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

Lawrence Rudski MD FRCPC FACC FASE
Professor of Medicine
Director, Division of Cardiology and Azrieli Heart Center
Jewish General Hospital, McGill University
President, Canadian Society of Echocardiography

Disclosure: Small holding of GE Stock outside managed portfolio

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
“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 Jasiunyte, MD, Aleksandar N. Neskovic, MD, PhD, Pet Claus, PhD, and Jivo-Uwe Vugt, MD, PhD, Lebanon, 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

![Diagram of Tricuspid Valve views](image-url)
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
Pacemaker Lead Interference

- (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; Anshu 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

Functional TR – Putting it all Together


**TABLE 1 Stages of Functional Tricuspid Regurgitation**

<table>
<thead>
<tr>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>TR severity</td>
<td>None or mild</td>
<td>Mild or moderate</td>
</tr>
<tr>
<td>Annular diameter, mm</td>
<td>&lt;40</td>
<td>&gt;40</td>
</tr>
<tr>
<td>Leaflet coaptation mode</td>
<td>Normal¹</td>
<td>Edge-to-edgeᵃ</td>
</tr>
<tr>
<td>Treatment</td>
<td>Medical treatment</td>
<td>Tricuspid annuloplasty</td>
</tr>
</tbody>
</table>

¹No leaflet tethering (<8 mm).  ⁡Leaflet tethering may be present (≥8 mm).  †If leaflet tethering is present.  
TR = tricuspid regurgitation.

Quantitation?

[Images of echocardiograms showing tricuspid regurgitation]
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

Chronic Tricuspid Regurgitation by Doppler Echocardiography

Yes, mild

Does TR meet most specific criteria for mild or severe TR?

Yes, severe

Minority of criteria or Intermediate Values:

- TR: Probably Moderate

Specific Criteria for Severe TR

- Dilated annulus with no valve replacement or lead artifact
- Large central jet > 50% of RA
- VC width > 0.7 cm
- PISA radius > 0.9 cm at Nyquist 30-40 cm/s
- Dorsal, triangular CW jet or sine wave pattern
- Systolic reversal of hepatic vein flow
- Dilated RV with preserved function

Performs VC measurement, and may perform quantitative PISA method, whenever possible

Yes

VC width < 0.3 cm

* EROA < 0.2 cm²
* RVol < 50 mL

Mild TR

VC width 0.3-0.6 cm

* EROA 0.3-0.4 cm²
* RVol 50-100 mL

Moderate TR

VC width 0.7-0.9 cm

* EROA > 0.5 cm²
* RVol > 100 mL

Severe TR

Indeterminate TR

Consider further testing: TEE or CMR for quantitation

- Poor TTE quality or low confidence in measured Doppler parameters
- Discordant qualitative and quantitative parameters at rest / stress data

* Clinical experience in quantification of TR is much less than that with mitral and aortic regurgitation
Color Doppler

Phase of Respiration

SEVERE : > 10 cm²

Vena Contracta

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

- Surrogates 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

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

EOA = \( \frac{6.28 \times 0.9^2 \times 32}{386} = 0.4 \text{ cm}^2 \)
RVol = 0.4 \times 109 = 44 mL

<table>
<thead>
<tr>
<th>Severity</th>
<th>EROA (cm²)</th>
<th>RVol (2D PISA) (mL)</th>
<th>PISA radius (cm)³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild</td>
<td>&lt;0.20</td>
<td>0.20–0.39</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.20–0.39</td>
<td>0.30–0.44</td>
<td>0.5–0.9</td>
</tr>
<tr>
<td>Severe</td>
<td>≥0.40</td>
<td>≥0.45</td>
<td>&gt;0.9</td>
</tr>
</tbody>
</table>

EOA = 2\( \pi R^2 \) \times \frac{V_{\text{alias}}}{V_{\text{max}}}

<table>
<thead>
<tr>
<th>Nyquist – Radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>cm/sec</td>
</tr>
<tr>
<td>28 – 0.9cm</td>
</tr>
<tr>
<td>25 – 1.0cm</td>
</tr>
<tr>
<td>31 – 0.8cm</td>
</tr>
<tr>
<td>37 – 0.68cm</td>
</tr>
<tr>
<td>43 – 0.59cm</td>
</tr>
</tbody>
</table>
Pulsed Doppler Hepatic Vein Reversal

<table>
<thead>
<tr>
<th>Optimization</th>
<th>Example</th>
<th>Advantages</th>
<th>Pitfalls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Align insonation beam with the flow in the hepatic vein</td>
<td><img src="image1.png" alt="Image" /></td>
<td>• Simple supportive sign of severe TR</td>
<td>• Depends on compliance of the right atrium</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Can be obtained with both TTE and TEE</td>
<td>• May not be reliable in patients with atrial fibrillation, paced rhythm with retrograde atrial conduction</td>
</tr>
</tbody>
</table>

Hepatic Vein Reversal

![Image](image2.png)

![Image](image3.png)

![Image](image4.png)

![Image](image5.png)
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
  - Small 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)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Abnormal</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. RV Basal (RV01)</td>
<td>&gt; 4.2 cm</td>
</tr>
<tr>
<td>RV Med (RV02)</td>
<td>&gt; 3.9 cm</td>
</tr>
<tr>
<td>RV Longitudinal (RV03)</td>
<td>&gt; 8.8 cm</td>
</tr>
<tr>
<td>B. RVOT PLAX proximal</td>
<td>&gt; 3.3 cm</td>
</tr>
<tr>
<td>C. RVOT PSAX distal</td>
<td>&gt; 2.7 cm</td>
</tr>
</tbody>
</table>
Tricuspid Stenosis

Etiology

Rheumatic

Infiltration – Carcinoid

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

A2 = \frac{A_1 \cdot V_1}{V_2}

\begin{itemize}
  \item A1 = LVOT CSA or RVOT CSA
  \item V1 = LVOT V1 or RVOT V1 (PW)
  \item V2 = Vmax of Tricuspid Inflow by CW Doppler
  \item VTI 63-74 cm
  \item TVA cm² = 190/PHT
\end{itemize}
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

Chronic Pulmonic Regurgitation by Color Doppler

- **Does PR meet most specific criteria for mild or severe PR?**
  - Yes, mild
  - No, severe

**Specific Criteria for mild PR**
- Small jet, mild narrowed width
- Small or absent DSR jet
- Slow deceleration time
- Normal RV size

**Minority of criteria or Intermediate Values**
- PR Probably Moderate

- **May Perform volumetric quantitative methods if possible, whenever significant PR is suspected**
  - **RF <20%**
    - Mild PR
  - **RF 20-40%**
    - Moderate PR
  - **RF >40%**
    - Severe PR

**Specific Criteria for Severe PR**
- Jet width/width ratio > 1
- Duration of jet < 100 m/s
- Early termination of PR flow
- Diastolic flow reversal in RV branches
- Dilated RV with normal function

**Indeterminate PR**
- Consider CMR for quantification
- Poor TTE quality or discordant parameters with clinical data, particularly when significant PR may be suspected

Pulmonic Regurgitation Index

**Figure 33.** CW Doppler 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
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
    
    $= (43 + 15) - 32 = 26 \text{ mmHg}$
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

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Structural</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TV morphology</td>
<td>Normal or mildly abnormal leaflets</td>
<td>Moderately abnormal leaflets</td>
<td>Severe valve lesions (e.g., flail leaflet, severe retraction, large perforation)</td>
</tr>
<tr>
<td>RV and RA size</td>
<td>Usually normal</td>
<td>Normal or mild dilatation</td>
<td>Usually dilated*</td>
</tr>
<tr>
<td>Inferior vena cava diameter</td>
<td>Normal &lt; 2 cm</td>
<td>Normal or mildly dilated 2.1 - 2.5 cm</td>
<td>Dilated &gt; 2.5 cm</td>
</tr>
<tr>
<td>Qualitative Doppler</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color flow jet area</td>
<td>Small, narrow, central</td>
<td>Moderate central</td>
<td>Large central jet or eccentric wall-impinging jet of variable size</td>
</tr>
<tr>
<td>Flow convergence zone</td>
<td>Not visible, transient or small</td>
<td>Intermediate in size and duration</td>
<td>Large throughout systole</td>
</tr>
<tr>
<td>CWD jet</td>
<td>Faint/partial/parabolic</td>
<td>Dense, parabolic or triangular</td>
<td>Dense, often triangular</td>
</tr>
<tr>
<td><strong>Semiquantitative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Color flow jet area (cm²)</td>
<td>Not defined</td>
<td>Not defined</td>
<td>0.10</td>
</tr>
<tr>
<td>VCW (cm²)</td>
<td>&lt; 0.3</td>
<td>0.3 - 0.69</td>
<td>≥ 0.7</td>
</tr>
<tr>
<td>PISA radius (cm)</td>
<td>&gt; 0.5</td>
<td>0.6 - 0.9</td>
<td>≥ 0.9</td>
</tr>
<tr>
<td>Hepatic vein flow</td>
<td>Systolic dominance</td>
<td>Systolic blunting</td>
<td><strong>Systolic flow reversal</strong></td>
</tr>
<tr>
<td>Tricuspid inflow</td>
<td>A-wave dominant</td>
<td>Variable</td>
<td>E-wave &gt; 1.0 m/sec</td>
</tr>
<tr>
<td><strong>Quantitative</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EROCA (cm²)</td>
<td>&lt; 0.20</td>
<td>0.20 - 0.39</td>
<td>≥ 0.40</td>
</tr>
<tr>
<td>RVol (2D PISA) (mL)</td>
<td>&lt; 30</td>
<td>30 - 44</td>
<td>≥ 46</td>
</tr>
</tbody>
</table>

*RA, Right atrium. Bolded signs are considered specific for their TR grade.

1. TV and RA size can be within the “normal” range in patients with acute severe TR.
2. With Nyquist limit >50-70 cm/sec.
3. With baseline Nyquist limit shift of 28 cm/sec.
4. Signs are nonspecific and are influenced by many other factors (RV diastolic function, atrial fibrillation, RA pressure).
5. There are little data to support further separation of these values.

---

**Normal PV**

![Normal PV Image](image-url)
Doppler Evaluation of PR

<table>
<thead>
<tr>
<th>Table 1A</th>
<th>Doppler echocardiography in evaluating severity of PR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Color Flow Doppler 2D</strong></td>
<td></td>
</tr>
<tr>
<td>VC</td>
<td>VCWPV similar diameter ratio</td>
</tr>
<tr>
<td>Directional or subvalvular</td>
<td>Parasternal short-axis view</td>
</tr>
<tr>
<td></td>
<td>Zoomed view</td>
</tr>
<tr>
<td>Color signal for effective regurgitant orifice</td>
<td>Independent of flow rate and transvalvular pressure for a fixed orifice</td>
</tr>
<tr>
<td>Not usable with multiple jets</td>
<td>Pulmonary artery flow reversal in the mitral regurgitant jet</td>
</tr>
<tr>
<td>Not easy to perform</td>
<td></td>
</tr>
</tbody>
</table>

**Power Doppler Imaging**

- Align interrogation beam with the flow in the LVOT and RVOT
- Obtain power Doppler image both from septal and posterior views
- Simple or complex jet

**Density of regurgitant jet**

- Parasternal long-axis view
- Parasternal short-axis view
- Severity of PR with dense jet

**Jet deceleration rate** (pressure half-time)

- Specific sign of pressure equalization
- Values < 100 mmHg consistent with severe PR

**Doppler beams**

- May result in eccentric jets providing low PHT
- Affected by RV and PA pressure difference, e.g., RV diastolic dysfunction.