1. Role of Two-dimensional Echocardiography

Evaluation of the tricuspid valve apparatus with 2D echocardiography is important in determining the etiology of TR. Secondary findings like right atrial and RV enlargement often accompany significant chronic TR. Such an evaluation is usually qualitative. Although enlargement of right-sided chambers is not specific for significant regurgitation, its absence suggests milder degree of TR. Paradoxical ventricular septal motion may occur with the RV volume overload due to severe TR. However, this sign is not specific for TR, as it is affected by many factors.[75-77] Lastly, imaging of the inferior vena cava in the subcostal view for size and respiratory variation provides an evaluation of right atrial pressure.[78-80]

2. Doppler Methods

a. Color flow Doppler. The simplest approach to evaluate TR severity is color flow imaging in several views to establish the characteristics, direction and the size of the regurgitant jet. Since the RV is situated in the anterior chest, transthoracic images usually are adequate and should include the parasternal RV inflow view, the parasternal short axis view, the apical four-chamber view and the subcostal four-chamber view. As a general rule, jets that extend deep into the right atrium represent more TR than small central jets that appear just superior to the tricuspid leaflets (Figure 7). Overall, color Doppler flow mapping of TR severity using jet area correlates well with angiographic evaluation[81] and clinical measures of regurgitant severity.[82,83] However, there can be considerable overlap of jet areas in patients with mild versus moderate TR.[83] Furthermore, and similar to MR, flow jets that are directed centrally into the right atrium generally appear larger by color Doppler than eccentric, wall-impinging jets with similar or worse severity.

Color flow imaging also may be used to determine TR severity by the PISA method. Visualization of a measurable contour of the flow convergence zone is more challenging than with MR. Quantitation of TR using the PISA method has been validated in small studies but is rarely needed clinically.[81,84] On the other hand, visualization of the vena contracta width is technically less demanding and can be utilized either quantitatively or qualitatively.[82,85,86] A jet width > 0.7 cm identifies severe TR with a sensitivity of 89% and a specificity of 93% and correlates well with EROA.[85,86] Both the PISA and vena contracta methods are more accurate for determining TR severity in central jets compared to eccentric jets, and appear to be more accurate than jet area. However, there can be overlap in values of jet width between mild and moderate TR. Underestimation of severe TR can also occur in 20-30% of patients using jet area or PISA.[81]

b. Continuous wave Doppler. Recording of TR jet velocity provides a useful method for noninvasive measurement of RV or pulmonary artery systolic pressure. It is important to note that TR jet velocity, similar to velocity of other regurgitant lesions, is not related to the volume of regurgitant flow. In fact, massive TR is often associated with a low jet velocity (< 2m/s), as there is near equalization of RV and right atrial pressures (Figure 7). Conversely, mild regurgitation may have a very high jet velocity, when pulmonary hypertension is present.

Similar to MR, the features of the TR jet by CW Doppler that help in evaluating severity of regurgitation, are the signal intensity and the contour of the velocity curve (Figure 7). With severe TR, a dense spectral recording is seen along with a triangular, early peaking of the velocity because of a prominent regurgitant pressure wave. With severe tricuspid regurgitation and normal RV pressures, the antegrade and retrograde CW flow signals across the valve are almost mirror images of each other, corresponding to the "to-and-fro" flow across the severely incompetence valve orifice.[87]

c. Pulsed Doppler. The severity of TR will affect the early diastolic tricuspid E velocity, similar to MR. Values above 1.0 m/s are often recorded in patients with severe regurgitation even without valve stenosis. In theory, tricuspid regurgitant volume can be calculated by subtracting the flow across a non-regurgitant valve from the antegrade flow across the tricuspid valve annulus. In contrast to MR and AR, this approach is rarely utilized for TR, partly because of errors in measuring the tricuspid valve annulus.

Similar to the use of pulmonary vein flow pattern in MR, PW Doppler examination of the hepatic veins helps corroborate the assessment of TR severity. With increasing severity of TR, the normally dominant systolic wave is blunted. With severe tricuspid regurgitation, systolic flow reversal occurs (Figure 7). However, hepatic vein flow patterns are also affected by abnormalities in right atrial and RV relaxation and compliance, the phase of the respiratory cycle, preload, and atrial fibrillation.[88] The sensitivity of flow reversal for severe TR is 80%.[83] While the specificity of systolic flow reversal is not well defined, experience has shown that it is also a specific sign of severe TR, provided that the modulating conditions mentioned above are accounted for during interpretation.

Table 8 Echocardiographic and Doppler parameters used in grading tricuspid regurgitation severity

Parameter	Mild	Moderate	Severe
Tricuspid valve	Usually normal	Normal or abnormal	Abnormal/Flail leaflet/Poor coaptation
RV/RA/IVC size	Normal*	Normal or dilated	Usually dilated**
Jet area-central jets (cm^2)§	< 5	5-10	> 10
VC width (cm)ϕ	Not defined	Not defined, but < 0.7	> 0.7
PISA radius (cm)ψ	≤ 0.5	0.6-0.9	> 0.9
Jet density and contour–CW	Soft and parabolic	Dense, variable contour	Dense, triangular with early peaking
Hepatic vein flow†	Systolic dominance	Systolic blunting	Systolic reversal

CW, Continuous wave Doppler; *IVC*, inferior vena cava; *RA*, right atrium; *RV*, right ventricle; *VC*, vena contracta width.

* Unless there are other reasons for RA or RV dilation. Normal 2D measurements from the apical 4-chamber view: RV medio-lateral end-diastolic dimension ≤ 4.3 cm, RV end-diastolic area ≤ 35.5 cm^2 , maximal RA medio-lateral and supero-inferior dimensions ≤ 4.6 cm and 4.9 cm respectively, maximal RA volume ≤ 33 ml/m^2(35;89).

** Exception: acute TR.

§ At a Nyquist limit of 50-60 cm/s. Not valid in eccentric jets. Jet area is not recommended as the sole parameter of TR severity due to its dependence on hemodynamic and technical factors.

ϕ At a Nyquist limit of 50-60 cm/s.

ψ Baseline shift with Nyquist limit of 28 cm/s.

† Other conditions may cause systolic blunting (eg. atrial fibrillation, elevated RA pressure).