Anatomy of the Tricuspid Valve, Pathophysiology of Functional Tricuspid Regurgitation, and Implications for Percutaneous Therapies

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KEYWORDS

• Tricuspid • Right ventricle • Transcatheter • Anatomy • Functional

KEY POINTS

- The tricuspid valve is a complex dynamic structure whose function depends on the harmony of several different components: annulus, leaflets, chordae, papillary muscles, and right ventricle.
- Several nonvalvular structures, such as the coronary sinus ostium, the conduction system, the membranous septum, and the right coronary artery are in close relationship with the tricuspid annulus.
- Annulus dilation and leaflet tethering due to right ventricle remodeling are the 2 major pathophysiologic mechanisms behind functional tricuspid regurgitation.
- Precise knowledge of tricuspid anatomy and function as well as careful preoperative planning is fundamental for the development of transcatheter tricuspid interventions.

Over the past few years, the development of transcatheter technologies allowed for the introduction of complex percutaneous procedures, such as prostheses implantation and valve repair, for the treatment of valvular heart diseases.[1,2] Although today the application of transcatheter technologies in their early phase of development is mostly limited to selected inoperable and high-risk patients, wide expansion to lower-risk patients can be anticipated in the future. Following the aortic valve and the mitral valve, the tricuspid valve is receiving increasing attention from the interventional cardiology community.[3]

The tricuspid atrioventricular (AV) valve separates the right atrium (RA) from the right ventricle (RV), controlling blood flow between them. Similar to the mitral valve, it is actually a complex apparatus whose function depends on the harmony of several different structures, closely linked to each other. The tricuspid valve anatomy, however, shows greater variability than the anatomy of the mitral valve. Close to the valve itself, other important surrounding structures, although not strictly valvular components, can be useful anatomic markers and need to be taken into consideration to avoid complications whenever the tricuspid valve apparatus is addressed by an intervention.

ANATOMY

Gross anatomy of the tricuspid valve and of the right heart is depicted in Figs. 1 and 2.

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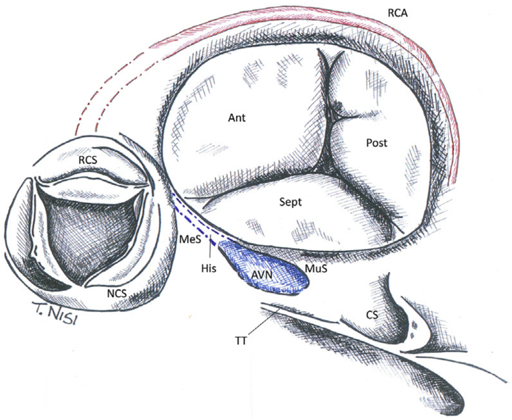

Fig. 1. Schematic representation of the surgical view of the tricuspid valve from the RA. Ant, anterior leaflet; AVN, AV node; CS, coronary sinus ostium; His, bundle of His; MeS, septum membranosum; MuS, muscular portion of the AV septum; NCS, noncoronary sinus of the aorta; Post, posterior leaflet; RCS, right coronary sinus of the aorta; Sept, septal leaflet; TT, tendon of Todaro.

The Tricuspid Apparatus

Historically, autopsy and open heart surgery have been the primary sources of anatomic knowledge on the tricuspid valve. With the development of ultrasound technology, 2-D/3-D echocardiography has become the most frequently used method to study the tricuspid and RV anatomy, thanks to its easy accessibility and ability to provide concomitant functional assessment. More recently, CT has been increasingly adopted to evaluate the anatomy of mitral and tricuspid valves in patients screened for new transcatheter technologies.[4] The principal advantages of CT are its high anatomic spatial resolution, its user-friendly multiplanar and 3-D interface, and the ability to simulate device positioning inside a patient's heart. CT assessment of the tricuspid is, however, challenging and still evolving.[5] Finally, MRI is currently the gold standard for the assessment of RV morphology and function and it may be useful in functional evaluation of the tricuspid valve in cases of poor echocardiographic imaging quality.[4] Nevertheless its use in real-word daily practice is still limited.

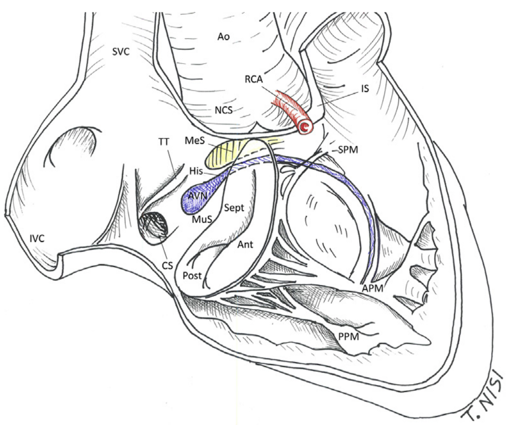

Fig. 2. Schematic representation of the RA, tricuspid valve and RV. Ant, anterior leaflet; Ao, aorta; APM, anterior papillary muscles; AVN, AV node; CS, coronary sinus ostium; His, bundle of His; IS, infundibular septum; IVC, inferior vena cava; MeS, septum membranosum; MuS, muscular portion of the AV septum; NCS, noncoronary sinus of the aorta; Post, posterior leaflet; PPM, posterior papillary muscle; Sept, septal leaflet; SPM, septal papillary muscle; SVC, superior vena cava; TT, tendon of Todaro.

The tricuspid is the most anterior (close to the chest wall and far from the esophagus) of all the heart valves. Its orientation within the normal heart is nearly vertical. The orifice of the normal tricuspid valve has an approximately oval shape, and it is larger than that of the mitral valve. Based on autopsy, the normal tricuspid orifice in the adult approximates a diameter of 20 mm/m^2 and an area of 5.8 cm^2/m^2.[6] The tricuspid annulus is relatively indistinct, especially in the septal region. When evaluated by echocardiography, the healthy annulus is a nonplanar structure with an elliptical pattern that can change markedly with loading conditions.[7,8] Posteroseptal and anterolateral segments of the annulus are closer to the RV apex, the lowest point being the posteroseptal segment near the coronary sinus. In contrast, anteroseptal and posterolateral segments are higher (toward the RA), the highest point in the anteroseptal segment, near the RV outflow tract and aortic valve. Physiologically the normal annulus moves up away from and down towards the RV apex within the cardiac cycle. Normal tricuspid annular plane systolic excursion (TAPSE) along the longitudinal axis of the RV, as assessed by echocardiography, is greater than or equal to 16 mm.[9] Tricuspid orifice increases its size from midsystole to early diastole, decreases during mid-diastole, and increases again in late diastole at the time of atrial contraction. The normal excursion of tricuspid area is 25% to 30%. Echocardiographic normal tricuspid valve actual diameter in adults is 28 mm $\pm$ 5 mm in the 4-chamber view and actual valve area is 11 cm^2 $\pm$ 2 cm^2.[10,11] 2-D echo is known to underestimate actual tricuspid annulus size compared with 3-D echo. Recent CT data report a maximum diastolic area of 10.7 cm^2 $\pm$ 2.2 cm^2 in healthy persons.[12]