Interventional Imaging of the Tricuspid Valve

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KEYWORDS

• Tricuspid regurgitation • Imaging • Interventional echocardiography
• Percutaneous tricuspid valve intervention • Transcatheter tricuspid valve repair/replacement

KEY POINTS

- Transcatheter tricuspid valve interventions (TTVIs) are emerging as attractive alternative options for patients affected by functional tricuspid regurgitation (FTR) due to some degree of annular dilation and leaflet tethering.
- Because of the complex nature of the tricuspid valve (TV), a comprehensive assessment should be performed from multiple transthoracic and transesophageal windows, including a 3-dimensional evaluation.
- The procedural planning for TTVIs is based on a multimodality imaging approach (based on echocardiography and computed tomography scan), aiming to define FTR, TV morphology, and anatomic relationships.
- A good target for TTVIs seems to be FTR with predominant annular dilatation and modest apical remodeling, without severe dysfunction of the right ventricle and/or severe pulmonary hypertension.
- Intraprocedural guidance is based mainly on transesophageal echocardiography (seldom transthoracic) and fluoroscopy, with the recent introduction of fusion imaging.

INTRODUCTION

Functional tricuspid regurgitation (FTR) impacts negatively on the prognosis of patients with mitral valve disease and advanced left ventricular dysfunction.[1] Usually these patients are managed conservatively[2] until advanced stages of disease when the surgical option becomes prohibitive.[3] Therefore, reasonable low-risk, less-invasive transcatheter tricuspid valve interventions (TTVIs) are emerging as attractive alternative options.

However, the dimensions and the angulation of the tricuspid annulus (TA) in relation to the caval veins, the slow flow and trabeculated structure of the right-heart, and the lack of annular calcification make the percutaneous implantation of a bioprosthesis challenging[4] and, thus, was performed only as valve-in-valve or valve-in-ring procedures.[5,6] The following percutaneous options are under development:

1. Implantation of a bioprosthetic valve in both caval veins[7]

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2. Percutaneous tricuspid valve (TV) repair mimicking the surgical Kay procedure (TriCinch System, 4Tech Cardio Ltd, Galway, Ireland; Trialign System, Mitralign, Inc, Boston, MA)[8–10]
3. Percutaneous TV repair targeting leaflets (MitraClip System, Abbott Vascular, Abbott Park, IL)[11]
4. Direct percutaneous TV annuloplasty (Cardioband, Edwards Lifesciences, Irvine, CA)[12]
5. Transcatheter delivery of a spacer providing a surface for leaflet coaptation (FORMA Spacer, Edwards Lifesciences, Irvine, CA)[13]
6. TV replacement[14]

As for other transcatheter procedures, preprocedural planning and intraprocedural monitoring are fundamental. All potential candidates should be screened with transthoracic echocardiography (TTE) and, if eligibility seems plausible, a second-level imaging evaluation with transesophageal echocardiography (TEE); in some cases, a computed tomography (CT) scan is mandatory in order to evaluate all the anatomic details needed. The screening process is also aimed at tailoring the procedure and choosing the best option for every single patient.

The intraprocedural imaging, mainly by TEE and sometimes TTE, is essential to monitor all the procedural steps, to check the results, and to timely detect complications.

TRICUSPID VALVE ANATOMY

Normal Anatomy

The right atrioventricular valve is the largest and most inferiorly positioned valve; its functional anatomy can be divided into 4 components: the fibrous annulus, the leaflets, the papillary muscles, and the chordal attachments.[15,16] The anatomic position of the tricuspid annular plane is nearly vertical and approximately 45° from the sagittal plane. The annulus is triangular or ovoid as well as saddle shaped superiorly (atrially), displaced in the anteroseptal portion near the right ventricular (RV) outflow tract and aortic valve and the posterolateral portion, and inferiorly (apically) displaced in the postero-septal portion near the inflow of the coronary sinus and the anterolateral segment.[17] Unlike the mitral valve, there is no fibrous continuity with the corresponding semilunar valve. Like the mitral valve, annular dynamism contributes to leaflet closure.[15,17–19] Normal tricuspid annular circumference and area in healthy subjects are 12 ± 1 cm and 11 ± 2 cm^2, respectively.[17,20] During atrial systole and again in late ventricular systole/early diastole, there is a significant increase in annular area (29.6% ± 5.5%) as well as circumference. Importantly, the right coronary artery courses within the right coronary sulcus and is typically embedded in fat, approximately 5 to 8 mm above the right fibrous annulus.[21] This relationship can vary, however, and should be understood before surgical or transcatheter-based therapy.

There is significant variability in the number of TV leaflets, with reports between 2 and 6 leaflets.[22] The increased number is most commonly due to the presence of supernumerary and/or commissural cusps: most cases in one pathologic study had 4 leaflets with the location of the fourth between the anterior and posterior leaflets. The most common description of the tricuspid, nonetheless, is of a 3-leaflet valve with leaflets varying in both circumferential (annular) and radial size. Because of the vertical position of the tricuspid annulus, the appropriate anatomic names of the leaflets are *anterosuperior*, *septal*, and *inferior*. However, the nomenclature commonly used for these leaflets are *anterior*, *septal*, and *posterior*. The anterior leaflet is the longest radial leaflet with the largest area and the greatest motion. The septal leaflet is the shortest in the radial direction and the least mobile. This short septal leaflet is attached to the TA directly above the interventricular septum with several third-order chordae attached directly to the septum; it is inserted into the septum 10 mm or less apical to the septal insertion of the anterior mitral leaflet (ie, apically displaced). The posterior (or mural or inferior) leaflet may have multiple scallops and is the shortest circumferentially; however, it may not be clearly separated from the anterior leaflet in approximately 10% of patients. Anatomic landmarks for each leaflet vary significantly depending on the size and shape of the annulus; however, the commissure between the septal and posterior leaflets (which are always clearly separated) is usually located near the entrance of the coronary sinus to the right atrium. A normal TV area is between 7 and 9 cm^2 and is, thus, the largest of the 4 cardiac valves. Because of its large size and the low-pressure differences between the right atrium and ventricle, peak transtricuspid diastolic velocities are typically lower than 1 m/s with mean gradients less than 2 mm Hg.

The papillary muscles of the TV also exhibit significant variability.[23,24] The large anterior papillary muscle is the most consistent, arising from the anterior wall near the trabeculations,