Tricuspid and Pulmonary Valve Disease- Still Forgotten in Time (15 minutes)

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Jewish General Hospital, McGill University
President, Canadian Society of Echocardiography

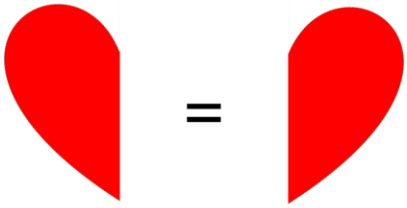
Disclosure: Small holding of GE Stock outside managed portfolio

McGill

Jewish General Hospital

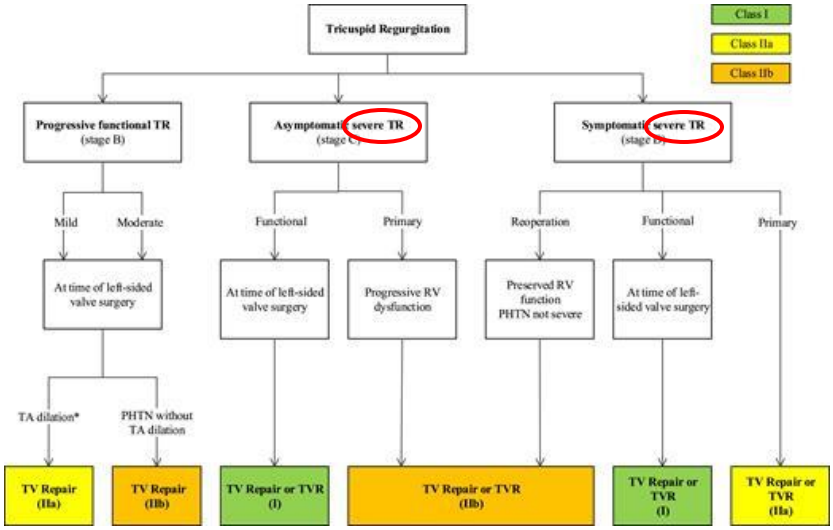
Tricuspid Regurgitation So What?

- Right Sided Failure
  - Edema
  - Gut congestion
  - Atrial fibrillation
  - DEATH – associated with increased risk of death

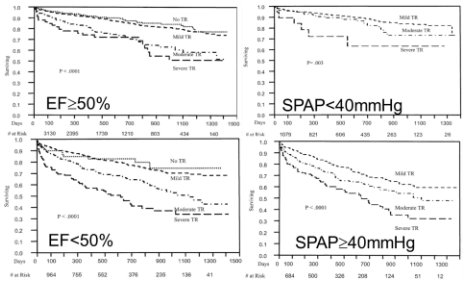


Dyspnea!!!

Little TR – OK (useful for us, in fact)
Lots of TR - BAD



TR predicts survival (n=5,223)



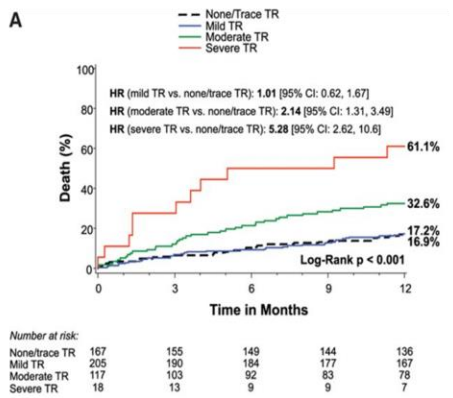
Nath et al (VA, Palo Alto), JACC 2004

Effect of Tricuspid Regurgitation and the Right Heart on Survival After Transcatheter Aortic Valve Replacement

Insights From the Placement of Aortic Transcatheter Valves II Inoperable Cohort

Brian R. Lindman, MD, MSCI; Hersh S. Maniar, MD; Wael A. Jaber, MD; Stamatios Lerakis, MD; Michael J. Mack, MD; Rakesh M. Suri, MD, DPhil; Vinod H. Thourani, MD; Vasilis Babaliaros, MD; Dean J. Kereiakes, MD; Brian Whisenant, MD; D. Craig Miller, MD; E. Murat Tuzcu, MD; Lars G. Svensson, MD, PhD; Ke Xu, PhD; Darshan Doshi, MD; Martin B. Leon, MD; Alan Zajarias, MD

Circ Cardiovascular Interventions 2015

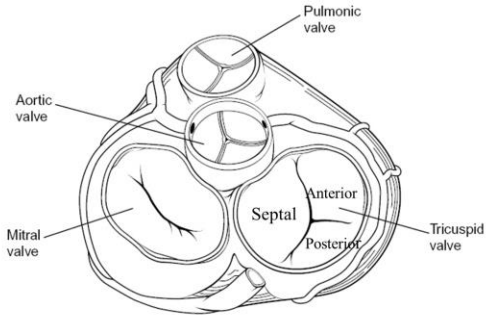


Number at risk:

None/trace TR	167	155	149	144	136
Mild TR	205	190	184	177	167
Moderate TR	117	103	92	83	78
Severe TR	18	13	9	9	7

"Complex" Anatomy (literally)

- Leaflet(s) – One continuous leaflet with indentations into Anterior, Septal, Posterior
- Annulus – D-shaped, with flatter portion along the central fibrous body - contractile
- Chordae
- Papillary muscles – usually 3
- Underlying Right Ventricular Myocardium



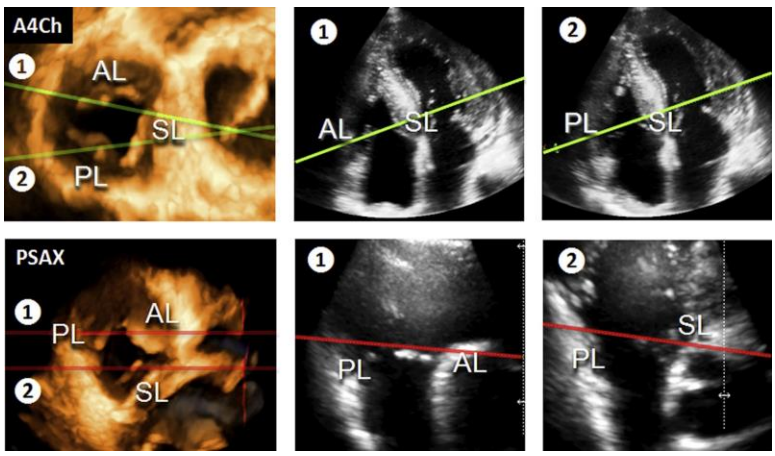
MUST EVALUATE:

- Leaflets
  - Thickening, doming, restriction
  - Coaptation
  - Flail
- Annulus diameter
- Mean gradient
- TR severity

- RA + RV dilatation, septal flattening
- RV systolic function
- PA pressure

Incremental Value of the En Face View of the Tricuspid Valve by Two-Dimensional and Three-Dimensional Echocardiography for Accurate Identification of Tricuspid Valve Leaflets

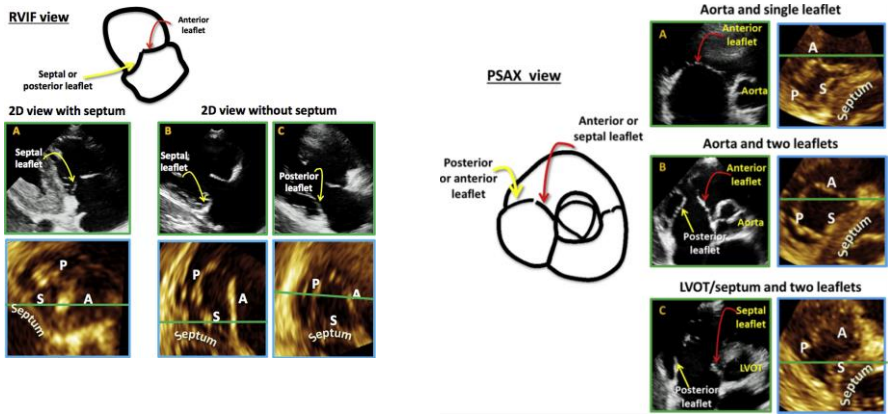
Ivan Stankovic, MD, Ana Maria Daraban, MD, Ruta Jasaityte, MD, Aleksandar N. Neskovic, MD, PhD, Piet Claus, PhD, and Jens-Uwe Voigt, MD, PhD, *Leuven, Belgium; Belgrade, Serbia*

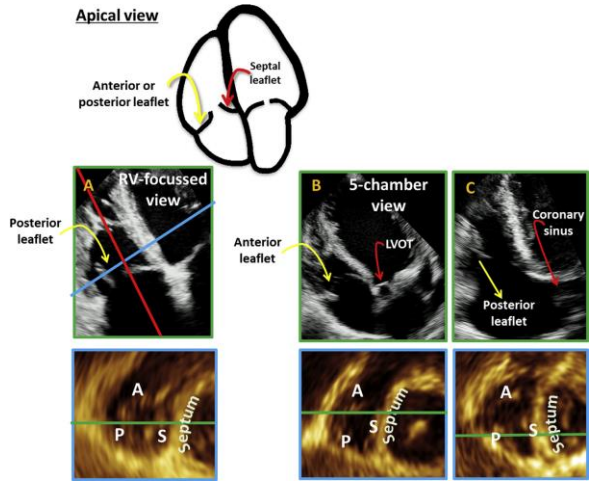


Journal of the American Society of Echocardiography
Volume 27 Number 4

Comprehensive Two-Dimensional Interrogation of the Tricuspid Valve Using Knowledge Derived from Three-Dimensional Echocardiography

Karima Addetia, MD, Megan Yamat, RDCS, Anuj Mediratta, MD, Diego Medvedofsky, MD, Mita Patel, MD, Preston Ferrara, RDCS, Victor Mor-Avi, PhD, and Roberto M. Lang, MD, *Chicago, Illinois*





What Can Go Wrong?

- Leaky
  - Stretched
  - Infected, with long-term sequelae
  - Perforated
  - Skewered
  - Ripped
- Narrowed
  - Rheumatic
  - Evil Humors

Etiologies of TR

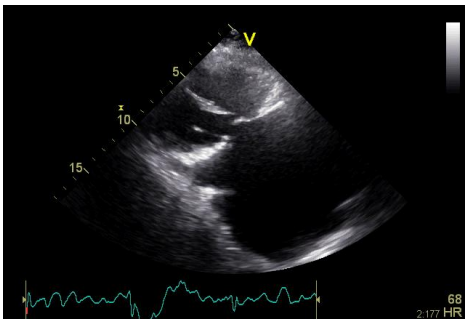
- Functional TR
  - PAH
  - Vol. Overload e.g. ASD
  - Cor Pulmonale
  - Left heart Disease
  - RV myocardial Disease
    - RV dysplasia
    - RV ischemia
    - Post-transplant
- Primary TR
  - Rheumatic
  - Myxomatous
  - Ebstein's Anomaly
  - Endocarditis
  - Carcinoid/Infiltrative
  - Traumatic – anterior structure-MVA
  - Iatrogenic
    - Pacer/ICD wires
    - RV biopsy

No reason why Carpentier's Classification can't apply

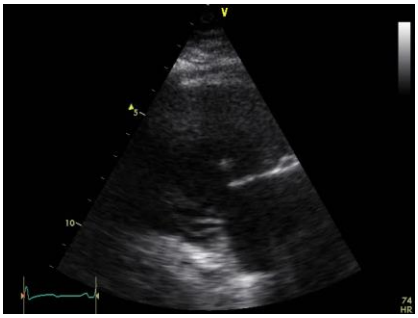
Primary or Secondary?
PA Pressure - As a ***general rule***…

- In setting of severe TR, PAPs > 55 mmHg is often associated with anatomically normal tricuspid valves, while PAPs < 55 mmHg usually associated with an abnormality of the tricuspid valve apparatus.

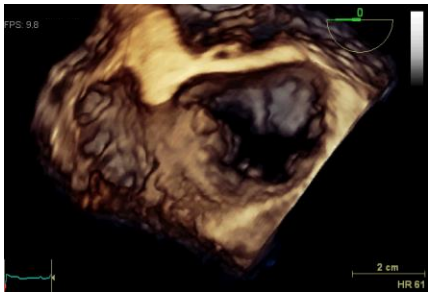
Leaflets

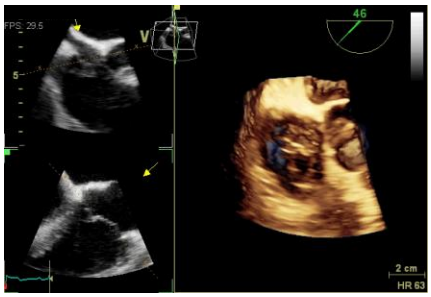


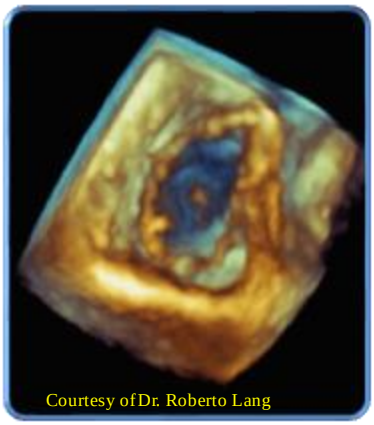
Rheumatic



Carcinoid

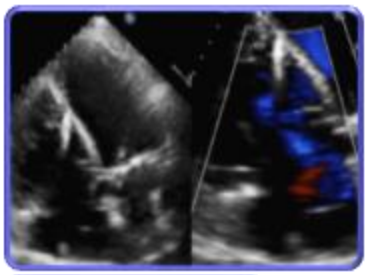


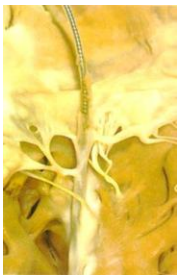




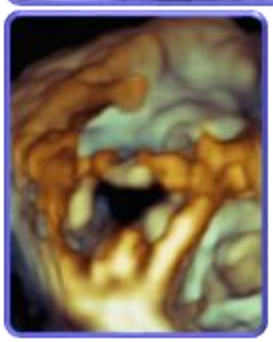
Myxomatous

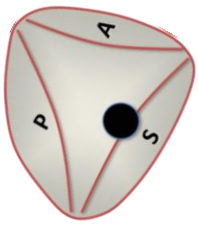
Pacemaker Lead Interference



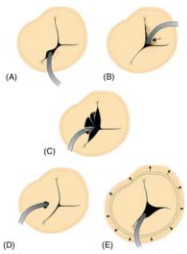


Al-Mohaissen and Chan (J Am Soc Echocardiogr 2012;25:245-52.)





Courtesy of Dr. Roberto Lang



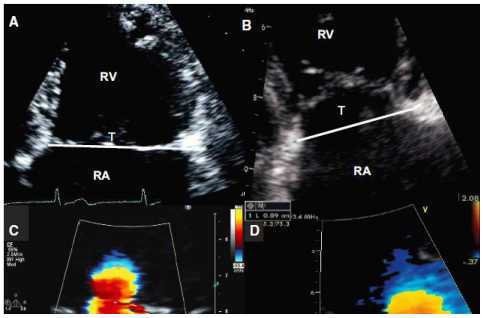
R. Al-Bawardy et al: TR in patients with pacemakers and ICDs Clin. Cardiol. 36, 5, 249–254 (2013)

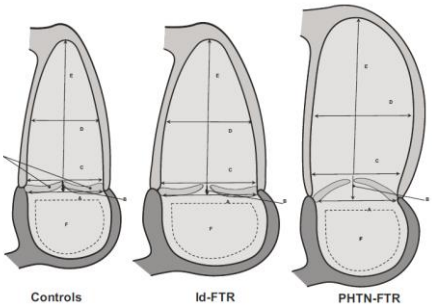
- (a) Valve obstruction caused by lead placed in between leaflets.
- (b) Lead adherence due to fibrosis and scar formation to valve causing incomplete closure.
- (c) Lead entrapment in the tricuspid valve apparatus
- (d) Valve perforation or laceration.
- (e) Annular dilatation.

FTR ≠ FTR

Clinical Context and Mechanism of Functional Tricuspid Regurgitation in Patients With and Without Pulmonary Hypertension

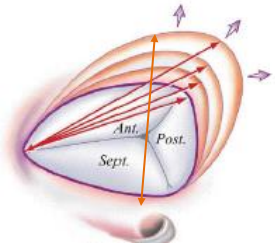
Yan Topilsky, MD; Amber Khanna; MD; Thierry Le Tourneau; MD; Soon Park; MD; Hector Michelena; MD; Rakesh Suri; MD, DPhil; Douglas W. Mahoney; MS; Maurice Enriquez-Sarano, MD



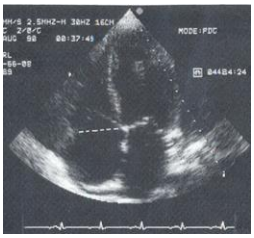


(*Circ Cardiovasc Imaging*. 2012;5:314-323.)

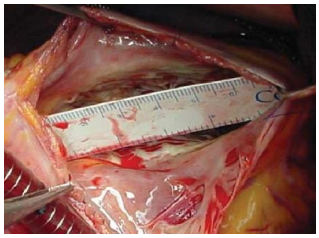
Annular Dimension

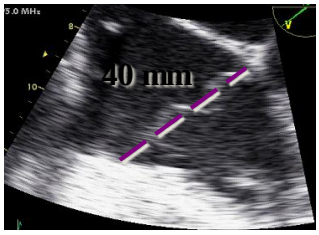


70 mm



40 mm or 21 mm/m2





Dreyfus G and al. Ann Thorac Surg 2005;79:127–32

Functional TR –Putting it all Together

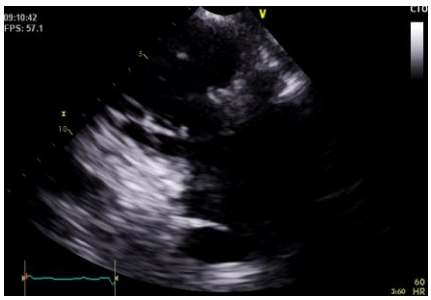
Dreyfus, G.D. et al. J Am Coll Cardiol. 2015; 65(21):2331-6.

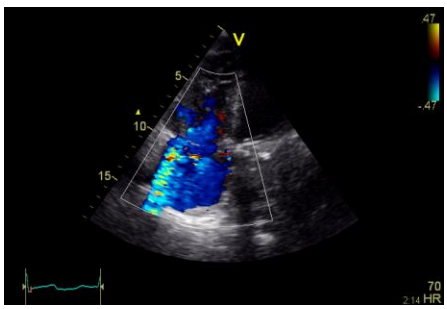
TABLE 1 Stages of Functional Tricuspid Regurgitation

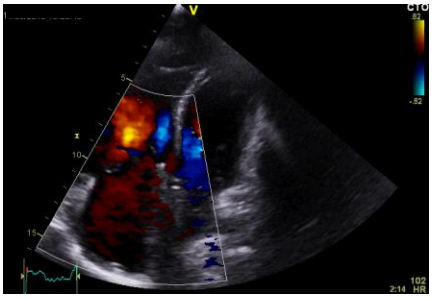
	Stage 1	Stage 2	Stage 3
TR severity	None or mild	Mild or moderate	Severe
Annular diameter, mm	<40	>40	>40
Leaflet coaptation mode	Normal*	Edge-to-edge*	Absent†
Treatment	Medical treatment	Tricuspid annuloplasty	Tricuspid annuloplasty + leaflet augmentation‡

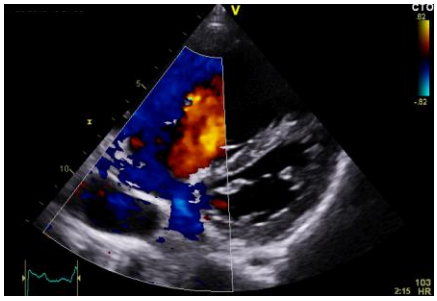
*No leaflet tethering (<8 mm). †Leaflet tethering may be present (≥8 mm). ‡If leaflet tethering is present.
TR = tricuspid regurgitation.

Quantitation?









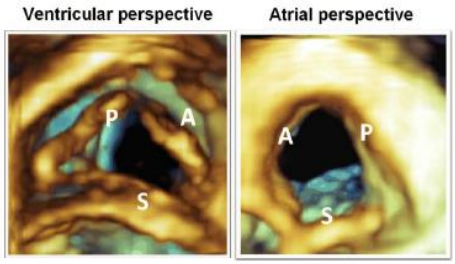
2017 Valvular Regurgitation Recommendations (Zoghbi et al JASE 2017)

Principles

- Comprehensive imaging
- Integrative interpretation
- Individualization
- Precise language
- Goal of imaging should be

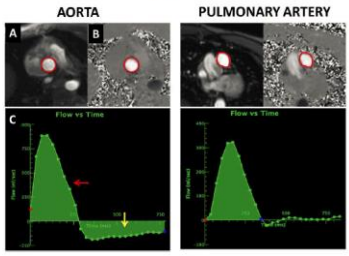
– **To define etiology, mechanism, severity, and impact on cardiac remodeling**

Use of 3D Approaches



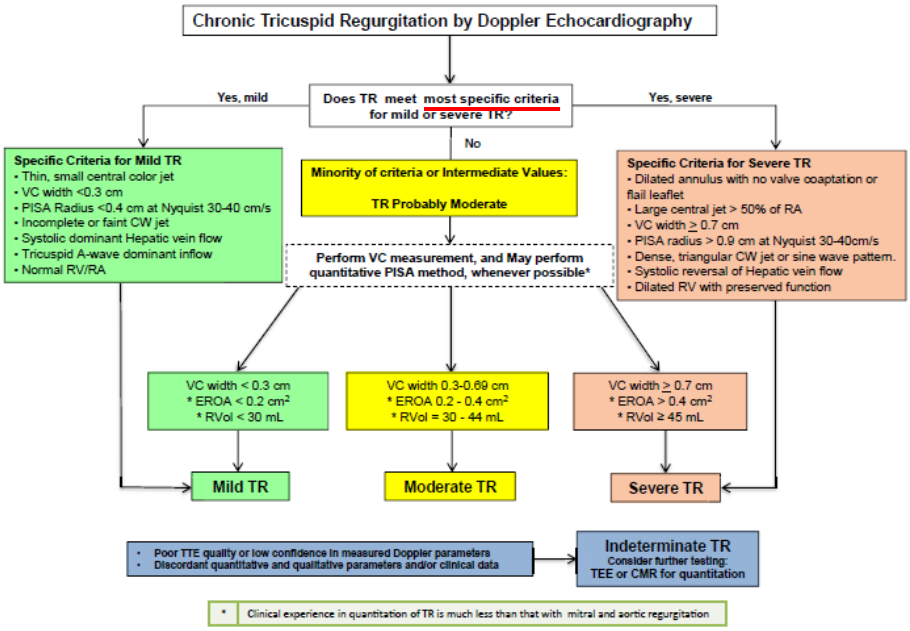
The use of cardiac MRI techniques

- Direct and Indirect Techniques



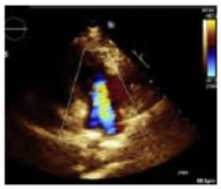
When is cardiac MRI indicated

- Echo images suboptimal
- Discrepancy between clinical TTE/TEE
  Discrepancy between quantitative techniques
- To understand mechanism / associations
- Assessment of consequences of regurgitation
  - LV/RV volumes function
  - AO/PA size



Color Doppler

- Four chamber, RV inflow or subcostal views



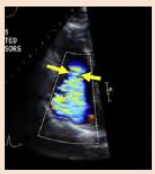
- Qualitative
- Dependent on the driving pressure and jet direction
- Direction and shape of jet may overestimate (central entrainment) or underestimate (eccentric, wall-impinging) jet area

Phase of Respiration

SEVERE : > 10 cm²

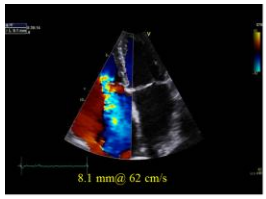
Vena Contracta

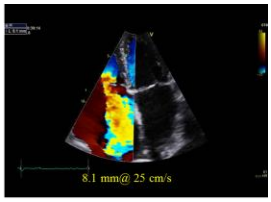
- Zoomed view
- Apical four chamber view
- RV inflow view



- Surrogate for regurgitant orifice size
- Independent of flow rate and driving pressure for a fixed orifice
- Less dependent on technical factors
- Good at identifying severe TR
- Problematic in the presence of multiple jets
- In order to measure it, convergence zone needs to be visualized

MILD	MODERATE	SEVERE
<0.3	0.3-0.69	≥0.7

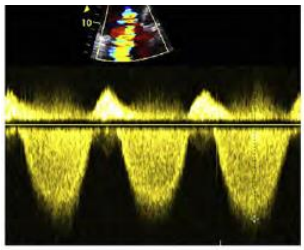




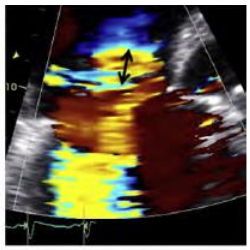
Severe : VC > 0.7 cm
Nyquist 50-60 cm/s

If you are brave… 3D Vena Contracta

TR Severity by PISA



TR Peak Velocity = 386 cm/s
VTI of jet= 109 cm

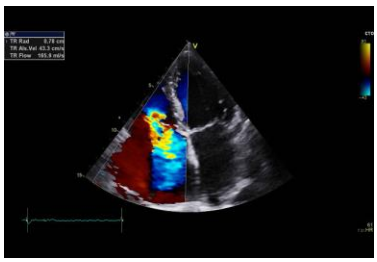


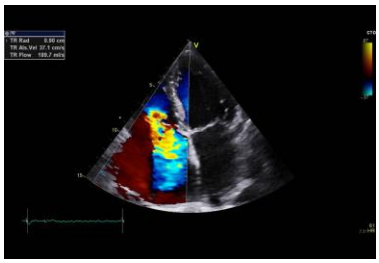
Alias Velocity = 32 cm/s
Radius = 0.9 cm

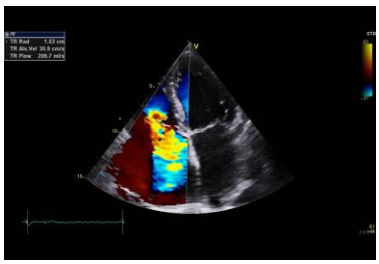
EROA = 6.28 * 0.9^2 * 32 / 386 = 0.4 cm^2
RVol = 0.4 * 109 = 44 mL

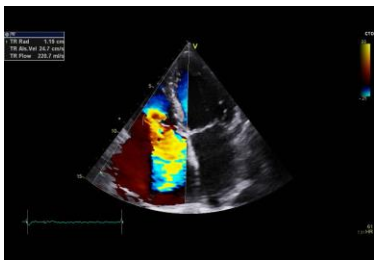
	Mild	Moderate	Severe
Quantitative			
EROA (cm^2)	<0.20	0.20-0.39‖	≥**0.40**
RVol (2D PISA) (mL)	<30	30-44‖	≥45
PISA radius (cm)‡	≤0.5	0.6-0.9	**>0.9**

$$EOA = 2\pi R^2 \times V_{alias} / V_{max}$$



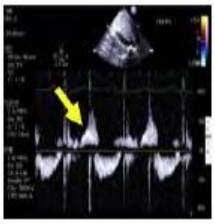




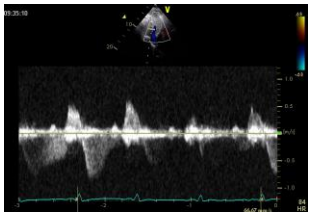


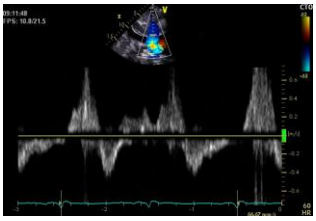
Nyquist – Radius cm/sec cm
28 – 0.9cm
25 – 1.0cm
31 – 0.8cm
37 – 0.68cm
43 – 0.59cm

Pulsed Doppler Hepatic Vein Reversal

Optimization	Example	Advantages	Pitfalls
• Align insonation beam with the flow in the hepatic vein		• Simple supportive sign of severe TR • Can be obtained with both TTE and TEE	• Depends on compliance of the right atrium • May not be reliable in patients with atrial fibrillation, paced rhythm with retrograde atrial conduction

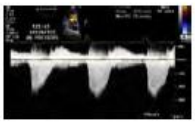
Hepatic Vein Reversal





TR signal – density and shape

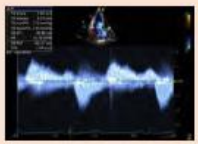
- Align insonation beam with the flow



- Simple
- Density is proportional to the number of red blood cells reflecting the signal
- Faint or incomplete jet is compatible with mild TR

- Qualitative
- Perfectly central jets may appear denser than eccentric jets of higher severity
- Overlap between moderate and severe TR

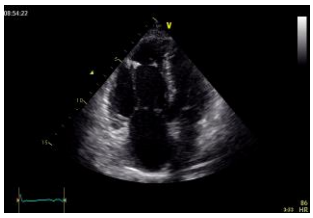
- Align insonation beam with the flow

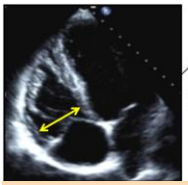


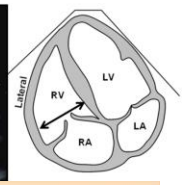
- Simple
- Specific sign of pressure equalization in low velocity, early peaking dense TR jet

- Qualitative
- Affected by changes that modify RV and RA pressures

Effect on RV (and vice versa)

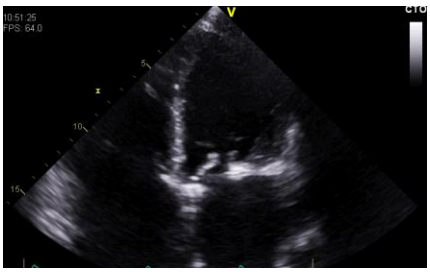


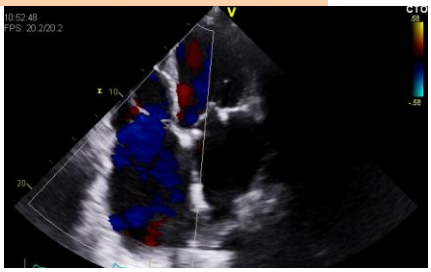




Chamber Quantification

Variable	Abnormal
A. RV Basal (RVD1)	> 4.2 cm
RV Mid (RVD2)	> 3.5 cm
RV Longitudinal (RVD3)	> 8.6 cm
B. RVOT PLAX proximal	> 3.3 cm
C. RVOT PSAX distal	> 2.7 cm





Key Points

- Physiologic mild TR is common in normal individuals.
- In patients with more than mild TR, identifying the mechanism of TR is important. TR is classified as primary or secondary (functional), and the precise mechanism of TR should be specified and reported (Table 12).
- No single Doppler and echocardiographic measurement or parameter is precise enough to quantify TR severity. Integration of multiple parameters is required (Tables 13 and 14). When multiple parameters are concordant, TR grade can be determined with high probability (especially for mild or severe TR).
- There is less experience with quantitation of TR severity with PISA or volumetric flow compared with MR and AR.
- Severe, wide-open TR may have low velocity, without aliasing or turbulence, and thus may be difficult to see as a distinct jet by color Doppler.
- The size of the right atrium and RV should be considered. Chronic severe TR almost always leads to dilated RV and right atrium. Conversely, normal chamber volumes are unusual with chronic severe TR.
- CMR assessment of TR is less established compared with other regurgitant valvular lesions. Few indirect quantitative techniques can be used.
- Additional testing with TEE or CMR is indicated when the TTE examination does not provide a mechanism for significant TR, the echo/Doppler parameters are discordant or inconclusive regarding the severity of TR, or there is discrepancy of echocardiographic findings with the clinical setting.

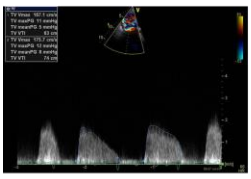
Tricuspid Stenosis

Etiology

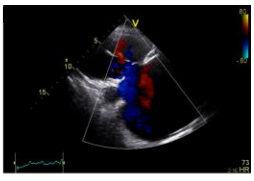
Rheumatic

Infiltration – Carcinoid

Compression – Rare – external (clot/tumor)/aorta



VTI 63-74 cm

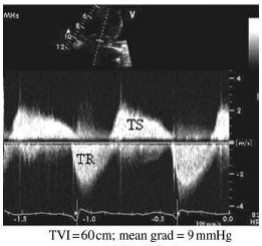


- TVA cm^2 = 190/PHT

$$A_2 = \frac{A_1 \cdot V_1}{V_2}$$

- A1 = LVOT CSA or RVOT CSA
- V1 = LVOT V1 or RVOT V1 (PW)
- V2 = Vmax of Tricuspid Inflow by CW Doppler

CW Doppler



TVI = 60 cm; mean grad = 9 mmHg
P1/2t = 173 ms

Table 10 Findings indicative of haemodynamically significant tricuspid stenosis

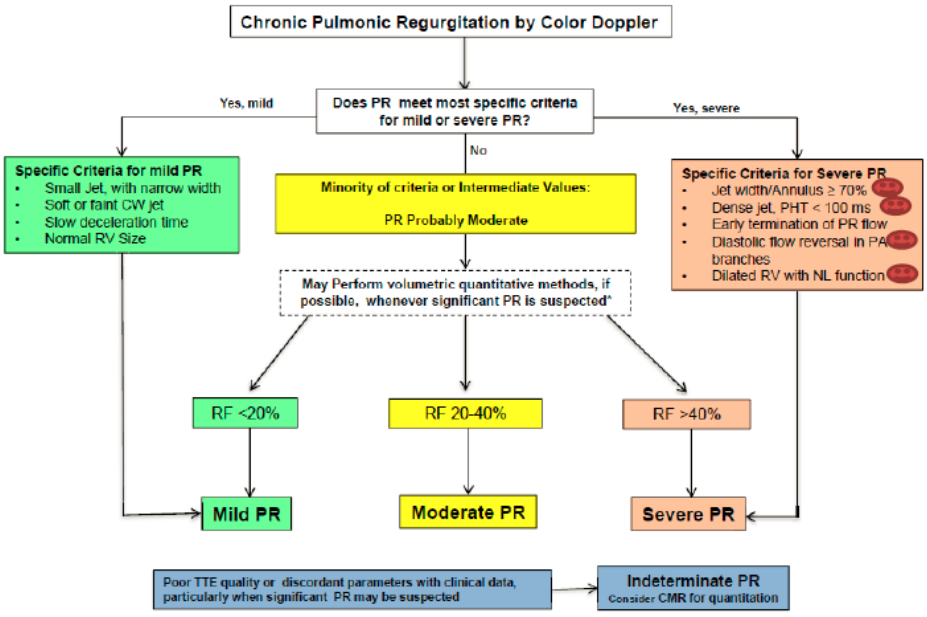
Specific findings	
Mean pressure gradient	≥5 mmHg
Inflow time–velocity integral	>60 cm
$T_{1/2}$	≥190 ms
Valve area by continuity equation[a]	≤1 cm^{2a}
Supportive findings	
Enlarged right atrium ≥moderate	
Dilated inferior vena cava	

[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.

Pulmonic Valve << Tricuspid Valve

- Stenosis – Valvar, Sub-, Supra
  - Congenital
  - Infiltrative
  - Iatrogenic – post Ross e.g.
- Regurgitation
  - PH
  - Congenital Surgery – Repaired Tetralogy
  - Endocarditis
  - Infiltrative

Pulmonic Regurgitation



Pulmonic Regurgitation Index

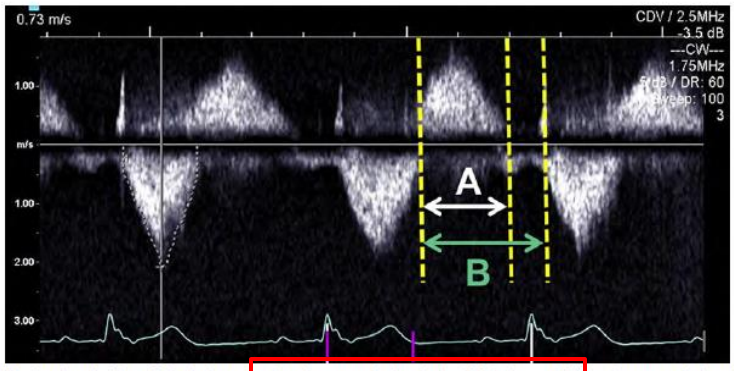
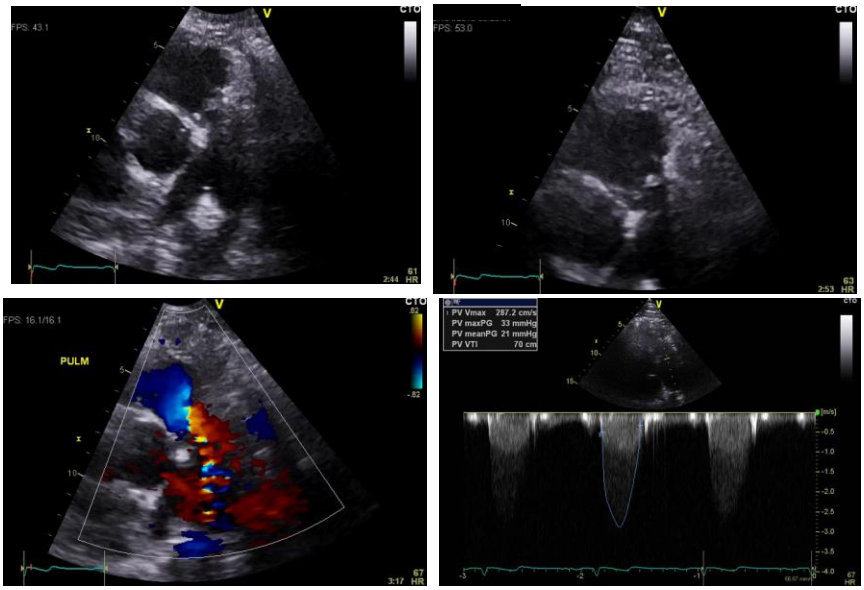


Figure 33 CWD of pulmonic flow. Calculation of pulmonic regurgitation index (PR index = A/B) is shown, an index of PR severity, quantitating early termination of diastolic regurgitant flow.

Pulmonic Stenosis



Pulmonic Valve Disease- Carcinoid

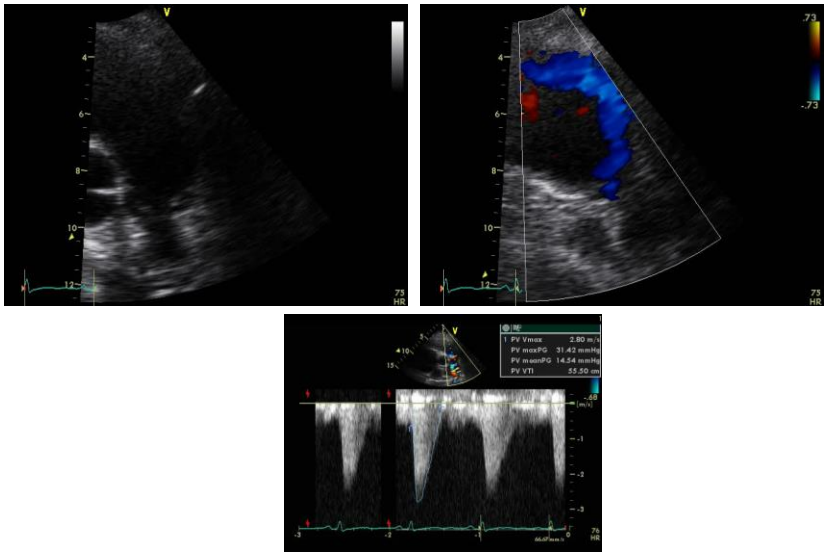
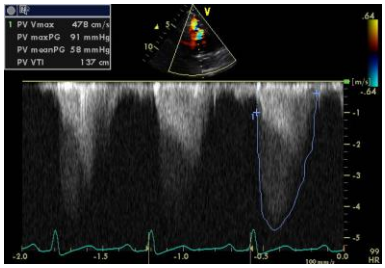


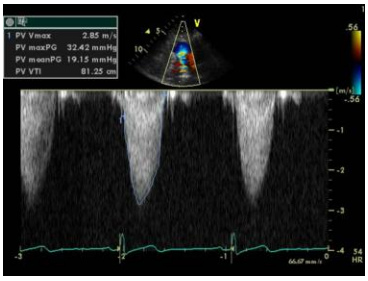
Table 11 Grading of pulmonary stenosis

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



Impact

- Same as for TR
  - Assess RV size, RA size, RV function



  - PAP Calculation Caveat – Subtract the PS Gradient**
  - SPAP = (TR gradient + RAP) – PV PG
    = (43 + 15) – 32 = 26 mmHg

Summary

More than eyeball of color jet

- Tricuspid
  - Morphology, Degree of dysfunction, Impact on cardiac size and function
- Pulmonic
  - Same as above
- Implications for Clinical therapy
  - When to intervene in primary and secondary TR, PR
  - When to intervene for TS and PS

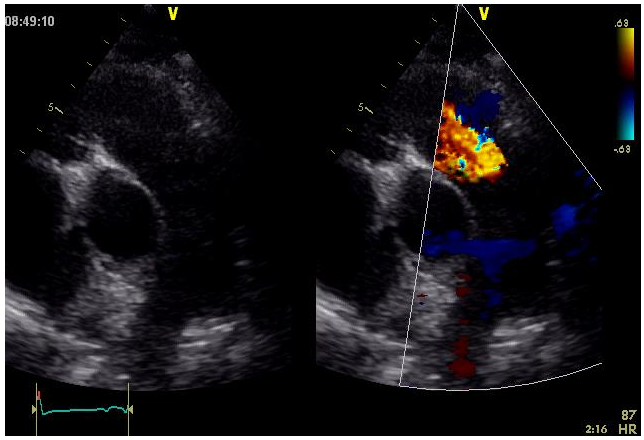
Images can be deceptive! – Integrate detail with the BIG PICTURE

Table 14 Grading the severity of chronic TR by echocardiography

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

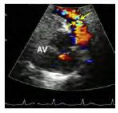
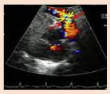
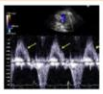
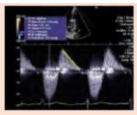
RA, Right atrium.
Bolded signs are considered specific for their TR grade.
*RV and RA size can be within the "normal" range in patients with acute severe TR.
†With Nyquist limit >50-70 cm/sec.
‡With baseline Nyquist limit shift of 28 cm/sec.
§Signs are nonspecific and are influenced by many other factors (RV diastolic function, atrial fibrillation, RA pressure).
‖There are little data to support further separation of these values.

Normal PV



Doppler Evaluation of PR

Table 15 Doppler echocardiography in evaluating severity of PR

Modality	Optimization	Example	Advantages	Pitfalls
Color flow Doppler 2D				
VC	• Parasternal short-axis or subcostal views • Zoomed view • Should visualize proximal flow convergence, distal jet, and the "narrow" neck in a single view • Measured in diastole immediately below PV		• Surrogate for effective regurgitant orifice area • Independent of flow rate and driving pressure for a fixed orifice • Less dependent on technical factors	• Not usable with multiple jets • The direction of the jet (in relation to the insonation beam) will influence the appearance of the jet • Cutoffs for various grades of PR not validated. • Not easy to perform
VCW/PV annular diameter ratio	• Parasternal short-axis view • Zoomed view • Optimize visualization of proximal PA		• Simple sensitive screen for PR • Rapid qualitative assessment	• Underestimates PR in eccentric jets • Overestimates PR in central jets • PR jet may expand unpredictably below the orifice
Pulsed wave Doppler: flow reversal in the branch PA	• Align insonation beam with the flow in the RPA and LPA • Obtain pulsed wave Doppler from both branch PAs		• Simple supportive sign of severe PR	• Depends on compliance of the PA • Brief velocity reversal is normal
CWD				
Density of regurgitant jet	• Align insonation beam with the flow • PSAX view or subcostal views	Severe PR with dense jet 	• Simple • Density is proportional to the number of red blood cells reflecting the signal • Faint or incomplete jet is compatible with	• Qualitative • Perfectly central jets may appear denser than eccentric jets of higher severity • Overlap between moderate and severe PR
Jet deceleration rate (pressure half-time)	• Align insonation beam with the flow • PSAX view or subcostal views		• Simple • Specific sign of pressure equalization • Values < 100 msec consistent with severe PR	• Poor alignment of Doppler beam may result in eccentric jets providing low PHT • Affected by RV and PA pressure difference, e.g., RV diastolic dysfunction.