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Geometric and hemodynamic determinants of functional tricuspid regurgitation: A real-time three-dimensional echocardiography study

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Abstract

Background: The geometric and hemodynamic determinants of functional tricuspid regurgitation (FTR) have not yet been established. Geometric alterations in the tricuspid valve can be accurately determined using 3-dimensional echocardiography.
Methods: Real-time 3-dimensional echocardiography was performed in 54 patients with various degrees of FTR to obtain real-time zoom 3D images of the tricuspid valve. The angles between the tricuspid annulus plane and the 3 leaflets (anterior: Aα, posterior: Pα, septal: Sα), the septal–lateral and anterior–posterior annulus diameters, and the tricuspid tenting volume were measured on a mid-systole frame. Pulmonary artery systolic pressure (PASP) was assessed using the maximal velocity of FTR, and the severity of FTR was quantified as the ratio of the distal jet area to the right atrial area (DJ/RA) using color Doppler 2D echocardiographic images.
Results: In patients with mild (DJ/RA < 0.2) and moderate (0.2 ≤ DJ/RA < 0.5) FTR, Pα and Sα were significantly larger than Aα, whereas in patients with severe (DJ/RA ≥ 0.5) FTR, only Sα was larger than Aα. All geometric variables and PASP correlated significantly with DJ/RA. Multiple stepwise regression analysis showed that Sα, septal–lateral annulus diameter and PASP were independent determinants of FTR severity. The tricuspid tenting volume strongly correlated (r = 0.84, p < 0.001) with the FTR distal jet area, and was the only determinant of the jet area.
Conclusion: FTR severity is mainly determined by septal leaflet tethering, septal–lateral annular dilatation, and the severity of pulmonary hypertension.

Keywords: Tricuspid valve regurgitation; Severity; Three-dimensional echocardiography

1. Introduction

Functional tricuspid regurgitation (FTR), which is often accompanied by various left-side valvular heart disease and myocardial disease has been reported to have an ominous prognosis and to limit exercise capacity [1–6]. Suggested FTR pathogenesis includes geometric alterations of the tricuspid valve apparatus, such as tricuspid annulus dilation and valvular tenting [7–14]. Hemodynamic factors such as pulmonary artery systolic pressure (PASP) were also reported to be associated with FTR severity [1,2,15–17].

Most previous studies have used 2-dimensional echocardiography for analyzing tricuspid valve geometry. However, this approach has some limitations since the 2-dimensional image is subject to the location of the imaging plane which in turn is dependent on the examiner as well as the patient's chest window. In addition, it is sometimes difficult to identify which portion of which leaflet is being observed in the 2-dimensional imaging plane. Such limitations can result in a subjective and inaccurate analysis of tricuspid valvular geometry. In contrast, more precise and objective imaging planes crossing the 3 leaflets of the tricuspid valve and annulus can be acquired using real-time 3-dimensional echocardiography (RT3DE). However, tricuspid valve geometric analysis in FTR patients using RT3DE remains to be demonstrated.

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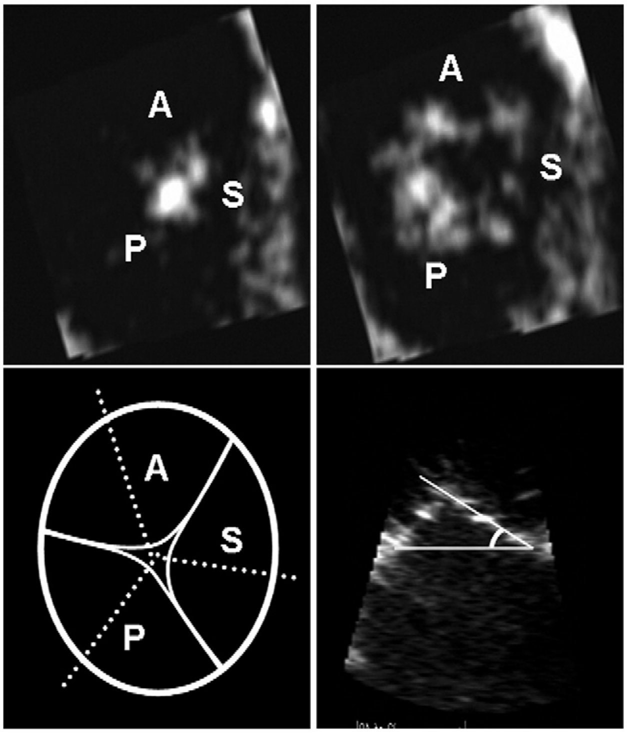

Fig. 1. A representative example of measuring angles between the tricuspid annulus plane and the 3 leaflets using a real-time 3-dimensional zoom image. In a mid-systole frame, the 3 tricuspid valve leaflets were identified on the short axis plane at the level of the valve tip (upper left panel) and mid-valve level (upper right panel). Three longitudinal planes (dotted lines, lower left panel) which perpendicularly crossed the middle of each leaflet were generated to measure the angles between the tricuspid annulus line and each leaflet (lower right panel). A, P and S represent anterior, posterior and septal leaflets, respectively.

Although significant FTR is usually surgically managed using tricuspid annuloplasty, such surgery does not always successfully eliminate FTR [8,18–20]. It is likely that more accurate geometric and hemodynamic investigation into FTR can help to solve this difficult clinical problem. Therefore, we sought to evaluate the main geometric and hemodynamic determinants of FTR using RT3DE and Doppler echocardiography.

2. Materials and methods

A total of 54 patients (27 females, age: 60±13 years) with various degrees of FTR were enrolled in the study. Mitral valve disease and left ventricular dysfunction were present in 16 and 10 patients, respectively. The remaining patients had no significant left-side heart disease. Thirty-nine of the 54 patients showed chronic atrial fibrillation, while 15 presented with a normal sinus rhythm. Patients with poor echocardiographic images or thickened and restricted tricuspid valves were excluded from this study.

RT3DE was performed to obtain a real-time zoom 3-dimensional image of the tricuspid valve from the low parasternal or apical view using a SONOS 7500 (Philips, Andover, MA). Care was taken to include the tricuspid annulus and valve leaflets in the zoom image set. Real-time zoom 3-dimensional imaging was used as it could be acquired during 1 cardiac cycle and did not require 4 regular consecutive cycles to form. Thus, this 3-dimensional imaging tool could be applied to patients with atrial fibrillation. In patients with atrial fibrillation, 3 images were acquired during the 3 different beats. The RT3DE images were digitally stored on the hard disk in the echocardiography machine, and transferred to a personal computer for off-line analysis.

Using dedicated software (Tomtec, Munich, Germany), 3 longitudinal planes which perpendicularly crossed the middle of each leaflet were generated with guidance of the short axis image of the tricuspid valve (Fig. 1). On each of the 3 longitudinal planes, the angles between the tricuspid annulus line and the 3 leaflets (anterior: Aα, posterior: Pα, septal: Sα) and the lengths of the 3 leaflets were measured on a mid-systole frame. The septal–lateral and antero-posterior longitudinal planes which were perpendicular to each other were created to measure septal–lateral and antero-posterior tricuspid annulus diameters (Fig. 2). The tricuspid tenting volume was also measured at mid-systole by tracing tenting

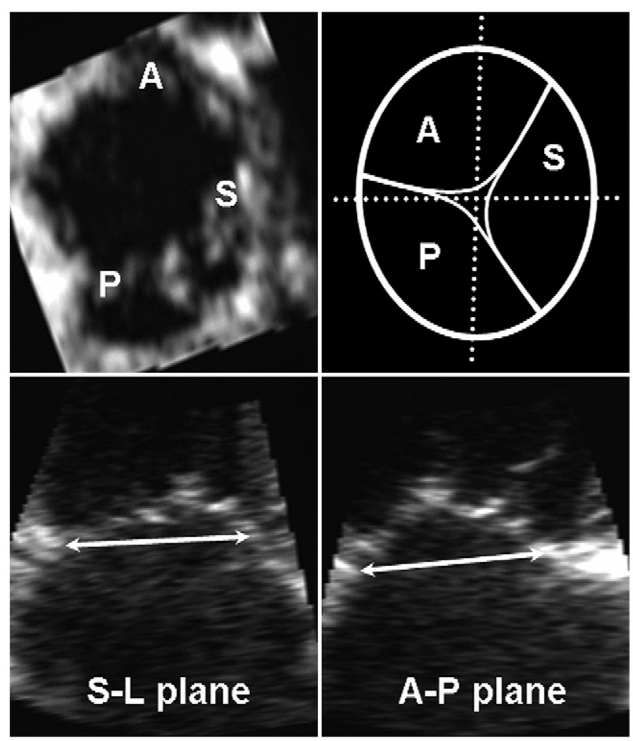

Fig. 2. A representative example of measuring the septal–lateral (S–L) and antero-posterior (A–P) tricuspid annulus diameters using a real-time 3-dimensional zoom image. In a mid-systole frame, the tricuspid annulus shape and orientation were assessed using the short axis image of the annulus (upper left panel). The S–L and A–P longitudinal planes (dotted lines, upper right panel) which were perpendicular to each other were created to measure the S–L (lower left panel) and A–P (lower right panel) tricuspid annulus diameters. A, P and S represent anterior, posterior and septal leaflets, respectively.