Role of Echocardiography in Transcatheter Mitral Valve Replacement in Native Mitral Valves and Mitral Rings

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Adaptation and evolution of transcatheter aortic valve replacement (TAVR) technologies has led to approval of TAVR for consideration in patients at intermediate risk for surgical aortic valve intervention. As TAVR becomes more mainstream, attention is shifting toward percutaneous mitral valve (MV) repair and transcatheter MV replacement (TMVR) techniques. Transcatheter heart valves (both purpose-built and off-label-use TAVR valves) are being implanted during TMVR procedures to treat clinically significant MV disease (native disease, degenerated bioprosthetic valves, and dysfunctional surgical MV annuloplasty repairs) when the risk of open heart MV surgery is prohibitive. The success of these high-risk procedures is directly related to accurate periprocedural imaging with echocardiography and other modalities. Although a multidisciplinary heart valve team approach is necessary for optimal patient selection, a multimodality team-based imaging approach and comprehensive understanding of the MV are required for safe procedural planning. Collaboration between noninvasive cardiac imagers and the intraprocedural interventional imaging team and translation of the periprocedural imaging to the implanting team are crucial to the success of TMVR technology. Currently, the TMVR procedures discussed here are conducted either as part of clinical research or off label. The US Food and Drug Administration–approved mitral valve-in-valve procedures for the treatment of degenerated mitral bioprosthetic valves are not discussed here. (J Am Soc Echocardiogr 2018;31:475-90.)

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The widespread success of transcatheter aortic valve replacement (TAVR) has had profound implications on the treatment of aortic stenosis, and TAVR is now considered a noninferior modality for intermediate-risk patients.[1-4] As TAVR becomes more mainstream, attention is shifting toward percutaneous mitral valve (MV) repair and transcatheter MV replacement (TMVR) techniques.[5] Specifically, transcatheter stentless and stented valves (both purpose-built transcatheter MV and off-label-use TAVR valves) are being implanted during TMVR procedures to treat clinically significant MV disease (native disease, degenerated bioprosthetic valves, and dysfunctional surgical MV annuloplasty repairs) when the risk of open heart MV surgery is prohibitive. Although these therapies are nascent, the global learning curve is exponential, with a rapidly expanding pool of early feasibility studies, clinical trials, and registry data.[6-12]

With the rise of transcatheter-based mitral interventions, the success of these high-risk procedures is directly related to a multidisciplinary heart valve team approach for optimal patient selection, a multimodality imaging approach for comprehensive understanding of the MV pathology, and accurate periprocedural imaging. Collaboration between noninvasive cardiac imagers and the intraprocedural interventional imaging team and translation of the periprocedural imaging to the implanting team are crucial to the success of TMVR technology. Given the complexity of transcatheter MV technology and imaging demands for a successful multidisciplinary heart valve team, the aim of this document is to describe key imaging considerations, discussions, and investments that must be applied for the development of a successful transcatheter MV program. For this purpose, this document is focused specifically on the pre-, intra-, and postprocedural echocardiographic imaging associated with the use of TMVR in native MV (valve–in–native valve [VinV]) and mitral annuloplasty rings (valve-in-ring [ViR]). Where appropriate, complementary imaging modalities are discussed as well. In-depth discussion of percutaneous MV repair (PMVR) techniques and of mitral valve-in-valve procedures for the treatment of degenerated mitral bioprosthetic valves (now a US Food and Drug

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Abbreviations

2D = Two-dimensional

3D = Three-dimensional

AML = Anterior mitral leaflet

CMR = Cardiovascular magnetic resonance

LV = Left ventricular

LVOT = Left ventricular outflow tract

MAC = Mitral annular calcification

MDCT = Multidetector computed tomography

MR = Mitral regurgitation

MS = Mitral stenosis

MV = Mitral valve

PMVR = Percutaneous mitral valve repair

PVL = Paravalvular leak

TAVR = Transcatheter aortic valve replacement

TEE = Transesophageal echocardiography

THV = Transcatheter heart valve

TMVR = Transcatheter mitral valve replacement

TTE = Transthoracic echocardiography

VinV = Valve–in–native valve

ViR = Valve-in-ring

Administration–approved procedure) is beyond the scope of this document.

ROLE OF ECHOCARDIOGRAPHY IN PATIENT SELECTION

Diagnosis

Adequate patient selection for TMVR depends on an accurate initial diagnosis of the underlying MV pathology. Cardiovascular ultrasound, both transthoracic echocardiography (TTE) and transesophageal echocardiography (TEE), are critical to the planing and guidance of these procedures. Because of its wide availability and low cost, TTE is the foundation for initial diagnosis as well as patient selection and preprocedural planning. TTE is particularly valuable because of its high temporal resolution, availability of multiple acquisition windows, and integration of Doppler echocardiography, which allows a robust integrative characterization of hemodynamically significant MV disease. TTE provides considerable information regardless of whether the pathology is mitral stenosis (MS), mitral regurgitation (MR), or some combination of mitral and other valvular pathologies. Because MV pathology is highly susceptible to hemodynamic perturbations such as heart rate, cardiac output, blood pressure, and the degree of MR, performance of a standard transthoracic echocardiographic examination, without anesthetic agents or sedatives, provides the single best hemodynamic assessment. In centers facile in advanced echocardiographic techniques such as three-dimensional (3D) echocardiography and speckle-tracking, TTE can provide a unique and nuanced understanding of the severity and impact of MS and/or MR, as well as the mechanics of the surrounding structures. In-depth discussion of the diagnosis and grading of MS and MR can be found in recent guideline documents.[13-17]

In addition to TTE, preprocedural TEE including 3D imaging is considered a key component of procedural planning. As a more recent imaging modality, 3D TEE has rapidly grown in the past decade with several technological breakthroughs in scanner design, beam formation, image acquisition, and display and quantification.[18]

Electrocardiographically gated multidetector computed tomography (MDCT) has evolved as an important imaging modality for anatomic characterization of the MV before TMVR procedures. The ongoing investigator-initiated, prospective, multicenter Mitral Implantation of Transcatheter Valves trial (ClinicalTrials.gov identifier NCT02370511) was designed to achieve most of the preprocedural imaging using MDCT and echocardiography and was supported by dedicated MDCT and echocardiography core laboratories. With patient enrollment now complete, new evidence on the utility of this imaging modality and its specific role in the planning of TMVR procedures will soon emerge.[19]

Risk Stratification

Once the initial diagnosis of severe MV disease has been confirmed, the heart valve team discusses patient selection for TMVR rather than a surgical or palliative approach. Stratification of surgical risk is often weighed via one of several quantitative databases, such as the Society of Thoracic Surgeons risk calculator and the European System for Cardiac Operative Risk Evaluation II, which assess the predicted risk for mortality and morbidity.[20-22] These calculators are robust but do not take into account more qualitative metrics such as frailty, which is increasingly recognized to have a large impact on patient outcomes. Some attempts to quantify frailty by tests such as the 6-minute walk test or grip strength are routinely used, but must be interpreted in the entire clinical context.[23-25] As transcatheter therapies develop, large registries such as the Society of Thoracic Surgeons/American College of Cardiology Transcatheter Valve Therapy Registry, the Valve-in-Valve International Data registry, or other multicenter global registries may become helpful in understanding risk and providing accurate data for informed consent.[9] Ultimately, the cardiac surgeon is required to determine the surgical risk profile of a given patient and declare the patient at prohibitive risk for surgery (in native MV disease) or repeat surgery (in patients with previous MV annuloplasty repair).

Valve Types for Transcatheter Mitral Replacement

TMVR is a dynamic space with rapidly changing technology. The initial tests of feasibility for TMVR began with patients who were deemed to be at too high risk for surgery but in addition had anatomy that was felt to be unfavorable for a percutaneous edge-to-edge repair technique. Other early efforts focused on valve-in-valve placement because of the preexisting landing zone provided by a prior prosthetic MV.[26] Experience with TMVR in native MVs came later and was first reported for use in native MS in 2014.[27] The early attempts at TMVR used existing valve technology and most commonly used second-generation balloon-expandable technology developed for TAVR. However, it quickly became evident that TMVR had unique challenges and potential complications and that the adaptation of valves meant for the aortic and pulmonic position was not ideal for the uniquely shaped mitral annulus. In addition to the challenging complex anatomy of the MV, other challenges of TMVR therapies include the prosthetic anchoring and annular retention, TMVR delivery systems, long-term durability, valve thrombogenicity from slower atrial flow, and proper patient selection.[5,28] The ideal purpose-built transcatheter heart valve (THV) for TMVR permits a percutaneous transseptal delivery via the left atrium into the MV position, provides sufficient anchoring and retention mechanisms that stabilize the valve within the dynamic MV annulus, results in optimal sealing to prevent paravalvular leak (PVL), and avoids significant left ventricular outflow tract (LVOT) obstruction. To this end, current THV designs include ventricular or annular anchors, annular winglets or flanges, valve stents with radial forces, annular docking rings or systems, or other designs that permit native leaflet engagement or mitral annular