Imaging the Tricuspid Valve

Roberto M Lang, MD

State-of-the-Art Echocardiography

31st ANNUAL

THE UNIVERSITY OF CHICAGO
CARDIAC IMAGING CENTER

2D Echocardiography

Anterior
Septal
Posterior

M-mode

Anterior
Septal

2/12/2018
THE TV ON 3D ECHO

RV perspective

RA perspective

THE TRICUSPID VALVE: ADDED VALUE OF 3D IMAGING

2D

< 5% of pts

3D

~ 85% of pts
THE NORMAL TRICUSPID VALVE COMPLEX

1. Three leaflets
   - Anterior
   - Septal
   - Posterior
2. Fibrous annulus
3. Chordae tendinae
4. Papillary muscles
5. RA myocardium
6. RV myocardium

Courtesy Dr. Stephen P. Sanders, Professor of Pediatrics (Cardiology), Harvard Medical School

How many leaflets does the TV have?
HOW MANY LEAFLETS DOES THE TRICUSPID VALVE HAVE?

- 36 adult human hearts
- # leaflets vary from 3-7
- Extra leaflets are called “accessory leaflets”
- Accessory leaflets are common

AMBIGUITY OF LEAFLET IMAGED ON 2D

RV inflow view

Apical 4-chamber view
Post LVAD study

RV inflow view

RV inflow view #1

Mild TR

RV inflow view #2

Severe TR

RV inflow view 2
MECHANISMS OF TRICUSPID REGURGITATION

Primary (or “Organic”)
Intrinsic abnormality of the valve apparatus
15-30%* of TR

Secondary (or “Functional”)
TV annular dilatation, RV dilatation and papillary muscle displacement
70-85%* of TR

Antunes MJ, Barlow JB, Heart 2007
Primary/Organic TR – PPM/ICD Device Location

26 year-old with dilated cardiomyopathy on the transplant list

ICD inserted and echo performed 8 days later

RV perspective

Pre-ICD

A4C

Severe TR

RV inflow

Post-ICD

RA perspective

P-S COMMISSURE: CORRECT POSITION

A:

Postero-septal

Antero-posterior

Middle

Antero-septal
89 year-old man with right heart failure
Past medical history: CAD, MV repair, TAVI in 2009
• Permanent pacemaker implantation post TAVI for bradycardia
POSTERIOR TV LEAFLET PERFORATION

PACEMAKER ADHERENCE
FUNCTIONAL TRICUSPID REGURGITATION

Chronic PE, Lung disease
RV ischemia, VOL, CM
Left-sided valve disease
Atrial fibrillation
L-R shunt

70-85%* of TR

TA dilatation
RV enlargement
PM displacement
TV tethering

TRICUSPID VALVE ≠ MITRAL VALVE

- Different valve orifices
- Different subvalvular apparatuses
- Different ventricles

Yet TR and MR are assessed in similar ways
# ASE Guidelines and Standards

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

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JASE 2017

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## Grading of Tricuspid Regurgitation Severity

<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><strong>Qualitative Doppler</strong></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>CW Doppler jet</td>
<td>Flat/partial parabolic</td>
<td>Parabolic or triangular</td>
<td>Dense, often turbulent</td>
</tr>
<tr>
<td><strong>Semi-quantitative</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>&gt;10</td>
</tr>
<tr>
<td>Vcw (cm)</td>
<td>&lt;0.3</td>
<td>0.3-0.40</td>
<td>≥0.7</td>
</tr>
<tr>
<td>PISA radius (cm)</td>
<td>≤0.5</td>
<td>0.6-0.9</td>
<td>&gt;0.9</td>
</tr>
<tr>
<td>Hepatic vein flow</td>
<td>Systolic dominance</td>
<td>Systolic blunting</td>
<td>Systolic flow reversal</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>Continuous</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EROA (cm²)</td>
<td>&lt;0.20</td>
<td>0.20-0.30</td>
<td>≥0.40</td>
</tr>
<tr>
<td>RWT GD PISA (mL)</td>
<td>&lt;30</td>
<td>30-44</td>
<td>≥45</td>
</tr>
</tbody>
</table>

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2/12/2018
TRICUSPID VALVE ≠ MITRAL VALVE

64 year-old man with a NICM

LVEF < 20%

TR IS LOAD DEPENDENT

9 months ago - CHF

Now - No CHF

Functional TR

- Tricuspid annulus dilatation may be a more reliable indicator of TV pathology than degree of regurgitation
- Good correlation between TA diameter and TR regurgitant volume

TR varies depending on preload, afterload, RV function
TRICUSPID VALVE ≠ MITRAL VALVE

Pre and post peritoneal dialysis

Normal tricuspid annular dimension

TRICUSPID VALVE ≠ MITRAL VALVE

Topilsky Y et. al. Circulation 2010;122

TR depends on respiratory phase

<table>
<thead>
<tr>
<th>Variable</th>
<th>Expiration</th>
<th>Inspiration</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>RV diastolic area, cm$^2$</td>
<td>26.5 (21.1–31.9)</td>
<td>27.8 (22.6–36.3)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>RV systolic area, cm$^2$</td>
<td>16 (12.9–26.4)</td>
<td>16.9 (13.1–27.4)</td>
<td>0.009</td>
</tr>
<tr>
<td>RV area shortening fraction, %</td>
<td>33.4 (17.6–47.5)</td>
<td>33.4 (20.5–49.7)</td>
<td>0.37</td>
</tr>
<tr>
<td>RV diastolic length, cm</td>
<td>6.9 (6.5–7.7)</td>
<td>6.9 (6.5–7.9)</td>
<td>0.55</td>
</tr>
<tr>
<td>RV diastolic midventricular width, cm</td>
<td>4.1 (3.4–4.7)</td>
<td>4.5 (3.8–5.1)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>RV diastolic length/width ratio</td>
<td>1.7 (1.46–2.1)</td>
<td>1.6 (1.37–1.90)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>RA volume, ml</td>
<td>85.8 (52.7–132.3)</td>
<td>89 (51.7–126.5)</td>
<td>0.36</td>
</tr>
<tr>
<td>Systolic annulus diameter, mm</td>
<td>2.9 (2.7–3.6)</td>
<td>3.1 (2.7–3.8)</td>
<td>0.003</td>
</tr>
<tr>
<td>Diastolic annulus diameter, mm</td>
<td>3.7 (3.4–4.3)</td>
<td>3.9 (3.5–4.4)</td>
<td>0.01</td>
</tr>
<tr>
<td>Systolic vavulinar annular coverage, %</td>
<td>104 (84–110)</td>
<td>100 (93–109)</td>
<td>0.006</td>
</tr>
<tr>
<td>Tenting height, cm</td>
<td>0.7 (0.53–0.92)</td>
<td>0.92 (0.74–1.3)</td>
<td>&lt; 0.0001</td>
</tr>
<tr>
<td>Tenting area, cm$^2$</td>
<td>1.1 (0.66–1.5)</td>
<td>1.4 (1.15–1.7)</td>
<td>&lt; 0.0001</td>
</tr>
</tbody>
</table>

TA = 51 mm

TA = 55 mm
The annulus is dilated if it measures
1. > 40 mm or > 21 mm/m² on 2D transthoracic echocardiography
   – Apical 4-chamber view
   – In diastole
2. > 70 mm on direct intraoperative measurement

ESC/EACTS Guidelines for management of VHD EHJ 2012
ACC/AHA Guidelines for management of VHD JACC 2014

IMPORTANCE OF THE TRICUSPID ANNULUS

Performing tricuspid annuloplasty based on TA dilatation rather than TR degree results in improved surgical outcome

Despite a sicker MV + TV repair group…

<table>
<thead>
<tr>
<th></th>
<th>MV + TV repair</th>
<th>MV repair only</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survival @ 10 years</td>
<td>90.3%</td>
<td>85.5%</td>
<td>NS</td>
</tr>
<tr>
<td>Grade III-IV TR</td>
<td>1%</td>
<td>34%</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Class III-IV CHF</td>
<td>0%</td>
<td>14%</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

Should Measurements of the Tricuspid Annulus be Performed Using Two-Dimensional Echocardiography?

• TA size measured by 2D echocardiography should be interpreted with caution because it is underestimated by both 2D TTE and TEE.

ROLE FOR 3D ECHOCARDIOGRAPHY

• Better approximation of septal-lateral dimension
• Also allows measurement of antero-posterior dimension

Addetia K, Muraru D, Veronisi F, Badano LP, Lang RM et. al. work in progress
On the horizon…
3D Echo

TRICUSPID ANNULUS

- Saddle-shaped
  - High points antero-posterior
  - Low points medial-lateral
- Ellipsoid shape


From side

Apex
FUNCTIONAL TRICUSPID REGURGITATION

- TA dilatation occurs mostly along the RV free-wall
- Septal portion of the tricuspid annulus relatively fixed

Dreyfus et al. ATS 2005

FUNCTIONAL TRICUSPID REGURGITATION

- With worsening TR, the annulus becomes larger, rounder and flatter

Taramasso M et al. J Am Coll Cardiol 2012
MECHANISMS OF TRICUSPID REGURGITATION

TR is highly dependent on annular dilatation, with significant TR occurring with only 40% dilatation, whereas it was seen at 75% dilatation in vitro MV studies. i.e. the TV leaks earlier than the MV.

THE ACC/AHA 2014 GUIDELINES

TA dilated if >40 mm in apical 4-chamber view

ESCI/EACTS Guidelines for management of VHD EHJ 2012
ACC/AHA Guidelines for management of VHD JACC 2014
Pre-operative TR, TV tethering distance and TV tethering area were independent predictors of residual TR after annuloplasty. Tethering distance 0.76 cm and tethering area 1.63 cm² had the best AUC (0.88 and 0.87 respectively)
### MECHANISMS OF TRICUSPID REGURGITATION

#### Table

<table>
<thead>
<tr>
<th>Group (N)</th>
<th>Controls (99)</th>
<th>Id FTR (141)</th>
<th>PHTN FTR (140)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>TR</strong></td>
<td>None</td>
<td>Matched for ERO</td>
<td></td>
</tr>
<tr>
<td><strong>sPAP</strong></td>
<td>Normal</td>
<td>&lt;50 mmHg</td>
<td>≥ 50 mmHg</td>
</tr>
<tr>
<td><strong>Associations:</strong></td>
<td>Controls</td>
<td>Aging, Afib</td>
<td></td>
</tr>
<tr>
<td><strong>TA</strong></td>
<td>Normal</td>
<td>↑↑↑↑</td>
<td>↑↑</td>
</tr>
<tr>
<td><strong>Tenting</strong></td>
<td>Normal</td>
<td>Normal</td>
<td>↑↑</td>
</tr>
<tr>
<td><strong>RV Base</strong></td>
<td>Normal</td>
<td>↑↑↑↑</td>
<td>↑</td>
</tr>
<tr>
<td><strong>RV Length</strong></td>
<td>Normal/Conical</td>
<td>↑↑↑↑</td>
<td>↑</td>
</tr>
<tr>
<td><strong>Remodeling</strong></td>
<td>Elliptical</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


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### MECHANISMS OF TRICUSPID REGURGITATION

TV tenting volume by 3DE (accounting for both enlarged annulus area and leaflet tenting) is the major determinant of residual functional TR after annuloplasty.

*Min SY et al. Eur Heart J 2010*
NEW DIRECTIONS: EVALUATION OF FTR
A MORE COMPREHENSIVE APPROACH

<table>
<thead>
<tr>
<th>TABLE 1 Stages of Functional Tricuspid Regurgitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage 1</td>
</tr>
<tr>
<td>---------</td>
</tr>
<tr>
<td>TR severity</td>
</tr>
<tr>
<td>Annular diameter, mm</td>
</tr>
<tr>
<td>Leaflet coaptation mode</td>
</tr>
<tr>
<td>Treatment</td>
</tr>
</tbody>
</table>

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

Dreyfus et. al. JACC 2015

ON THE HORIZON...

Muraru D and al. European Heart Journal Cardiovascular Imaging
Beware... the ultrasound beam often elicits findings the history and physical exam cannot...