Transcatheter Tricuspid Valve-in-Valve Intervention for Degenerative Bioprosthetic Tricuspid Valve Disease

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Isolated reoperative tricuspid valve replacement is one of the highest risk operations classified in the Society of Thoracic Surgeons registry, particularly in the setting of preexisting right ventricular dysfunction. Transcatheter tricuspid valve-in-valve implantation represents an attractive alternative to redo surgery in patients with tricuspid bioprosthetic valve degeneration who are considered high-risk or unsuitable surgical candidates. In this review article, the authors discuss the emergence of transcatheter tricuspid valve-in-valve therapy, preprocedural echocardiographic assessment of tricuspid bioprosthetic valve dysfunction, periprocedural imaging required for tricuspid valve-in-valve implantation, and postprocedural assessment of tricuspid transcatheter device function. (J Am Soc Echocardiogr 2017;■:■-■.)

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Transcatheter valve-in-valve (ViV) procedures are attractive alternatives to redo conventional surgery to treat dysfunctional aortic[1] and mitral[2] bioprostheses. Until recently, transcatheter tricuspid valve (TV) implantation within either an existing surgical bioprosthesis (tricuspid ViV implantation) or a previously repaired TV had been limited to small case series or case reports.[3-12] However, with the recent publication of the global transcatheter tricuspid Valve-in-Valve International Database (VIVID) registry,[13] and recognition that redo surgery for failing TV bioprosthesis carries increased morbidity and mortality, particularly when preexisting right ventricular (RV) dysfunction is present,[14-17] it is likely that tricuspid ViV procedures will become an increasingly recognized alternative to redo surgical TV intervention. Moreover, novel transcatheter techniques to repair native regurgitant TVs are also emerging.[18-21] Facilitation of successful transcatheter TV procedures requires comprehensive understanding of two-dimensional (2D) and real-time (RT) three-dimensional (3D) transthoracic echocardiographic and transesophageal echocardiographic (TEE) images of the normal and diseased TV, to permit early and accurate detection of TV disease, to direct the timing and assess the effectiveness of treatment, to guide transcatheter TV interventions, and to assess residual TV disease.

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ANATOMIC CONSIDERATIONS AND IMPLICATIONS FOR TV SURGERY

The TV apparatus is composed of three leaflets (anterior, posterior, and septal) attached to the myocardium of the right ventricle either directly or by the means of chordae linked to a papillary muscle. Autopsy studies, however, report highly variable anatomy; in one study, the TV was found to be a single leaflet in 17% of cases, bicuspid in 72%, and tricuspid in only 17%, with the posterior leaflet being frequently either absent or incorporated into the anterior or septal leaflets.[22] Other studies report absent septal papillary muscle[23] or presence of accessory leaflets[24] in a high proportion of human hearts. In tricuspid regurgitation (TR), anatomic distortion may be accentuated by multiple chordal attachments between the myocardium and valve leaflets, resulting in secondary leaflet tethering with RV dilatation. This process is aggravated by volume overload, which results not only in TV distortion but progressive deterioration in RV systolic function. As a result, severe TV disease has been associated with a threefold increase in all-cause mortality rate and a four- to fivefold increased incidence of cardiac events during long-term follow-up,[25] while elective tricuspid annuloplasty for patients with functional TR undergoing elective left-sided heart surgery is associated with a reduction in cardiac-related mortality and improved echocardiographic outcomes.[26]

Because of the anatomic complexity of the TV and coexisting advanced RV disease, almost 30% of patients are deemed unsuitable for surgical TV repair at presentation and are instead offered TV replacement.[27] Although robust comparative data are unavailable,[28,29] implantation of a bioprosthesis is preferred in current practice.[27] In addition, the increased bleeding risk associated with long-term oral anticoagulation and mechanical valve replacement can be avoided. A recently published meta-analysis of observational studies showed no differences between mechanical and biologic TV replacement in terms of survival and reoperation. However, the risk for valve thrombosis was significantly higher in patients with mechanical prostheses.[30] For reasons still unclear,

Abbreviations

2D = Two-dimensional
3D = Three-dimensional
CW = Continuous-wave
EOA = Effective orifice area
IVC = Inferior vena cava
LOE = Level of evidence
LVOT = Left ventricular outflow tract
MSCT = Multislice computed tomography
PHT = Pressure half-time
RT = Real-time
RV = Right ventricular
TEE = Transesophageal echocardiographic
TR = Tricuspid regurgitation
TS = Tricuspid stenosis
TTE = Transthoracic echocardiography
TV = Tricuspid valve
ViV = Valve-in-valve
VIVID = Valve-in-Valve International Database
VTI = Velocity-time integral

the longevity of tricuspid bioprostheses seems shorter compared with that of bioprostheses exposed to the systemic circulation (aortic, mitral). This translates into a reoperation rate of about 20% for valve degeneration within 10 years and freedom from reintervention of only 53% at 15 years after surgical valve replacement.[14,15,31]

EMERGENCE OF TRANSCATHETER TREATMENT ALTERNATIVES

Reoperation for valve degeneration is associated with mortality ranging from 17% to 37%,[14-17] and isolated reoperative TV replacement is one of the highest risk operations classified in the Society of Thoracic Surgeons registry. Novel transcatheter therapies are emerging for the treatment of TR,[32] including transcatheter tricuspid ViV implantation for patients with tricuspid bioprosthetic valve stenosis and/or transvalvular regurgitation deemed too high risk or unsuitable for reoperation. Notwithstanding, younger patients with Ebstein's anomaly requiring multiple valve replacements because of somatic growth or bioprosthesis degeneration may also benefit from transcatheter intervention as a mechanism to extend the duration between repeat valve operations.[33,34]

Tricuspid ViV transcatheter treatment of degenerated tricuspid bioprostheses was first successfully performed using the Melody valve (Medtronic, Minneapolis, MN) in 2010 through a jugular venous route in a patient with previous TV replacement (27-mm Medtronic Mosaic valve) 8 years after treatment for TV endocarditis.[3] Evolution of the access routes subsequently followed: in 2010, a 26-mm Edwards SAPIEN transcatheter heart valve (Edwards Lifesciences, Irvine, CA) was implanted for the first time into a Medtronic Mosaic 27-mm bioprosthesis through a right atriotomy (off pump),[4] and a fully percutaneous procedure using the jugular venous approach was described shortly later using a 23-mm SAPIEN valve[5] in 2011. Upon commercial availability of the steerable RetroFlex delivery system, transfemoral venous implantation of a SAPIEN XT valve became technically possible, paving the way for a simplified and more convenient tricuspid ViV procedure.[6] Subsequently, the safety, feasibility, and efficacy of the tricuspid bioprosthesis ViV procedure has been confirmed in multiple case reports and series.[35] The largest series published to date, the tricuspid VIVID registry, reported on the outcomes of 152 patients.[13] In this cohort, the age of the failing surgical bioprostheses was ≤5 years in as many as 30% of the patients, highlighting the accelerated degeneration observed in tricuspid bioprostheses. Overall, the study confirmed high procedural success (99%) as well as excellent safety, with only one procedural death and no acute conversion to open-heart surgery despite two valve embolizations that were managed percutaneously. Significant improvement of invasive transvalvular gradient and severity of TR were observed regardless of the type of valve implanted, which translated into sustained functional improvement in 76% of patients. Survival free from reintervention was 85% at 1 year. Valve thrombosis was suspected in 4 patients (3%), and 4 additional patients (3%) met the criteria for valve endocarditis. All-cause mortality was low, with a reported incidence of 3% at 30 days and a total of 22 deaths (15%) during a median follow-up period of 13 months.

Table 1 Doppler parameters of prosthetic TV function: current American Society of Echocardiography guidelines

	Consider TV stenosis*
Peak velocity†	>1.7 m/sec
Mean gradient†	≥6 mm Hg
PHT	≥230 msec
EOA and VTI_{PrTV}/VTI_{LVOT}	‡

PrTV, Prosthetic TV.
*Average more than five cycles to account for respiratory variation.
†May also be increased with valvular regurgitation. Reprinted from Zoghbi *et al*.[40]
‡Although the current guidelines for the echocardiographic assessment of TV prostheses do not include cutoffs for EOA and VTI_{PrTV}/VTI_{LVOT}, Blauwet *et al*.[41] published data on a large series (*N* = 285) of a number of TV prosthesis models and sizes that include proposed cutoffs for these hemodynamic variables.

TRANSTHORACIC ECHOCARDIOGRAPHIC ASSESSMENT OF DEGENERATIVE TV BIOPROSTHESIS

Preprocedural transthoracic echocardiography (TTE) is an excellent first-line diagnostic tool in the assessment of tricuspid bioprosthetic valve function, as the anterior location of the TV permits favorable echocardiographic visualization and evaluation of prosthetic valve function. The primary goal of TTE is to evaluate the severity, mechanism, and anatomic substrate for prosthetic valve dysfunction, which may involve tricuspid stenosis (TS), TR, or a combination of TS and TR. Common causes of tricuspid bioprosthetic valve dysfunction include leaflet degeneration, leaflet thrombosis, endocarditis-related leaflet damage, and pannus formation. Paravalvular regurgitation is usually related to endocarditis or surgical suture tear. TTE should determine the presence or absence of thrombus, infective endocarditis, or paravalvular leak, as these are exclusion criteria for transcatheter tricuspid ViV. The specific role of TTE in determining the size of surgical and transcatheter valve devices is limited; operative notes, multislice computed tomography (MSCT), TEE imaging, and fluoroscopy are more reliable modalities for selecting transcatheter device size (see below).

Comprehensive assessment of a patient with tricuspid bioprosthesis degeneration should include 2D and 3D imaging, as well as color flow, continuous-wave (CW), and pulsed-wave Doppler imaging. Multiple windows should be used: parasternal RV inflow and short-axis, apical four-chamber, and subcostal views.