ECHOCARDIOGRAPHIC ASSESSMENT OF "FORGOTTEN VALVE"

Adina Ionac, Irina Popescu

ABSTRACT

Tricuspid valve apparatus can be fully evaluated by transthoracic and transesophageal echocardiography. In the future, the three-dimensional echocardiography will offer the integral image of tricuspid valve. Spectral Doppler shows the tricuspid flow with the same morphology as mitral flow, but with lower velocity. A mild tricuspid regurgitation (TR) is present in 80 - 90% of normal subjects. Tricuspid stenosis (TS) is rare, and in most cases accompanies a left valvulopathy. The echocardiography offers a complete positive, etiologic (congenital, rheumatic, carcinoid syndrome, infective, or tumor that mimicks the TS), severity and functional diagnosis. The same methods as in mitral stenosis are used for the severity classification of TS, but the limits are different. Severe TS is defined by tricuspid orifice area \( \leq 1 \text{ cm}^2 \), mean transtricuspid gradient (Pmed) \( \geq 7 \text{ mmHg} \), and pressure half time (PHT) \( > 190 \text{ ms} \) and has indication for surgery. Tricuspid regurgitation is more frequently encountered in daily practice, and in most cases is secondary to right ventricular (RV) systolic and/or diastolic pressure rise. TR is very rarely organic, secondary to various diseases (rheumatic fever, infective endocarditis, carcinoid syndrome, rheumatic arthritis, post radiation, postrumatic, tricuspid valve prolapse, congenital). As the case is for TS, the echocardiography offers the TR complete diagnosis, using the same methods as for mitral regurgitation and with the same limits. Two-dimensional echocardiographic data suggest the etiology, while spectral and color Doppler indicate the severity of TR. Severe TR is defined by a color Doppler jet area \( > 10 \text{ cm}^2 \), vena contracta \( > 0.7 \text{ cm} \) and PISA radius \( > 0.9 \text{ cm} \). Inferior vena cava flow and respectively suprahepatic veins flow are other echocardiographic signs useful for TR severity evaluation. The right chambers are also dilated in severe TR, but this is not a specific sign. Surgical indications for tricuspid valvulopathy are published in the last American Society of Echocardiography Guidelines. As a general rule, severe TR with tricuspid annulus dilation must undergo surgical correction.

Key Words: tricuspid valve, transthoracic and transesophageal echocardiography, tricuspid stenosis, tricuspid regurgitation.

Learning Objectives: After studying this article, the internal medicine practitioner and cardiologist should be able to: 1. Understand the anatomy and the function of tricuspid valve; 2. Have knowledge about the main causes of tricuspid valvulopathy; 3. Understand the echocardiographic evaluation of pulmonary hypertension; 4. Understand the indications and the correct moment of surgical intervention for tricuspid valvulopathy.

INTRODUCTION

The tricuspid valve (TV) is probably correctly called by surgeons the „forgotten valve”. Sometime the cardiologist uses TV only to calculate the pulmonary systolic arterial pressure, and the surgeon hopes to repair this valvulopathy only through decreasing the pulmonary hypertension.
THE ANATOMY OF TRICUSPID VALVE

The tricuspid valve is a complex structure formed by:
- Three leaflets: anterior (A) or lateral, posterior (P) and septal (S); the septal leaflet is smaller than the other two and has an apical insertion compared with the anterior leaflet of the mitral valve;
- The tricuspid annulus with a complex geometry which is not plane but became plane when is dilated;
- Chordae
- Three papillary muscles with interventricular septum (IVS) and free right ventricular (RV) wall insertion.1

THE ECHOCARDIOGRAPHIC EVALUATION OF TV

The TV can be well visualized from multiple transthoracic echocardiographic (TTE) views: (Fig. 1)
- Right ventricular inflow tract view, the single view where the posterior leaflet can be clearly seen, near the anterior; (Fig. 1a)
- Parasternal short-axis view; (Fig. 1b)
- Apical four chambers (4C) view; (Fig. 1c)
- Subcostal 4C view.
In the last three views the septal and anterior leaflets can be visualized.
Transesophageal echocardiography (TEE) offers multiple views for the tricuspid valve evaluation planes as well: (Fig. 2)
- 4C view, similar to TTE 4C view; (Fig. 2a)
- At the base of the heart in a 60° view.
In these two views the anterior and septal leaflets can be visualized:
- Bi-caval view; (Fig. 2b)
- Gastric longitudinal view of RV. (Fig. 2c)
The last two allow the visualization of the anterior and posterior leaflets.
The tricuspid inflow and tricuspid regurgitation can be evaluated from multiple ecocardiographic windows by spectral and color Doppler. The effective orifice area of the tricuspid valve is greater than that of the mitral valve and the right cavities pressure is smaller than on the left.2,3 Because of that the inflow velocities are lower for TV than for the mitral valve. Normally, the tricuspid diastolic flow E/A ratio exceeds 1.0.1 Color flow imaging can be used to detect the presence of tricuspid regurgitation (TR). This is present physiologically in 80-90% of healthy subjects.4,6 The physiological TR has low velocities and right ventricular systolic pressure is in the normal range.1

Figure 1. Transthoracic echocardiographic views for tricuspid valve visualization: A. right ventricular inflow tract view; B. parasternal short-axis view; C. apical 4C view.

TRICUSPID STENOSIS (TS)

Tricuspid stenosis is a relative rare disease in both adults and children, and when is present in most cases accompanies a left valvulopathy.2 The echocardiography offers a complete positive, etiologic, severity and functional diagnosis of this valvulopathy.
The positive diagnosis (similar to mitral stenosis) uses M mode and bidimensional (2D) data, which described the morphology and mobility of tricuspid
Figure 2. Transesophageal echocardiographic views for tricuspid valve visualization: A. 4C view at 0°; B. bicaval view; C. gastric longitudinal view of RV.

valve. The continuous wave and color Doppler registered the diastolic tricuspid turbulent flow.

The 2D data are very helpful for the etiologic diagnosis:
1. Rheumatic fever;
2. Congenital disease;
3. Carcinoid syndrome;
4. Infective endocarditis;
5. Obstructive tumors which mimick a TS.

The evaluation of TS severity uses methods similar to those employed for mitral stenosis:
- Continuous wave Doppler measurement of maximum and medium velocities and pressures on tricuspid inflow wave (Vmax, Vmean, Pmax, Pmean); (Fig. 3)

Figure 3. Transesophageal echocardiagnosis, continuous wave Doppler at the level of tricuspid valve in a patient with tricuspid stenosis. Measurement of medium diastolic gradient.

- Pressure half time (PHT) method with the constant of 190;5,7 (Fig 4)

$$TV \text{ orifice area} (S) = \frac{\text{PHT}}{190}$$

- The continuity equation.

The TS is considered severe when Pmean ≥ 7 mm Hg, S ≤ 1 cm², PHT > 190 ms;3,5,7,8

The echocardiographic evaluation must include the measurements of the right atrium (RA) enlargement.

TRICUSPID REGURGITATION (TR)

Doppler echocardiography represents the gold standard for diagnosis of TR. Continuous wave and color Doppler are the main methods of detection and quantification of severity of TR. Another true
positive diagnosis data are given by Color M mode which shows the timing of TR.\textsuperscript{4,6} Echocardiographic positive diagnosis uses M mode and 2D indirect data: annulus dilation, enlargement of RV, raised RV/LV ratio, paradoxical IVS motion.\textsuperscript{4,6} We must exclude from diagnosis the physiological TR with the following criteria:

- TR jet in RA < 1 cm long;
- TR jet area < 2.5 cm\textsuperscript{2};
- TR jet area / RA area < 18%.

The underlying cause of TR can be detected by 2D and M-mode echocardiography.\textsuperscript{4,6,7} TR can be due to primary disease of TV or secondary to annulus dilation (functional TR).\textsuperscript{1}

Etiologies of tricuspid regurgitation are listed below:\textsuperscript{5,10}

1. Primary TR:
   - Rheumatic fever;
   - Infective endocarditis;
   - Carcinoid syndrome;
   - Rheumatoid arthritis;
   - Post radiation therapy;
   - Posttraumatic (repeated biopsies);
   - Tricuspid valve prolapse;
   - Congenital (Ebstein disease; cleft of tricuspid valve);
   - Anorectic drugs.

2. Secondary:
   - Elevation of RV systolic pressure (mitral stenosis, pulmonary stenosis);
   - Elevation of RV diastolic pressure (RV myocardial infarction).

The severity of TR can range from mild to severe.\textsuperscript{1} It is important to remember that maximum velocity of tricuspid regurgitant flow represents the pressure difference between RV and RA, and has nothing to do with TR severity grade. More than that, the intensity of continuous wave signal is directly proportional with TR severity and the shape of flow can suggest the acute TR (flow with early peak velocity and cut-off of descendent part of the slope).

Quantification of TR can be done in a manner analogous to that for the mitral valve but the publishing data are less well established. The intensity and the shape of continuous wave signal is useful to evaluate the TR severity of to differentiate an acute TR from a chronic one. When TR is severe, the dilation and systolic pulsation of inferior vena cava along with loss of respiratory variation in size can be detected. Additionally, retrograde systolic flow in hepatic veins can be seen.\textsuperscript{11,13} Table 1 presents 2D echocardiographic data and Doppler parameters used in evaluating TR severity.\textsuperscript{1,11,15}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
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</thead>
<tbody>
<tr>
<td>TV</td>
<td>N</td>
<td>N/abN</td>
<td>Modified; flail; no coaptation</td>
</tr>
<tr>
<td>RV / RA / IVC size</td>
<td>N</td>
<td>N/dilated</td>
<td>Dilated</td>
</tr>
<tr>
<td>Jet area - central jet (cm\textsuperscript{2})</td>
<td>&lt; 5</td>
<td>5 - 10</td>
<td>&gt; 10</td>
</tr>
<tr>
<td>vc width (cm)</td>
<td>N</td>
<td>&lt; 0.7</td>
<td>&gt; 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>Jet density and contour CW</td>
<td>Soft and parabolic variable</td>
<td>Dense, (with early peak)</td>
<td></td>
</tr>
<tr>
<td>Hepatic vein flow</td>
<td>Systolic dominance blunting</td>
<td>Systolic reversal</td>
<td></td>
</tr>
</tbody>
</table>

TV - tricuspid valve; RV - right ventricle; RA - right atrium; IVC - inferior vena cava; N - normal; vc - vena contracta; PISA - proximal isovelocity surface area; CW - continuous wave; N - normal.

Sometimes the differential diagnosis is necessary. For example, the eccentric jets which are directed along interatrial septum must be differentiated from a normal caval inflow or an atrial septal defect. In other cases, we must differentiate TR from abnormal pulmonary venous return.

### PARTICULAR CONDITIONS

#### Rheumatic disease

In 20 - 30\% of cases with rheumatic valvular disease the tricuspid valve is involved, associated with mitral valve and aortic valve disease, the most common findings in this cases being combined mitral stenosis and tricuspid regurgitation. The issue of these cases, in fact the surgical issue is whether tricuspid regurgitation will or will not be improved after MS correction. So if we have severe deformity of tricuspid valve or dilation of tricuspid annulus in the presence of severe tricuspid regurgitation, tricuspid valve should be repaired.\textsuperscript{6,9}

#### Infective endocarditis

Endocarditis involving the tricuspid valve is most commonly seen in the settings of intravenous drug use. Tricuspid vegetation is usually greater than in the left side, with a higher risk of embolization; some degree of tricuspid regurgitation is generally present.\textsuperscript{16,17}

#### Tricuspid valve prolapse

Tricuspid valve prolapse is seen in myxomatous valve syndrome in most cases associated with mitral valve prolapse.\textsuperscript{1}

#### Ischemic heart disease

Tricuspid regurgitation can be seen in ischemic heart disease with involvement of right ventricle (RV myocardial infarction). The TR mechanism is annulus
dilation and papillary muscles ischemia. Several signs can lead the diagnose to RV ischemia: low maximal velocity of TR, RV hipo/akinesia, RV and RA dilation, IVS paradoxic motion, tricuspid annulus plane systolic excursion(TAPSE) < 15 mm, RV thrombi.

**Ebstein anomaly**

Ebstein anomaly is a congenital abnormality of the tricuspid valve in which one or more tricuspid leaflets is/are dysplastic with apical displacement from tricuspid annulus toward the right ventricular apex. For definition, the distance between mitral or tricuspid annulus plane and the insertion of tricuspid pathologic leaflet is greater than 1 cm (or more than 0.8 mm/m²). Frequently a tethering of anterior and/or posterior tricuspid leaflet to RV wall is present. (Fig. 5) These modifications lead to atrialization of a RV part. The atrialized RV/total RV ratio more than 30% indicates severe disease with poor prognosis. Commonly the tricuspid regurgitation is severe with low velocity on continuous wave Doppler.

**Carcinoid disease**

Carcinoid heart disease consists in an inflammatory reaction of the endothelium of the valves, usually affecting the right-side heart valve, that develops when an endocrine-secreting tumor releases high levels of serotonin and its metabolites into the bloodstream. Typically the entire TV is involved and becomes rigid, thickened, shortened and retracted. Tricuspid regurgitation usually results in non-coaptation of the valve and has relatively low velocity.

**Endocardial fibroelastosis**

Endocardial fibrosis is due to an inflammatory response of chordae and leaflets in a variety of diseases such as hypereosinophilia syndrome and tropical forms of endocardial fibroelastosis. The leaflets appear to be restricted and the obliteration of the right ventricular apex due to inflammatory tissue and secondary thrombosis can be seen.

**Pacemakers and catheters**

Occasionally a catheter or a pacemaker’s wire interferes with tricuspid valve function and interrupt normal coaptation of the tricuspid valve. Fibrosis of the leaflet can occur due to chronic contact with a catheter resulting in variable degree of tricuspid regurgitation. Furthermore, the presence of the wires represents a risk for infective endocarditis, and these cases are not so uncommon. (Fig. 6)

**Figure 5.** Transthoracic echocardiography, apical 4 chamber view in a patient with Ebstein disease. The tricuspid septal leaflet has a pathological apical insertion and the anterior leaflet is attached to right ventricular wall.

**Figure 6.** Transthoracic echocardiography, apical 4-chamber view in a patient with pacemaker. In right cavities there are the wires with attached vegetations (arrow).

**EVALUATION OF RIGHT VENTRICULAR SYSTOLIC PRESSURE AND OF PULMONARY SYSTOLIC ARTERY PRESSURE**

Pulmonary hypertension (PH) can be evaluated through three methods: evaluation of pulmonary arterial systolic pressure (PASP) using tricuspid regurgitation (the most used method), evaluation of pulmonary arterial diastolic pressure (PADP) using pulmonary regurgitation and evaluation of pulmonary arterial medium pressure using pulmonary ejection flow.

The maximum velocity (Vmax) of tricuspid regurgitation flow is measured on continuous wave Doppler in apical 4-chamber view, for the evaluation of PASP. The maximum gradient (Pmax) is calculated using Bernouli formula. A very good correlation has been demonstrated between the gradient evaluated echocardiographic and the value determined invasively by catheterism.

This maximum gradient represents the pressure gradient (ΔP) between RV pressure (RVP) and RA pressure (RAP) in systole. The RVP in systole is equal with PASP, in the absence of pulmonary valvular stenosis.
\[ P_{\text{max}} = 4V_{\text{max}}^2 \]
\[ \Delta P = RVP - RAP \]
\[ 4V_{\text{max}}^2 = RVP - RAP = \text{PASP} - RAP \]

The RAP can be evaluated using IVC diameter or right cardiac failure signs.

When IVC diameter is < 2 cm and inspiration decrease > 50% : RAP = 5 mmHg; when IVC diameter is > 2 cm and inspiration decrease > 50% : PAD = 10 mmHg; and when IVC is > 2 cm without respiratory variation: PAD = 15 mmHg.

The evaluation of RAP using right cardiac failure signs:
- No right cardiac failure: PAD = 5 mmHg;
- Mild right cardiac failure: PAD = 10 mmHg;
- Severe right cardiac failure: PAD = 15 mmHg. Then the SPAP can be calculated:

\[ \text{SPAP} = 4V_{\text{max}}^2 + RAP \]

Pulmonary hypertension is severe when SPAP is greater than 70 mmHg or more than 75% from systemic systolic arterial pressure.1

**SURGICAL INDICATIONS**

Surgical or percutaneous intervention on the tricuspid valve is usually carried out at the time of intervention on the other valves (left-side heart valves).

Table 2. Indications for surgery in tricuspid valve disease, according to European Society of Cardiology Guidelines.7

<table>
<thead>
<tr>
<th>Indication</th>
<th>Class</th>
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<tbody>
<tr>
<td>Severe tricuspid regurgitation (TR) in a patient undergoing left-side valve surgery</td>
<td>Ic</td>
</tr>
<tr>
<td>Severe primary TR and symptoms despite medical therapy without severe right ventricular dysfunction</td>
<td>Ic</td>
</tr>
<tr>
<td>Severe TS with symptoms despite medical therapy</td>
<td>Ic</td>
</tr>
<tr>
<td>Severe TS - TR in a patient undergoing left-side valve intervention</td>
<td>Ic</td>
</tr>
<tr>
<td>Moderate organic TR in a patient undergoing left-side valve surgery</td>
<td>Ila</td>
</tr>
<tr>
<td>Moderate secondary TR with dilated annulus (&gt; 40 mm) in a patient undergoing left-side valve surgery</td>
<td>Ila</td>
</tr>
<tr>
<td>Severe TR and symptoms, after left-side valve surgery, in the absence of left-sided myocardial, valve, or right ventricular dysfunction and without severe pulmonary hypertension (systolic pulmonary artery pressure &gt; 60mmHg)</td>
<td>Ila</td>
</tr>
<tr>
<td>Severe isolated TR with mild or no symptoms and progressive dilatation or deterioration of right ventricular function</td>
<td>Iib</td>
</tr>
</tbody>
</table>

TS - tricuspid stenosis; TR - tricuspid regurgitation.

Conservative surgery or valve replacement, according to anatomy and surgical expertise in valve repair, is preferred to balloon commissurotomy in cases of severe tricuspid stenosis.30 In cases of severe tricuspid regurgitation annuloplasty is the key to conservative surgery and it is preferable to valve replacement if technically possible. If valve replacement is necessary the current experience favors the use of bioprostheses over mechanical valve.8,10,30

Table 2 presents the indications for intervention in tricuspid valve disease according to European Society of Cardiology Guidelines published in January 2007.9

Transeosophageal echocardiographic evaluation is frequently necessary in tricuspid valve surgery: intraoperative when annuloplasty for TR secondary annular dilatation is performed or after procedure in case of TV replacement (for severe modified leaflets).9,10,30

**REFERENCES**


