MITRAL VALVE PATHOLOGY WITH TRICUSPID REGURGITATION (AND PHT)

Luigi P. Badano**, MD, PhD, FESC, FACC

**Dr. Badano has received honoraries and research grants from GE Healthcare, EsaOte, Samsung Elect, Sorin cardio S.p.A., Siemens, Actelion, Edwards Lifesciences

*No off-label use of device
Pathophysiology of Functional Tricuspid Regurgitation

Badano LP, Muraru D, Enriquez-Sarano M. Eur Heart J 2013
Tricuspid Regurgitation and Survival

Shiran A et al, J Am Coll Cardiol 2009
Changing Paradigms About Tricuspid Regurgitation

• "TV is not so important as left valves and severe TR is relatively benign...”

• “Functional (secondary) TR spontaneously disappears after correction of the mitral valve disease...”

• “TR frequency is expected to decrease, due to the progressively lower prevalence of rheumatic MV disease...”

• “Residual TR immediately after tricuspid valve repair will improve with time”

• TR is an independent determinant of patients survival and is associated with significant morbidity

• Functional TR does not resolve after left-sided valve surgery and actually worsens, with tricuspid annular dilation as the most important cause and target for intervention.

• TR frequency is expected to increase, as patients live longer and percutaneous interventions for left-sided valves (TAVI, Mitral clip etc) will be increasingly offered as alternative to traditional surgery.

• TV replacement is better than a poor TV annuloplasty with residual or recurrent TR

Braunwald NS et al. Circulation 1967

Comprehensive Assessment of the Tricuspid Valve Apparatus
Functional Tricuspid Regurgitation: Anatomy

Badano LP, Muraru D, Enriquez-Sarano M. Eur Heart J 2013
Functional Tricuspid Regurgitation: Grading Severity
# Tricuspid Regurgitation: Grading Severity

## Table 9: Grading the severity of TR

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tricuspid valve morphology</td>
<td>Normal/abnormal</td>
<td>Normal/abnormal</td>
<td>Abnormal/flail/large coaptation defect</td>
</tr>
<tr>
<td>Colour flow TR jet&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Small, central</td>
<td>Intermediate</td>
<td>Very large central jet or eccentric wall-impinging jet</td>
</tr>
<tr>
<td>CW signal of TR jet</td>
<td>Faint/parabolic</td>
<td>Dense/parabolic</td>
<td>Dense/triangular with early peaking (peak &lt; 2 m/s in massive TR)</td>
</tr>
<tr>
<td>Semi-quantitative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC width (mm)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>Not defined</td>
<td>&lt;7</td>
<td>&gt;7</td>
</tr>
<tr>
<td>PISA radius (mm)&lt;sup&gt;b&lt;/sup&gt;</td>
<td>≤5</td>
<td>6–9</td>
<td>&gt;9</td>
</tr>
<tr>
<td>Hepatic vein flow&lt;sup&gt;c&lt;/sup&gt;</td>
<td>Systolic dominance</td>
<td>Systolic blunting</td>
<td>Systolic flow reversal</td>
</tr>
<tr>
<td>Tricuspid inflow</td>
<td>Normal</td>
<td>Normal</td>
<td>E-wave dominant (≥ 1 m/s)&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Quantitative</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EROA (mm&lt;sup&gt;2&lt;/sup&gt;)</td>
<td>Not defined</td>
<td>Not defined</td>
<td>≥40</td>
</tr>
<tr>
<td>R Vol (mL)</td>
<td>Not defined</td>
<td>Not defined</td>
<td>≥45</td>
</tr>
<tr>
<td>+ RA/RV/IVC dimension&lt;sup&gt;e&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Severity of Functional Regurgitation

Muraru D, Badano L et al. Curr Cardiol Rep 2011
Quantitation of Functional Regurgitation

Vena contracta area

Vena contracta area and TR severity:
- <0.5 cm²: Mild
- 0.5-0.75 cm²: Moderate
- >0.75 cm²: Severe

Velayudhan DE et al. Echocardiography 2006
Quantitation of Functional Regurgitation

Chen TE et al. J Am Soc Echocardiogr 2013

$\text{r} = 0.62$
$p < 0.0001$
Quantitation of Functional Regurgitation

Chen TE et al. J Am Soc Echocardiogr 2013
Quantitation of Functional Regurgitation: 3D PISA

Tricuspid Regurgitation
Measurement Current Peak
Volume PISA 10.01 cm²
ERO 1.05 cm²
Aliasing Velocity 0.28 m/s
Inst. Flow Rate 275.31 ml/s
Peak Regurg Vol 62.81 ml
Peak RF -- -- %
VTI 0.6 m
Quantitation of Functional Regurgitation: 3D PISA

Courtesy of Miglioranza MH, data on file
Tricuspid Annulus Size

Tricuspid Annulus Size and Shape Changes in Functional Tricuspid Regurgitation

Ton-NU T et al. Circulation 2006
How to Measure Tricuspid Annulus by 2D?

How to Measure Tricuspid Annulus by 2D?

- 219 healthy volunteers (aged 43±15 years, range 18-76 years, 95 men)

- Linear measurements of TV annulus in 3 different views by 2D echo

Dedicated Software for TV Quantitative Analysis by Transthoracic 3DE

Volume rendering (surgical view)

Automatically traced leaflets

3D TV computed by the software

Red color denotes flail leaflet

Different colors for each leaflet

Veronesi F et al. EuroECHO 2013 (P891)
### Tricuspid Annulus in Functional Regurgitation

24 pts with severe (30%) and non severe (70%) functional tricuspid regurgitation

<table>
<thead>
<tr>
<th></th>
<th>3D TASA (cm²)</th>
<th>2D diameter (4CH)</th>
<th>2D diameter (PLAX)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>p Value</td>
<td>r</td>
</tr>
<tr>
<td>3D EROA (mm²)</td>
<td>0.78</td>
<td>&lt;0.0001</td>
<td>0.408</td>
</tr>
<tr>
<td>3D PISA surface (cm²)</td>
<td>0.727</td>
<td>&lt;0.0001</td>
<td>0.418</td>
</tr>
<tr>
<td>3D Regurgitant volume (ml)</td>
<td>0.754</td>
<td>&lt;0.0001</td>
<td>0.453</td>
</tr>
</tbody>
</table>

Miglioranza G. et al. EuroEcho 2014 (P#1004)
Tricuspid Annulus in Functional Regurgitation

24 pts with severe (30%) and non severe (70%) functional tricuspid regurgitation

<table>
<thead>
<tr>
<th>3D TA geometry parameters</th>
<th>3D EROA (mm²)</th>
<th>3D PISA (cm²)</th>
<th>3D Regurgitant volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>p Value</td>
<td>r</td>
</tr>
<tr>
<td>Perimeter (cm)</td>
<td>0.697</td>
<td>0.001</td>
<td>0.680</td>
</tr>
<tr>
<td>Surface area (cm²)</td>
<td>0.719</td>
<td>0.001</td>
<td>0.679</td>
</tr>
<tr>
<td>Long axis (cm)</td>
<td>0.734</td>
<td>0.001</td>
<td>0.649</td>
</tr>
<tr>
<td>Short axis (cm)</td>
<td>0.685</td>
<td>0.002</td>
<td>0.665</td>
</tr>
</tbody>
</table>

Cavalli G et al. EuroEcho 2014 (P#1281)
Tricuspid Annulus in Functional Regurgitation

43 pts with severe (30%) and non severe (70%) functional tricuspid regurgitation

<table>
<thead>
<tr>
<th>TA geometry parameters</th>
<th>RV volume (ml)</th>
<th>RA volume (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>p Value</td>
</tr>
<tr>
<td>Perimeter (cm)</td>
<td>0.698</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Surface area (cm$^2$)</td>
<td>0.650</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Long axis (cm)</td>
<td>0.550</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Short axis (cm)</td>
<td>0.599</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Muraru D et al. EuroEcho 2014 (P#552)
Tricuspid Annulus in Functional Regurgitation

- TR is highly dependent on annulus dilation
- 40% increase in TA is enough for the valve to leak (FMR: 75%)

Spinner E et al. Circulation 2011
In comparison with MV, PMs are smaller, widely separated and carrying chordae to a single leaflet, allowing a greater leaflet separation if annulus and RV cavity dilate.

Badano LP, Muraru D, Enriquez-Sarano M. Eur Heart J 2013

Courtesy of Dr William Edwards, Mayo Clinic, Rochester, MN
Valve Leaflet Tenting

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

The major goal of TV repair is an effective reduction of TV tenting volume; however, current annuloplasty techniques worsen leaflet tethering and actually increase TV tenting volume.

Min SY et al. Eur Heart J 2010
Valve Tenting in Functional Regurgitation

• **Not all patients with annulus dilation have significant TR**

  - Annulus area = 11.0 cm$^2$
  - Tenting vol = 1.2 cm$^3$
  - Mild TR

  - Annulus area = 11.2 cm$^2$
  - Tenting vol = 3.3 cm$^3$
  - Severe TR

• For the same annulus size, variation in leaflet tenting and size may account for TR occurrence

• In case of very enlarged RVs, downsizing ring annuloplasty should be associated with leaflet augmentation and/or PMs repositioning techniques

Spinmer E et al. Circulation 2011
Predictors of Residual Regurgitation After Tricuspid Annuloplasty

TV tenting volume (annulus size and leaflet tenting) measured before and after annuloplasty is a major determinant of residual functional TR regardless of the TR quantification method employed (VC or jet area).

Min SY et al. Eur Heart 2010
Clinical Case

- 63-yr-old caucasian man
- Functional TR treated by downsizing ring annuloplasty
Tricuspid Annuloplasty and Wrong Annulus Sizing
Conclusions

- TV annulus and leaflets are different than MV annulus and leaflets, and the same quantification algorithms/tools not necessarily work the same for both valves
- Conventional 2D/Doppler echocardiographic parameters do not seem to provide accurate quantification of tricuspid regurgitation severity
- TV annulus 3D shape and function are key players in the development of functional TR, and 2D echo is clearly inadequate to quantify them
- A dedicated semi-automated software for tricuspid valve analysis by 3D echo commercially-available is highly needed
- Future studies will confirm if a more accurate quantification of tricuspid annulus size and regurgitation severity will translate in better selection of patients for tricuspid valve repair/annuloplasty
### 3D ECHO INTENSIVE COURSE

**Course Directors:** Luigi P. Badano, Denisa Muraru

The advent of three-dimensional echocardiography (3D echo) has significantly improved the impact of non-invasive imaging on our understanding and management of cardiac diseases in clinical practice. Transesophageal 3D echo enables an easier, more accurate and reproducible interpretation of the complex cardiac anatomy, overcoming the intrinsic limitations of conventional echocardiography.

The availability of unprecedented views of cardiac structures from any perspective in the beating heart provides valuable clinical information and new levels of confidence in diagnosing heart disease. One major advantage of the third dimension is the improvement in the accuracy and reproducibility of chamber volume measurement by eliminating geometric assumptions and errors caused by foreshortened views. Another benefit of 3D echo is the realistic en face views of heart valves, enabling a better appreciation of the severity and mechanisms of valve diseases in a noninvasive manner.

However, 3D echo is a technically demanding technique and, for its effective use, echocardiographers need specific education and training. They have to learn how to acquire volumetric data sets without artifacts, and navigate within the data set to obtain the desired view. New tools like cropping, slicing and thresholding are available to manipulate the data sets in order to visualize the cardiac structure of interest. Finally, various ways to display the information are available and can be used to address different clinical issues.

To help echocardiographer who wish to implement 3D echo in the routine of their echo lab, a 4-day intensive theoretical and practical course with hands-on sessions in the morning and theoretical lessons in the afternoon has been set up.

**Course Language:** English (no translation will be available)

**Venue:** Department of Cardiac, Thoracic and Vascular Sciences, University of Padua Medical School, Via Giustinian 2, 35128 Padua, Italy

**Learning Objectives:**
- Those who will attend the theoretical sessions will receive a comprehensive up-to-date data state-of-the-art 3D transesophageal and transthoracic echocardiography.
- Those who will attend both theoretical and practical sessions will also learn how to acquire 3D echo data sets, display them and perform quantitative analyses at workstation. No practical 3D transesophageal echo acquisition will be allowed to attendees for safety and legal reasons.

**Important! The practical sessions will be performed using Vivid E9 and IE 33 echo scanners and EchoPac BT 12 and Qlab 9.0 workstations.**

**Teaching Material and Tools:**
- A collection of review papers written by the course directors covering most of the topics will be sent electronically in advance to all the attendees.
- Those attending the practical sessions will also be allowed to access a large data base of various clinical cases to practice during free time.
- 3 hours morning of practical course (acquisition + post processing on EchoPac workstations) with a dedicated tutor.

**Suggested Readings:**

**Theoretical Sessions at 2:00 PM to 5:00 PM, from Monday to Thursday**

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### THEORETICAL LESSON PROGRAMME

<table>
<thead>
<tr>
<th>Day</th>
<th>Course</th>
<th>Topics</th>
</tr>
</thead>
</table>
| **Day 1** | **General concepts about 3D vs 2D** | - Why do we need 3D?  
- 3D probes (TTE and TOE)  
- Physics of 3D echocardiography  
- The third dimension |
| **Day 2** | **How to acquire and display 3D data sets** | - Acquisition modes  
- Rendering techniques  
- Cropping  
- Slicing  
- Thresholding  
- Artifacts and how to avoid them  
- Acquisition protocols  
- 3D echo anatomy |
| **Day 3** | **How to implement 4D echo in the routine of the echo lab?** | - Mitral valve  
- Aortic valve  
- Tricuspid valve |
| **Day 4** | **Left ventricle** | - Acquisition and display techniques  
- Volumes  
- Mass  
- Shape  
- Regional and global function (ischemic heart disease, cardiomyopathies) |
| **Day 5** | **Right ventricle** | - Acquisition and display techniques  
- Regional and global function |
| **Day 6** | **Left and right atrium** | - Acquisition and display  
- Echo anatomy: left atrial appendage, pulmonary veins  
- Global geometry and phasic function |
| **Day 7** | **Third-generation 3D transoesophageal echo** | - Congenital heart diseases  
- Atrial septal defects  
- Patent foramen ovale  
- Ventricular septal defects  
- Uni-, bi- and quadricuspid aortic valve  
- Mitral cleft  
- Parachute mitral valve  
- Cor triatriatum  
- Univentricular heart  
- Ebstein disease |
| **Day 8** | **Masses** | - Tumors  
- Thrombi |
| **Day 9** | **Pharmacological stress echo** | - Six seats for theoretical sessions only and 2 seats for both theoretical and practical sessions will be reserved to EACVI Club 35 members with a 50% discount on the registration fee. |

For further information, please contact: barbara.hildenafil@unipd.it