JACC: CASE REPORTS VOL. 2, NO. 8, 2020

EDITORIAL COMMENT

Edge-to-Edge Tricuspid Valve Repair

Closing the Gap on Tricuspid Regurgitation*

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Current transcatheter tricuspid valve (TV) device trials have been integral to our understanding of tricuspid regurgitation (TR) and right heart failure. Parikh et al. (1), in this issue of *JACC: Case Reports*, present a patient in whom a significant increased forward stroke volume (2.6 to 3.9 l/min/m^2) was accomplished with the off-label use of a mitral valve edge-to-edge device on the TV. Despite a seemingly modest reduction in TR from torrential to moderate-severe, the increase in cardiac index was associated with a significant clinical improvement both in hospital and at follow-up. The TriValve Registry showed that a reduction in TR to moderate using a variety of transcatheter devices was associated with clinical and functional benefits (2). Based on the early feasibility of the TRILUMINATE trial (Trial to Evaluate Treatment with Abbott Transcatheter Clip Repair System in Patients with Moderate or Greater Tricuspid Regurgitation) (3), the TriClip (Abbott Structural, Minneapolis, Minnesota) edge-to-edge repair system is the second Conformité Européene mark device to treat patients with severe TR and resistant right-sided heart failure. The currently enrolling TRILUMINATE Pivotal Trial (NCT03904147) will randomize participants to receive the TriClip or medical therapy and will evaluate the hierarchical composite number of participants with all-cause mortality, the participants who undergo tricuspid valve surgery, and the rate of heart failure hospitalizations and will assess quality of life improvement using the Kansas City Cardiomyopathy Questionnaire. A recent propensity-matched cohort study from the TriValve Registry demonstrated that transcatheter TV interventions improved prognosis compared to medical treatment alone (4), supporting the design of this pivotal trial.

Appropriate patient selection may be the key to improving outcomes, although baseline right ventricular (RV) size and function as well as estimates of systolic pulmonary artery pressure predict outcomes in untreated populations with severe TR (5). A substudy of the TriValve Registry recently reported that these parameters did not predict clinical outcomes after transcatheter tricuspid valve repair (6). Procedural success, on the other hand, was associated with improved survival, and coaptation gap (≤7 mm), central or anteroseptal jet location, and tethering height (≤1 cm) determined procedural success (2,7). Appropriate anatomic selection and intraprocedural imaging are, thus, key determinants of TR reduction and improved outcomes (8,9).

Imaging of the TV by transesophageal echocardiography should include a multilevel assessment that includes mid-esophageal, deep esophageal, shallow transgastric, and deep transgastric views (8,10,11). Tethering height is typically measured from the mid-esophageal view, and coaptation gap is measured either from a shallow transgastric 2-dimensional (2D) short-axis view (at the leaflet tips) or from a 3D image reconstruction. Because parts of this procedure are image-dependent on high temporal and spatial resolutions (i.e., leaflet grasp), the ability to image the thin TV leaflets and device arms from multiple views cannot be understated. Atypical imaging windows are often required in the setting of acoustic shadowing from left heart structures (including prosthetic

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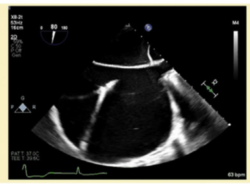
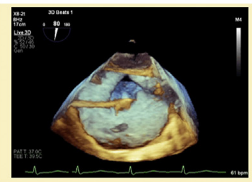
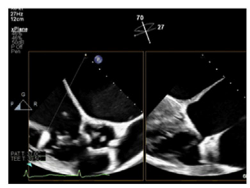
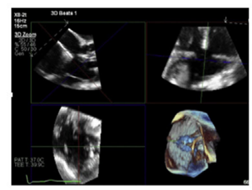
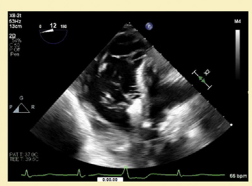
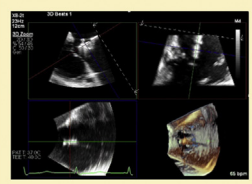
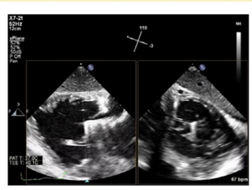
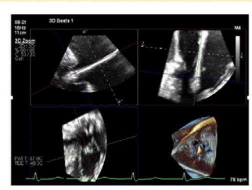
ISSN 2666-0849 https://doi.org/10.1016/j.jaccas.2020.06.018

FIGURE 1 **Summary of Intraprocedural TEE Imaging Recommendations for TV Edge-to-Edge Repair**

A

Procedural Step	Imaging Recommendations	Imaging Example: 2D and 3D		Comments
1. Navigating CDS to TV.	TEE Bicaval view of the navigate clip delivery system within the right atrium to TV.			2D imaging with cross-plane or 3D imaging should follow the tip of the clip delivery system to prevent tissue damage during clip delivery system advancement.
2. Adjustment of CDS trajectory and clip rotation (in right atrium).	TEE Mid-/deep-esophageal "commissural" view (60° to 80°) with bi-plane imaging to optimize the clip delivery system trajectory to the TV, and for preliminary adjustment of clip position and rotation at the target zone. Complete valve analysis by secondary sweeping through valve in secondary plane.			3D enface imaging or transgastric short-axis view (see Step 3 image) should be used to orient clip arms Live 3D multiplanar imaging can used to image the CDS trajectory in orthogonal planes.
3. Final positioning of clip at target site (in right atrium).	TEE Transgastric short axis view (10°—40°) to visualize all 3 leaflets and analyze valve anatomy; localize leaflet coaptation gaps (at leaflet tips) and associated regurgitation based on flow convergence and vena contracta.			Multiple angulations of the imaging or live 3D multiplanar reconstruction may be required if no single 2D view can display the lines of coaptation.
4. CDS advancement into right ventricle.	TEE Transgastric imaging with bi-plane imaging facilitates navigation of clip while providing simultaneous visualization of clip in the right ventricle. Allows for final adjustment of clip delivery system position and rotation.			Live 3D multiplanar imaging can used to confirm clip location and orientation.

2D = 2-dimensional; 3D = 3-dimensional; CDS = clip delivery system; TEE = transesophageal echocardiogram; TTE = transthoracic echocardiogram; TV = tricuspid valve.

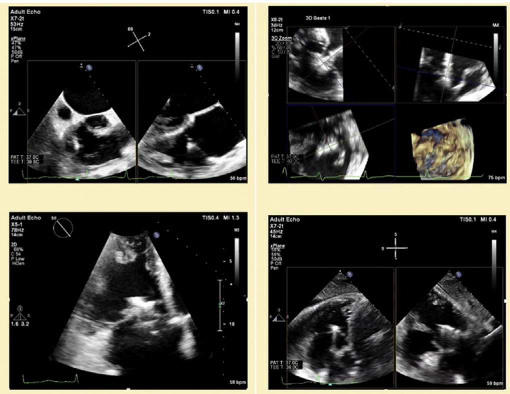
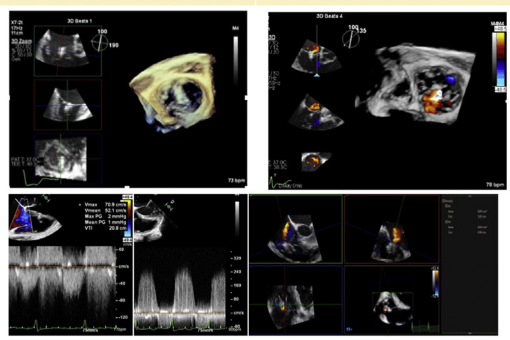
Continued on the next page

material) or the device guide itself and unusual anatomic position of the dilated right heart with frequently elevated diaphragm (i.e., due to hepatic congestion or ascites). A consideration should be made for evaluating the quality of the various views with the patient in a supine position during pre-procedural studies.

Procedural guidance can be broken into 6 steps. Step 1 (Figure 1A) is to safely guide the clip delivery system (CDS) through the right atrium to the TV. Imaging in the mid-esophageal bicaval view with either 2D (with or without biplane) or live 3D imaging can ensure safe advancement of the CDS without injury to the interatrial septum or other structures. Next, the imager must confirm an appropriate trajectory for the CDS (i.e., to allow for simultaneous grasping of 2 leaflets) and position of the clip within the annulus by using a mid- or deep esophageal "commissural" view (60° to 80°) with biplane imaging or live 3D multiplanar reconstruction. In step 3, the clip arms are aligned perpendicular to the coaptation gap by using both 3D-rendered en face views of the TV or by transgastric short-axis views (10° to 40°). In Step 4, the clip is advanced into the RV, and the clip position or orientation is readjusted if needed by using 3D-rendered en face views (from any imaging

FIGURE 1 Continued

B

Procedural Step	Imaging Recommendations	Imaging Example: 2D and 3D	Comments
5. Grasping view.	TEE A mid-/deep-esophageal "commissural" view (60° to 80°) with bi-plane imaging. Adjust primary plane perpendicular to clip arms to verify the clip position along commissure, and to simultaneously display both arms and leaflets in the secondary plan. TTE If adequate leaflet visualization cannot be obtained by TEE, additional TTE views with bi-plane imaging may be used for grasping and confirmed by TEE.		Live 3D multiplanar reconstruction allows for device/leaflet alignment from any window. Small tidal ventilation volumes or breath-holds reduce out-of-plane movements of the clip during the grasping process.
6. Reevaluation of TV repair.	TEE A mid-/deep-esophageal "commissural" view (60° to 80°) with bi-plane imaging is also useful for reevaluation of TR severity and inflow gradient. 3D imaging allows for assessment of tissue bridge, planimetry of TV area (sum of orifices), and 3D vena contracta area. TTE A post procedure TTE for grading of TR is recommended as baseline for follow-up.		3D vena contracta area planimetered from multi-planar reconstruction is recommended for TR severity grading post edge-to-edge leaflet repair. CW of the diastolic and systolic transtricuspid flow should be recorded.

window) with gain reduced to result in dropout of the leaflets, allowing imaging of the device in the RV. Transgastric short-axis views are also used to confirm clip position and orientation. For leaflet grasping, both clip arms must be imaged in a 2D single view by using a mid or deep esophageal commissural view (60° to 80°), using biplane imaging with the clip arms seen in a secondary plane or a single plane image of the clip open arms (often at 150° to 170° or sometimes at 0° to 20°). If visualization in this view is limited, alternatives include the use of live 3D multiplanar reconstruction, transthoracic imaging, or intracardiac echocardiography. Leaflet grasping should be recorded, and closure of the clip is typically imaged on color Doppler to see the effects of edge-to-edge repair. The final steps in procedural guidance are to confirm adequate leaflet grasp, to define the residual severity of TR, and to document both the transvalvular gradient and the TV orifice area (Figure 1B).

Adequate leaflet grasp can be confirmed by review of the recorded leaflet grasp, documentation of a tissue bridge, and reduction of TR. Determining the severity of TR can be performed by visual reduction of color Doppler parameters as well as improvement in hepatic vein inflow. This final step relies on adequate 3D imaging to confirm the tissue bridge, planimetry of the remaining valve area (sum of orifices), and planimetry of the 3D vena contracta area (averaged over systole). A post-procedure transthoracic echocardiogram is recommended to serve as a baseline for follow-up.

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KEY WORDS RV, right ventricle, TR, tricuspid regurgitation, TV, tricuspid valve