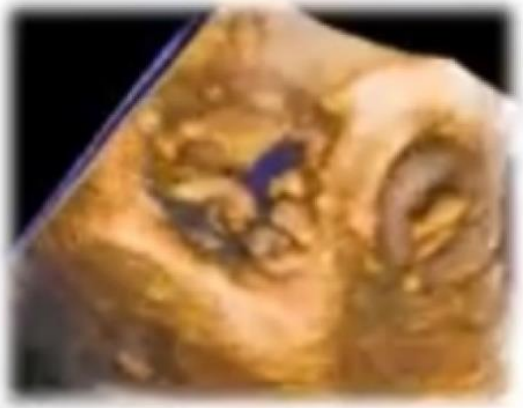


3D echocardiography allows a more complete and reliable assessment of TV leaflets, and the correct identification of individual leaflet involvement

AETIOLOGY OF TRICUSPID REGURGITATION

Functional (secondary)

- ☐ *Normal leaflets (80-90%)*
- ☐ Pulmonary hypertension
- ☐ Right ventricular dilation
- ☐ Right ventricular dysfunction
- ☐ Atrial fibrillation



Tethered leaflets and dilated annulus
- view from the ventricle

Organic (primary)

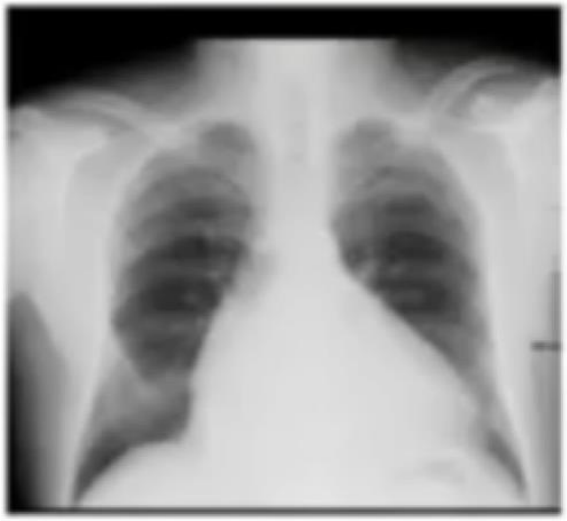
- ☐ *Leaflet abnormalities (10-20%)*
- ☐ Prolapse
- ☐ Rheumatic
- ☐ Congenital
- ☐ Endocarditis
- ☐ Carcinoid
- ☐ Traumatic
- ☐ Iatrogenic

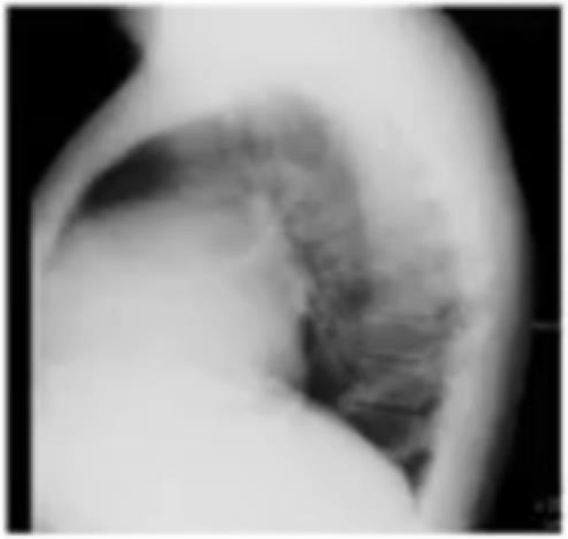
TV flail leaflet
- view from the atrium

TRICUSPID REGURGITATION

Clinical case

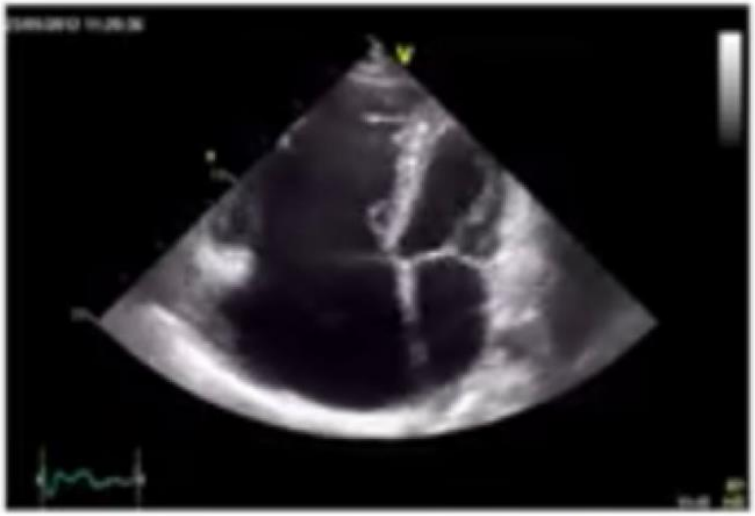
- 50-yr-old caucasian man
- Functional class III (NYHA)
- Clear lungs
- Leg oedema
- ECG: AFib, RBBB
- ECG Holter: non-sustained VT run
- Echo: RV enlargement with severe TR

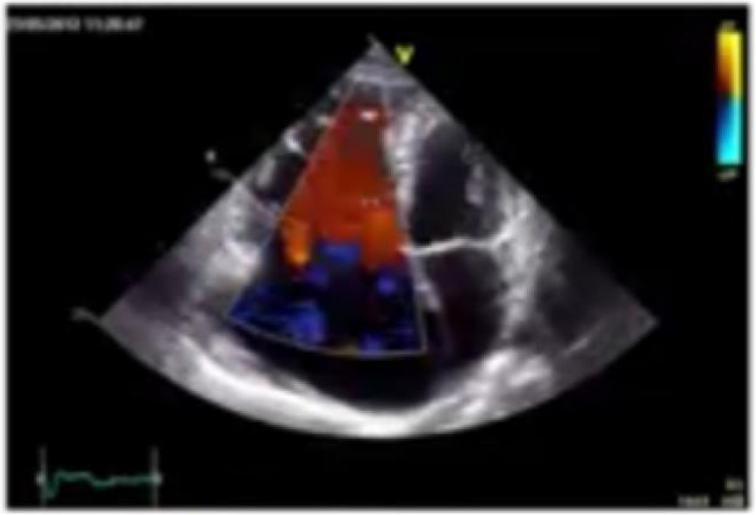


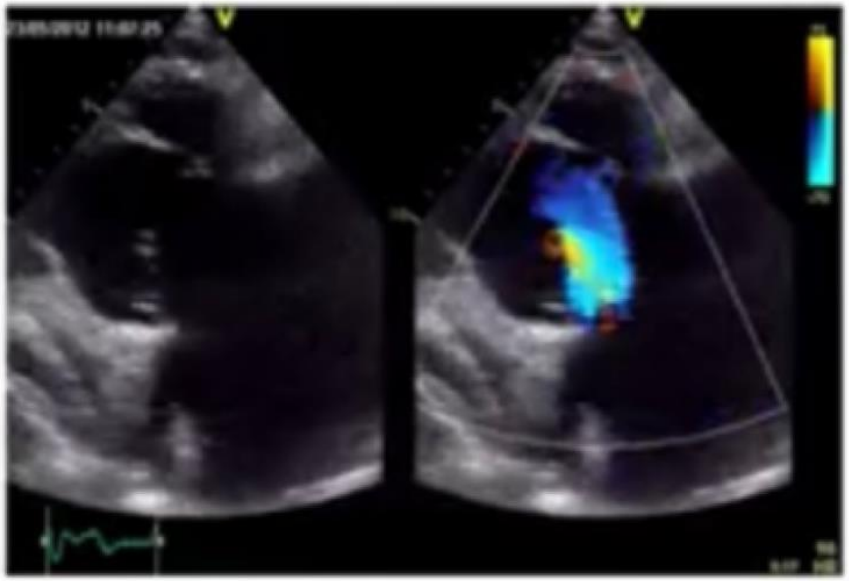


TRICUSPID REGURGITATION

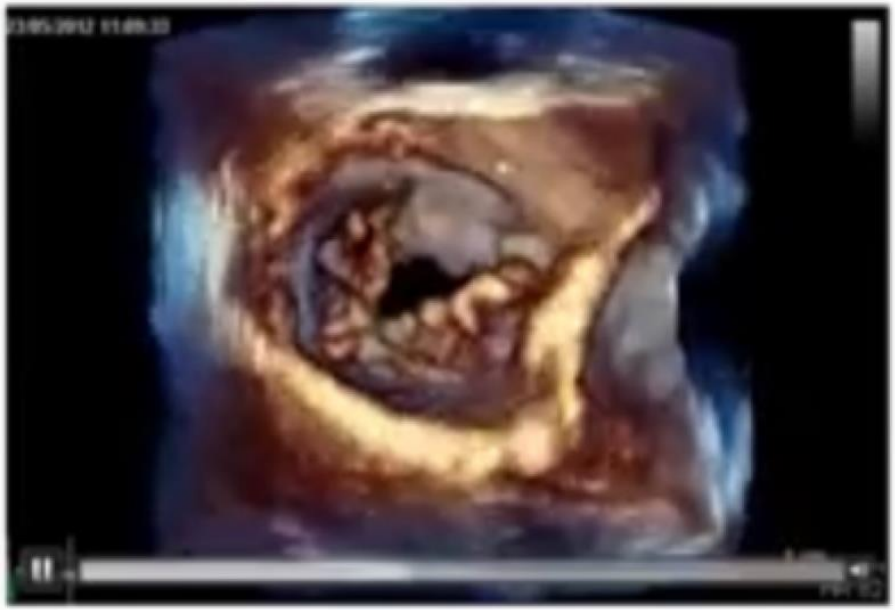
Functional TR >> TV annuloplasty

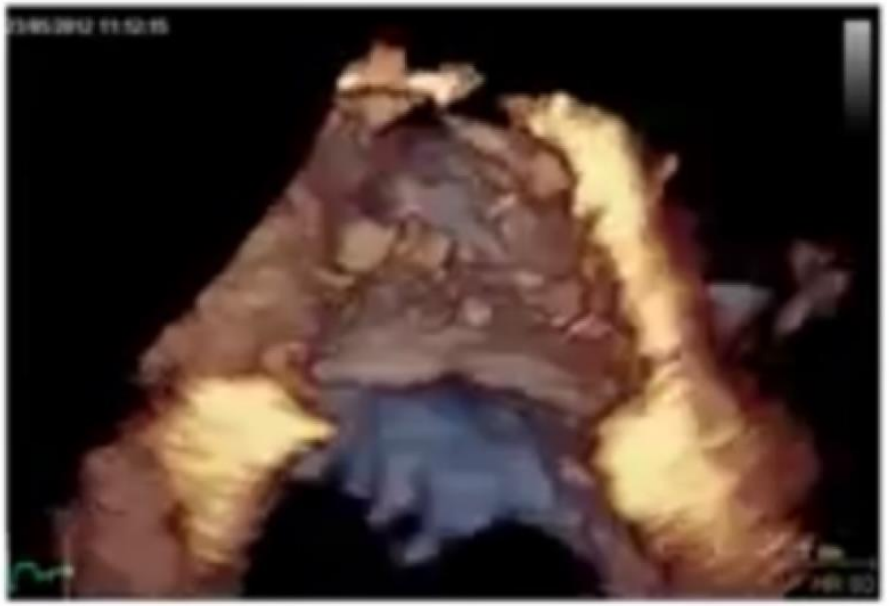






TRICUSPID REGURGITATION

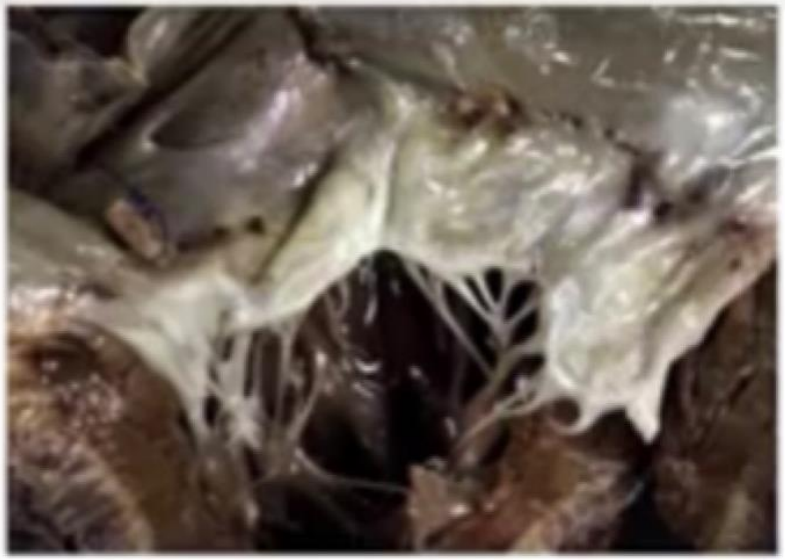


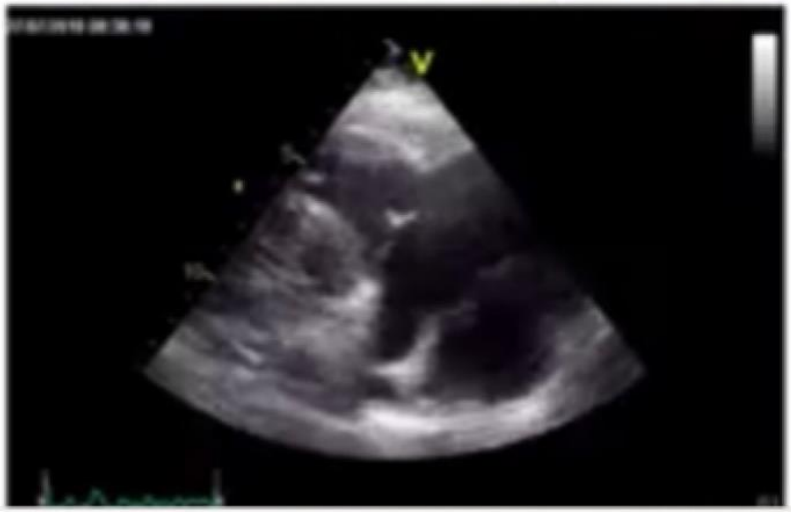


TRICUSPID REGURGITATION

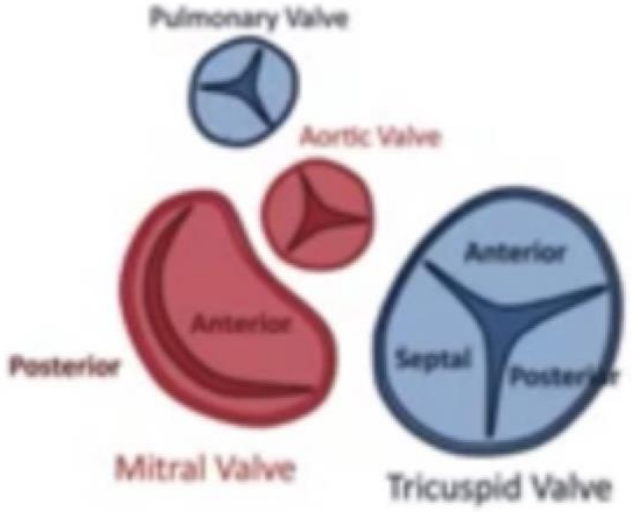
Rheumatic TV disease

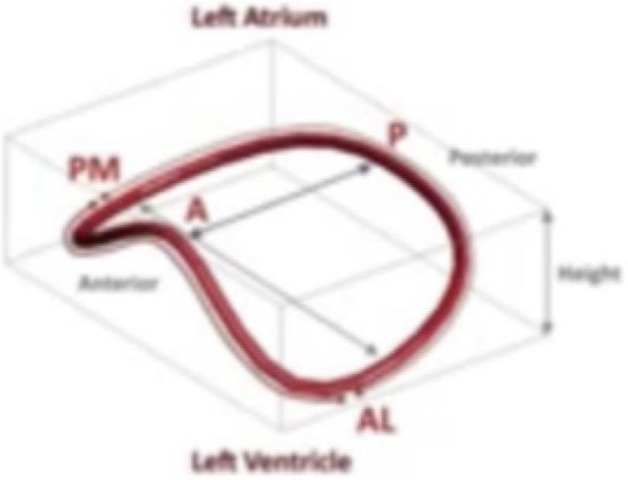
- Diffuse fibrous thickening of the leaflets
- Fusion of the commissures
- Calcification is usually absent
- Chordae tendineae may be thickened and shortened, but chordal fusion is less frequent than in the MV

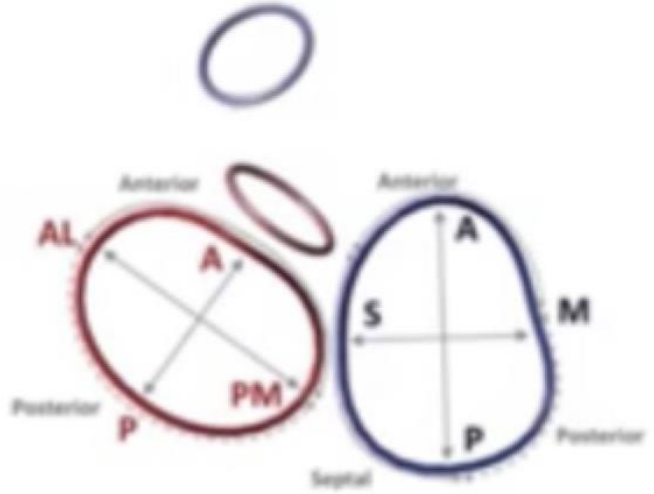


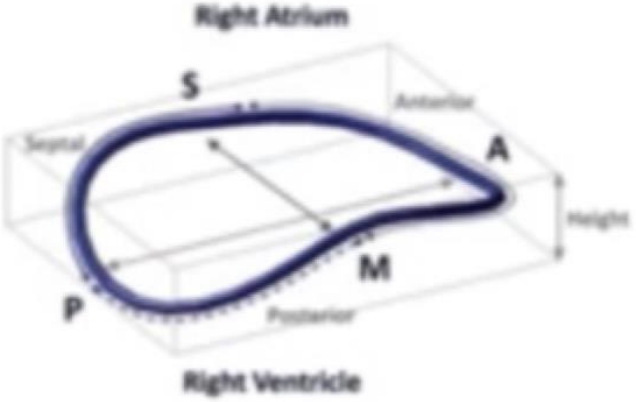


TRICUSPID ANNULUS SADDLE SHAPE



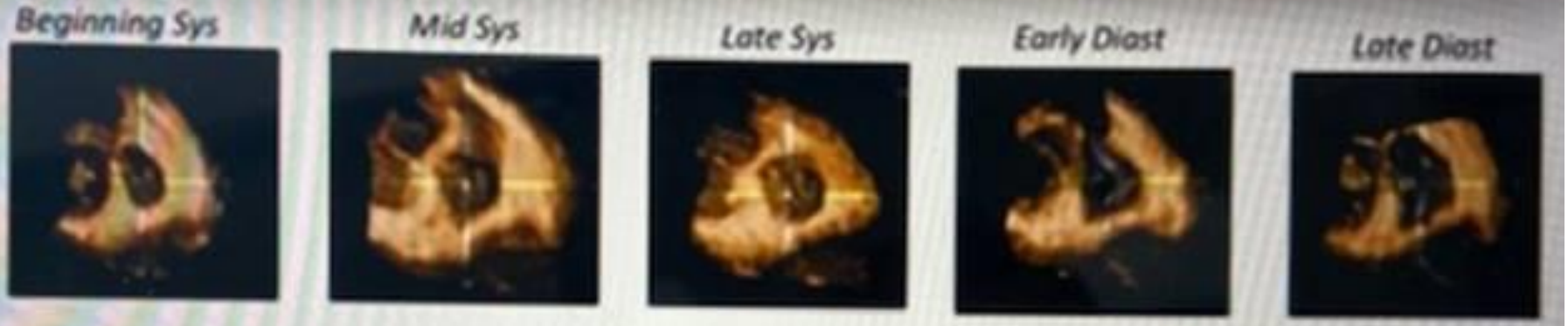






Maffessanti F et al. Eur Heart J Cardiovasc Imaging 2013

Tricuspid Annulus is a Highly Dynamic Structure



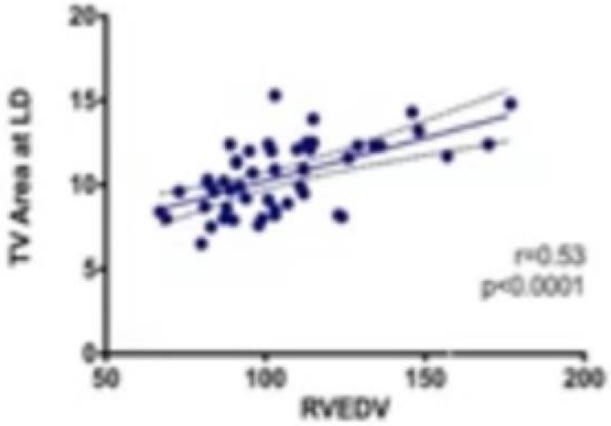
N=98 healthy subjects
Aged 19-80 years

- Largest TA area was in late-diastole and the smallest at the onset of systole
- Average TA fractional area change was close to 40%.
- Antero-posterior diameter was larger than the septo-lateral dimension throughout the cardiac cycle
- Relative changes in antero-posterior direction were larger than in septo-lateral direction (23% and 18%, respectively).

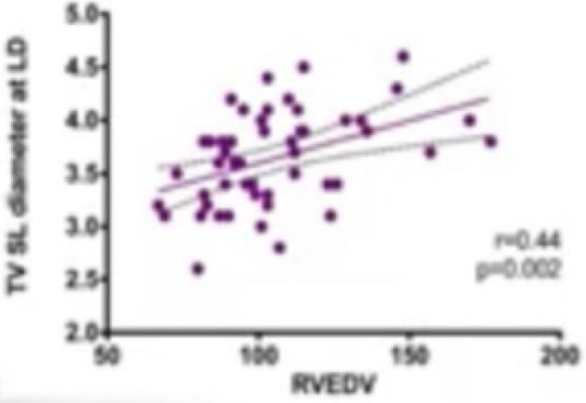
TRICUSPID VALVE ANATOMY AND FUNCTION

Tricuspid annulus size is related to right ventricular volume

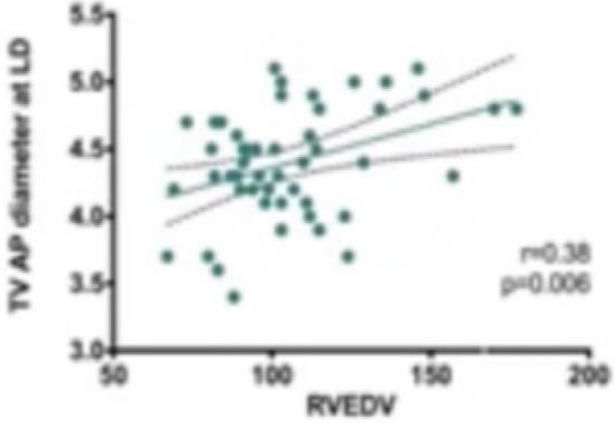
Correlation of TA area with RV size



Correlation of TA SL diameter with RV size



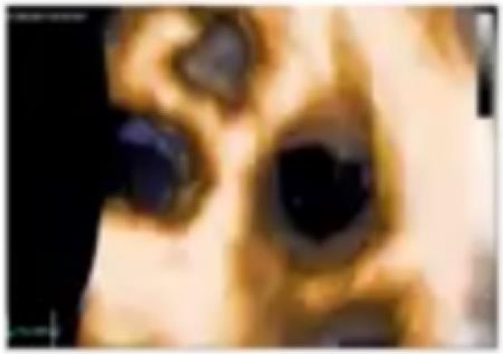
Correlation of TA AP diameter with RV size



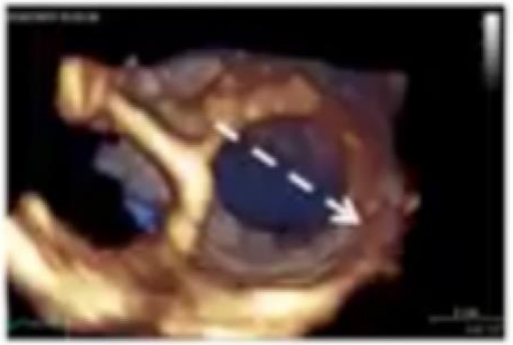
Muraru D, Addetia K et al. Eur Heart J Cardiovasc Imag 2013 (abstract)

TRICUSPID ANNULUS SHAPE CHANGES IN FTR

Normal



Functional TR



- Annulus becomes larger, rounder and flatter with worsening TR
- Annular dilation does not evolve in a symmetric fashion

Tricuspid Regurgitation-2020

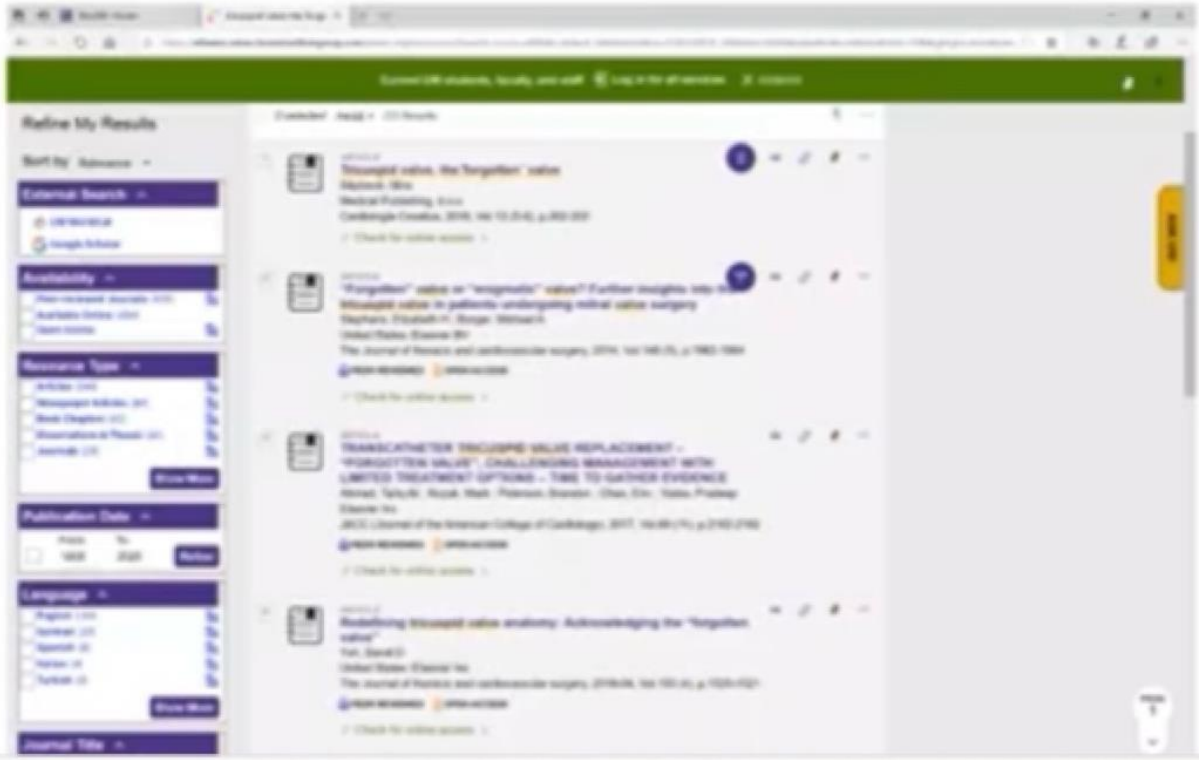
A search for the "forgotten valve"

Who to treat

When to treat

Method of therapy

- Medical therapy
- Surgical
- Percutaneous
  - Which technology



Tricuspid Regurgitation-2020

A search for the "forgotten valve"

Who to treat

When to treat

Metho

Medi

Surgi

Percu

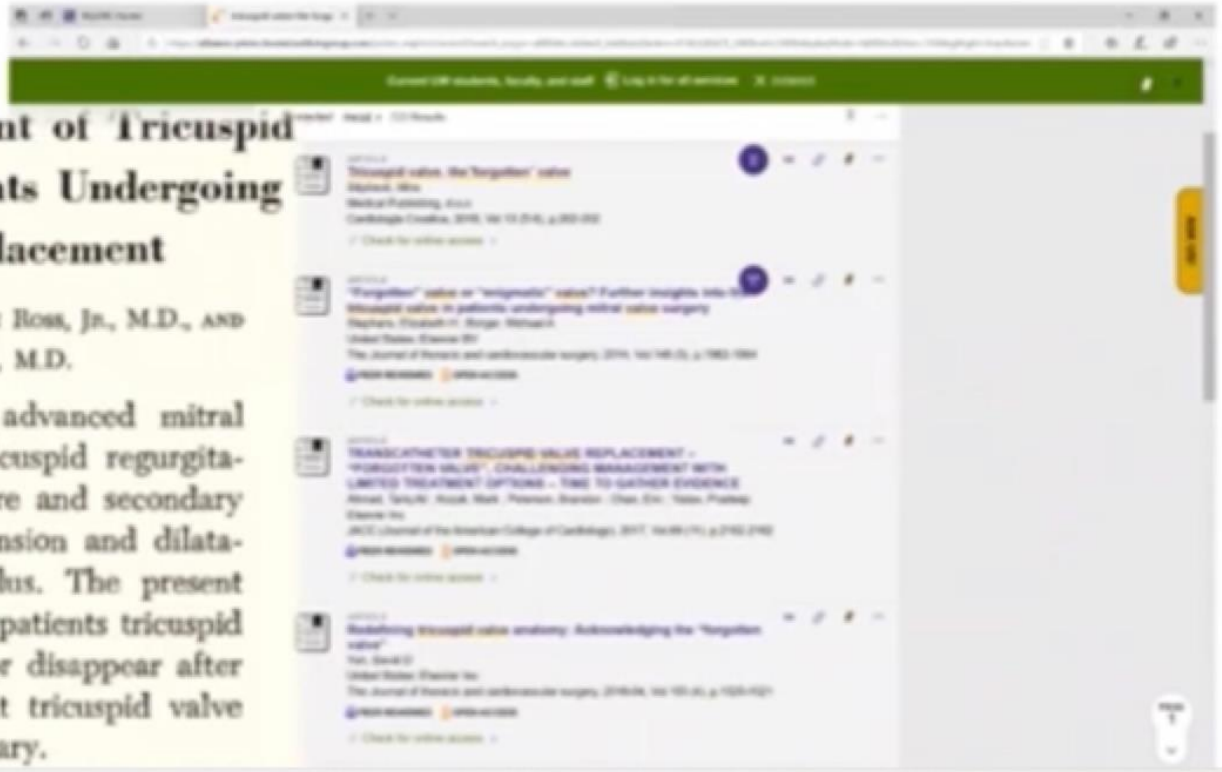
Which

Conservative Management of Tricuspid Regurgitation in Patients Undergoing Mitral Valve Replacement

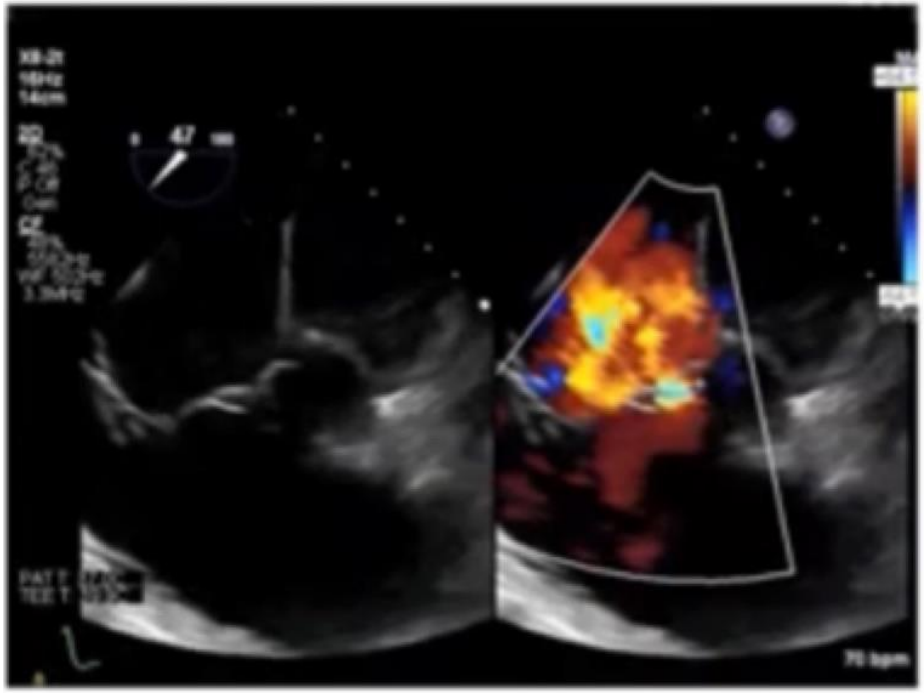
By Nina S. Braunwald, M.D., John Ross, Jr., M.D., and Andrew G. Morrow, M.D.

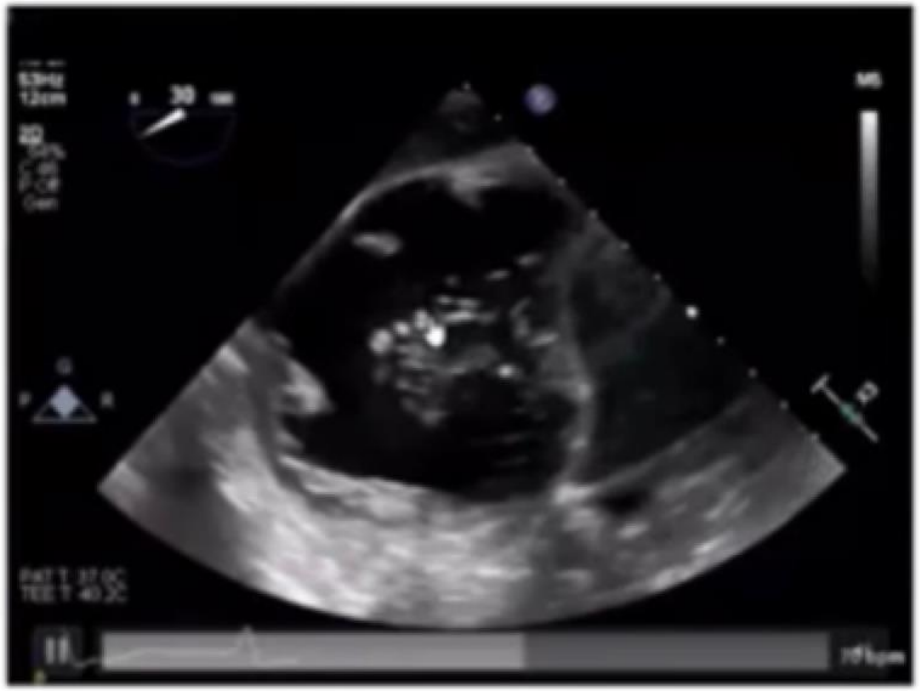
Summary

In many patients with advanced mitral valve disease, associated tricuspid regurgitation is of a functional nature and secondary to right ventricular hypertension and dilatation of the tricuspid annulus. The present results indicate that in such patients tricuspid regurgitation will improve or disappear after mitral replacement and that tricuspid valve replacement is seldom necessary.



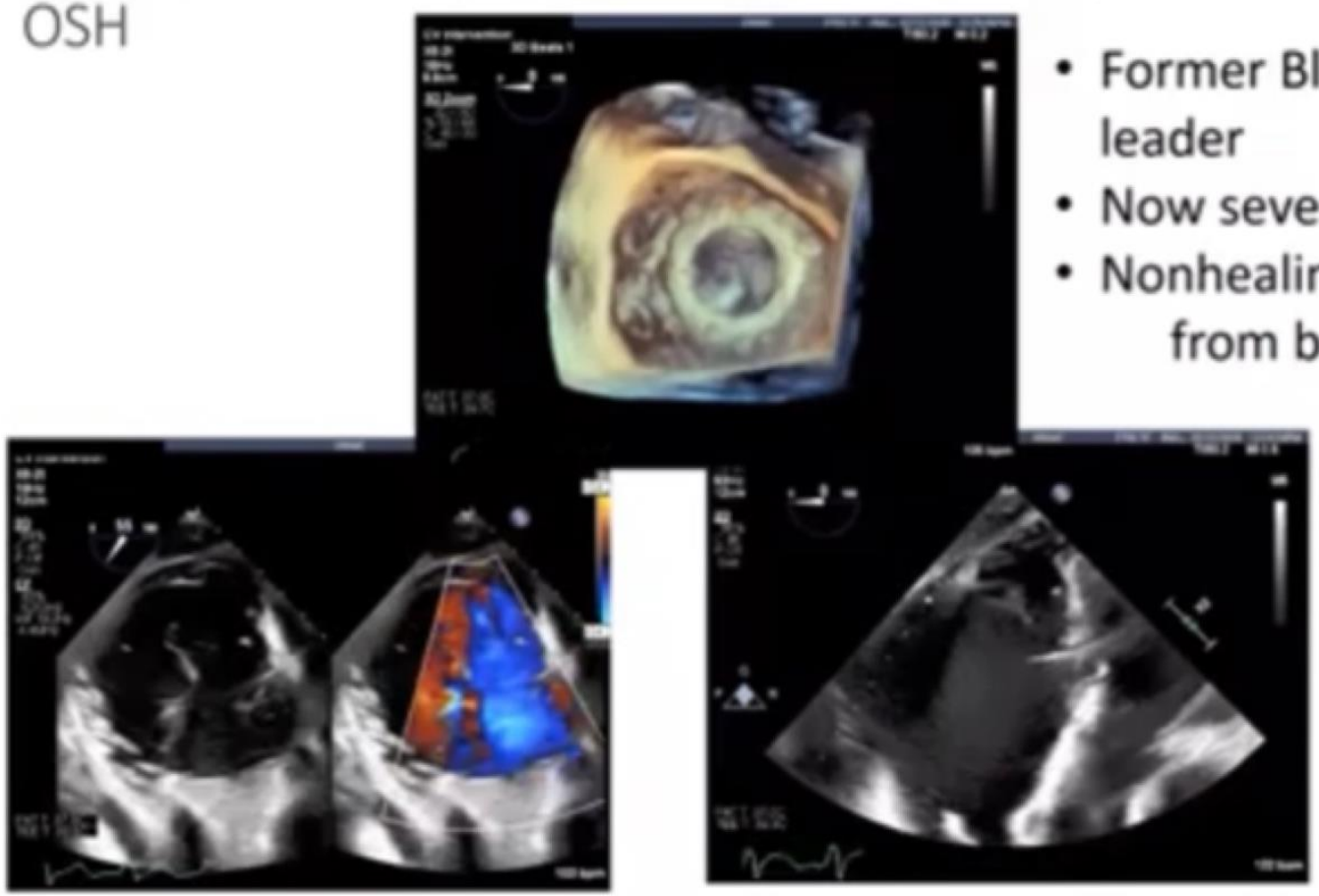
Severe TR-multiple admissions for hepatic encephalopathy





Hospitalized, somnolent, difficult to arouse

s/p mitral valve repair -120 day hospital stay, referred from OSH



- Former Blue Angel squadron leader
- Now severely debilitated
- Nonhealing pressure sore from being bedridden


Current TR Treatment
Recommendations and
Outcomes

Guidelines for Tricuspid Regurgitation	ESC/ EACTS	AHA/ ACC
Primary TR		
Symptomatic isolated severe TR without severe RV dysfunction	I	IIa
Severe TR undergoing left-side surgery	I	I
Moderate TR undergoing left-side surgery	IIa	NM
Asymptomatic isolated mild or moderate TR and progressive RV dilatation or RV function deterioration	IIa	IIb (only for severe TR)
Secondary TR		
Severe TR undergoing left-side surgery	I	I
Mild or moderate TR at the time of left-side surgery with either dilated annulus (≥40 mm or >21 mm/m^2) or prior evidence of right heart failure	IIa/IIb[a]	IIa
Moderate TR and PH undergoing left-side surgery	NM	IIb
After left-side surgery, severe TR with symptoms OR progressive RV dilatation/dysfunction but without severe RV or LV dysfunction, left-sided valve dysfunction and severe PH	IIa	IIb[b]

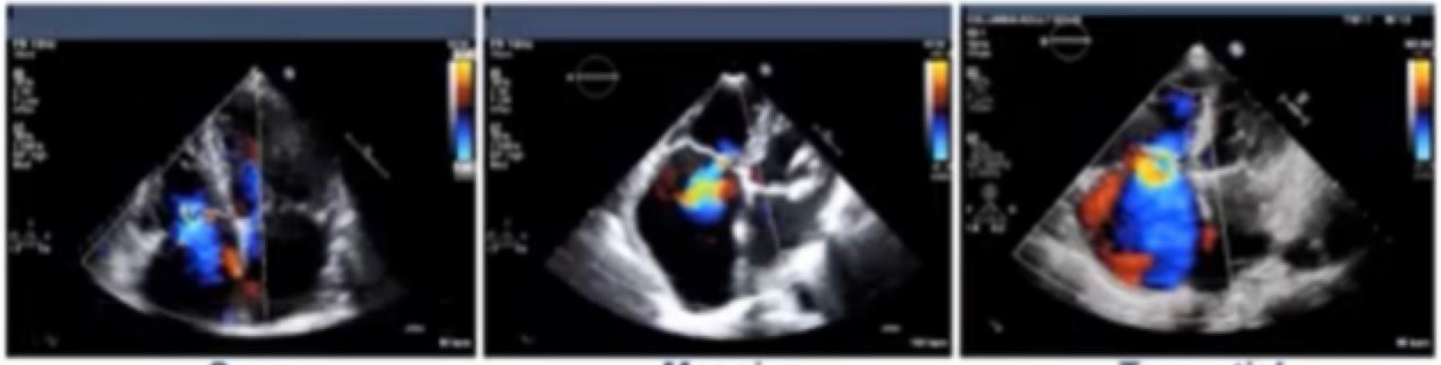
Tricuspid Regurgitation
Extended Grading scheme

Table 1 **Proposed expansion of the 'Severe' grade**

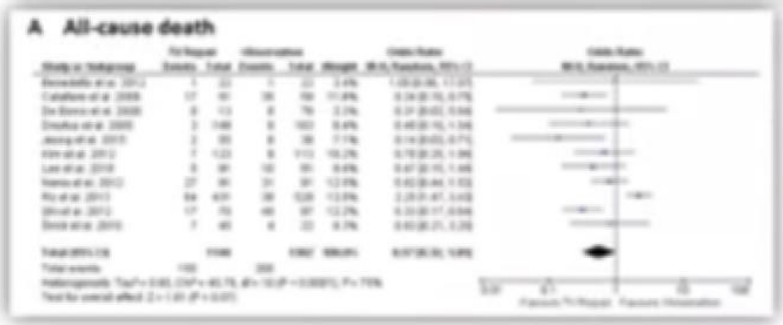
Variable	Mild	Moderate	Severe	Massive	Torrential
VC (biplane)	<3 mm	3-6.9 mm	7-13 mm	14-20 mm	≥21 mm
EROA (PISA)	<20 mm^2	20-39 mm^2	40-59 mm^2	60-79 mm^2	≥80 mm^2
3D VCA or quantitative EROA*			75-94 mm^2	95-114 mm^2	≥115 mm^2

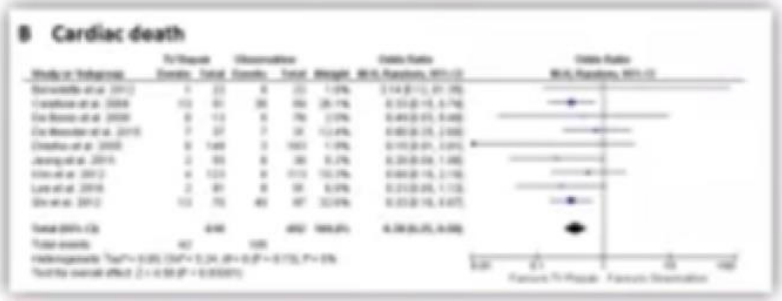
VC, vena contracta; EROA, effective regurgitant orifice area; 3D VCA, three-dimensional vena contracta area.
*3D VCA and quantitative Doppler EROA cut-offs may be larger than PISA EROA.

Rebecca T. Hahn, and Jose L. Zamorano. "The Need for a New Tricuspid Regurgitation Grading Scheme." European Heart Journal - Cardiovascular Imaging, 201

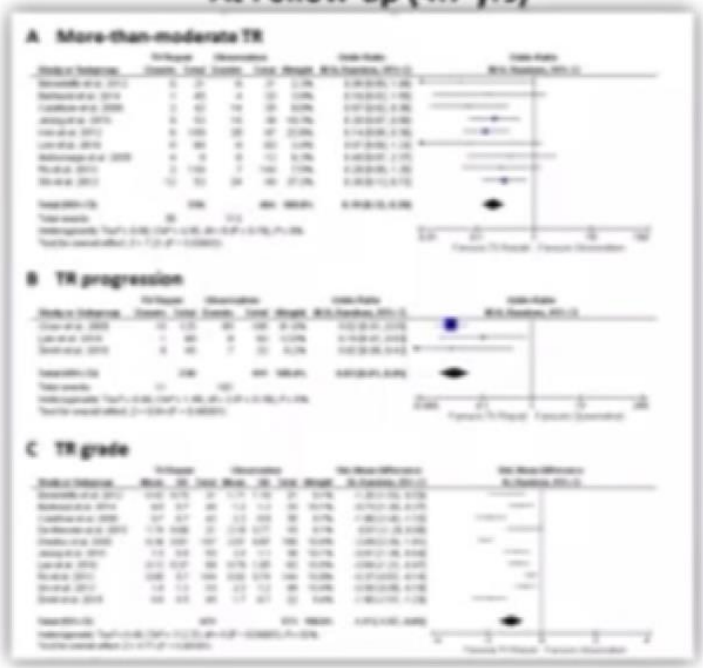


Severe ***Massive*** ***Torrential***





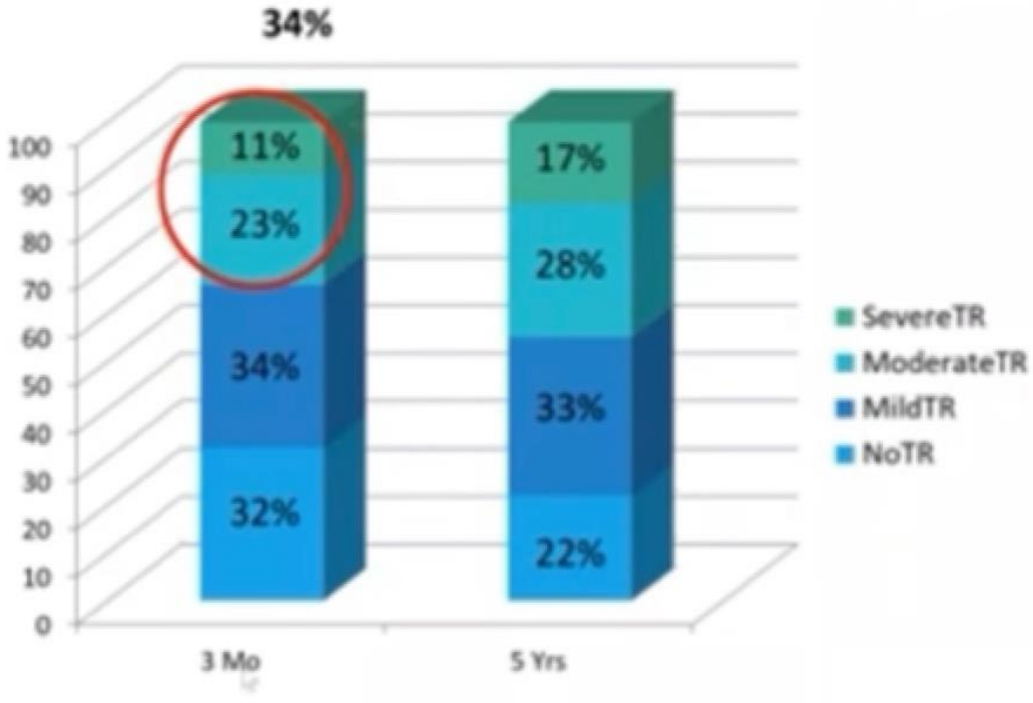
At Follow-up (4.7 yrs)



The present meta-analysis showed that a concomitant TV repair strategy at the time of left-sided valve surgery is associated with a lower risk of cardiac-related mortality and improved echocardiographic TR outcomes at long-term follow-up.

Pagnesi et al. International Journal of Cardiology 240 (2017) 138–144

Is Repair the Right Intervention?
Residual TR following TV Repair



Key point:
Eliminating secondary TR using an annuloplasty repair are imperfect, possibly because other anatomic levels (subvalvular, papillary muscle, and right ventricular) contributing to its pathophysiology are unaddressed

Predictors of Recurrence Post-TV Annular Repair

Predictors for residual regurgitation after surgical repair include:

- **Tricuspid Valve Variables**:
  - Greater preoperative TR severity
  - Tricuspid annular diameter
  - Advanced leaflet tethering (tethering distance, area, or volume)
- Presence and persistence of **severe pulmonary hypertension** after TV repair
- **Mitral replacement** rather than repair
- **Worse left ventricular dysfunction**
- Presence of **pacemaker leads** through the valve

ANNULAR REPAIR MAY NOT ALWAYS Be THE RIGHT OPERATION!

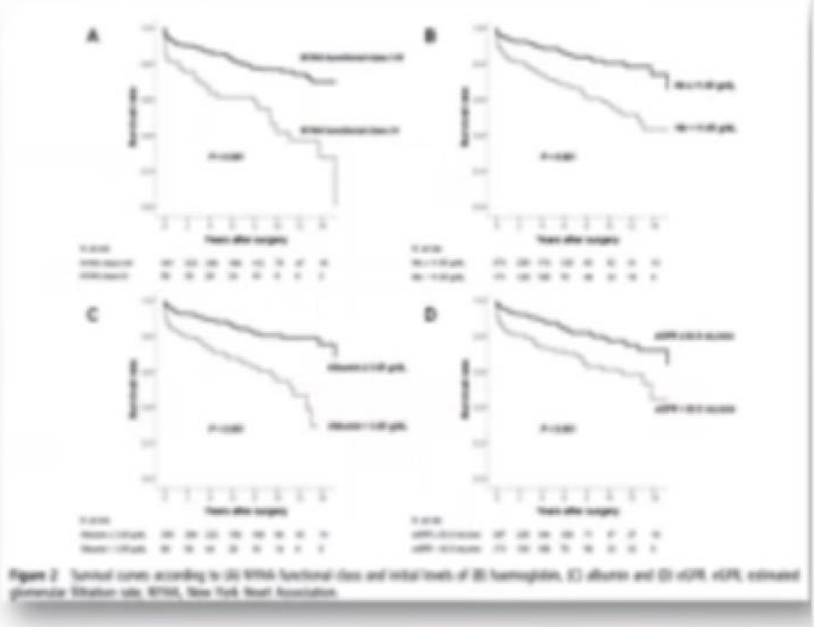
1. Fukuda S, Song JM, Gillinov AM et al. Tricuspid valve tethering predicts residual tricuspid regurgitation after tricuspid annuloplasty. Circulation 2005;111:975-9.
2. McCarthy PM, Bhudia SK, Rajeswaran J et al. Tricuspid valve repair: durability and risk factors for failure. J Thorac Cardiovasc Surg 2004;127:674-85.
3. Min SY, Song JM, Kim JH et al. Geometric changes after tricuspid annuloplasty and predictors of residual tricuspid regurgitation: a real-time three-dimensional echocardiography study. Eur Heart J 2010;31:2871-80.
4. Fukuda S, Gillinov AM, McCarthy PM et al. Determinants of recurrent or residual functional tricuspid regurgitation after tricuspid annuloplasty. Circulation 2006;114:I582-7.
5. Kabasawa M, Kohno H, Ishizaka T et al. Assessment of functional tricuspid regurgitation using 320-detector-row multislice computed tomography: risk factor analysis for recurrent regurgitation after tricuspid annuloplasty. J Thorac Cardiovasc Surg 2014;147:312-20.

449 consecutive patients who underwent TV surgery (397 repairs and 52 replacements) due to severe TR between 1997 and 2010.

Cox-regression analysis revealed independent determinants of mortality:

- Age (HR=1.03; 95% CI 1.01 to 1.05)
- Male gender (HR=1.96; 95% CI 1.29 to 2.99)
- NYHA functional class IV (HR=2.08; 95% CI 1.31 to 3.30)
- Liver cirrhosis (HR=2.51; 95% CI 1.11 to 5.68)
- Preoperative levels of hemoglobin (HR=0.89; 95% CI 0.80 to 0.99)
- Albumin (HR=0.52; 95% CI 0.33 to 0.81)
- GFR (HR=0.86; 95% CI 0.78 to 0.95)

WE OPERATE TOO LATE!!



Procedural type was not predictive of mortality (p=0.58) or causes of TR (p=0.97)

Percutaneous Approaches for Tricuspid Regurgitation