Editorial

Multimodality Imaging in Transcatheter Mitral Interventions

Buzzword or Modern Age Toolbox?

Omar K. Khalique, MD; Rebecca T. Hahn, MD

The secret of change is to focus all of your energy, not on fighting the old, but on building the new.

–Socrates

Both echocardiography (specifically transesophageal echocardiography [TEE]) and multidetector row computed tomography (MDCT) have played an integral role in preprocedural planning for transcatheter aortic valve replacement, heavily influencing the moniker of "multimodality imaging." The strengths of each modalities are complementary (Table), although there is overlap between the preprocedural analyses which can be performed.[1,2] Having 2 modalities capable of accurately measuring the same anatomic structure[3] has clinical utility. For instance, mandated MDCT annular measurements could not be performed accurately by the core laboratory in 6% to 8% of patients in the Placement of Aortic Transcatheter Valves II SAPIEN 3 trial[4] and thus required 3-dimensional (3D)-TEE for transcatheter valve sizing.

See Articles by Suh et al and Mak et al

Perhaps, the most important imaging lesson learned from the transcatheter aortic valve replacement (TAVR) experience is not whether one modality is better or worse than another, but the fact that because of the obvious utility of multiple imaging modalities, the imager has become an essential part of the Heart Team and integral to the preprocedural and intraprocedural planning for any successful transcatheter device implantation.[5,6] The imager must have a comprehensive understanding of the anatomy of interest, as well as the intended transcatheter device. Without this knowledge, recommendations for sizing and positioning, as well as anticipation of complications, are not possible. At our institution, review of both MDCT and echocardiographic imaging is part of the initial patient assessment. In addition, an imager is always present for all structural heart disease interventions, allowing the interventionalist or surgeon and the imager to gain experience together. Mutual respect is key to this learning process.

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Transcatheter mitral interventions have largely been discussed in the context of percutaneous edge-to-edge repair with the MitraClip (Abbott Vascular, CA) for mitral regurgitation. TEE has been essential from the inception of the device, with desirable outcomes attributed to imaging guidance.[7,8] Since that time, the role of 3D-TEE in detailed imaging assessment of not only mitral regurgitant severity but also complex mitral anatomic details has become indisputable.[9]

As we enter the next phase of transcatheter mitral valve interventions of new repair and replacement devices as well as standardization of transcatheter paravalvular leak (PVL) closure, the role of imaging is evolving. MDCT and 3D-TEE are currently being used to screen patients anatomically for transcatheter mitral valve replacement. Real-time 3D-TEE has been integral to our understanding of the dynamic nature of the mitral valve complex in normal patients, as well primary and secondary mitral valve disease.[10–14] Screening methods for transcatheter mitral valve replacement have been largely undefined because of the lack of experience in this field and the confidentiality of early feasibility studies. The idea of the D-shaped annulus has been popularized in recent literature as a method to measure the mitral annulus, which simplifies the annulus shape while making it more planar; this is also partially based on the observation that the anterior saddle as a portion of the annulus measurement projects past the anterior mitral leaflet into the left ventricular outflow tract.[15] As a continuation of these investigations, Mak et al,[16] in this issue of *Circulation: Cardiovascular Imaging*, use the Mitral Valve Quantification program (Philips Healthcare, Inc., Andover, MA) in a modified fashion to perform a D-shaped segmentation of the mitral annulus using 3D-TEE similar to the same group's original method on a semiautomated MDCT software segmentation. In this analysis of 41 patients, annular area and circumference, were not different when comparing MDCT and 3D-TEE measurements. Correlation between modalities was also strong. The current study importantly highlights the ability to interchangeably use MDCT and 3D-TEE for mitral annulus sizing early in the experience. More specifically, the study emphasizes using similar methodology across both modalities to achieve these results rather than incorrectly comparing incongruous methods, as was done early with many aortic annulus publications which compared 3-dimensional MDCT measurements to 2-dimensional echocardiographic measurements. Although the D-shaped model developed by Blanke et al appears to mimic the nature of the mitral annulus at the hinge point of the anterior leaflet, it is unclear at this early stage whether this is the best method of measurement before transcatheter mitral replacement. The aortic–mitral continuity is a complex portion of the saddle-shaped structure of the annulus, and this area bows to and fro throughout the

Table. Advantages and Limitations of Imaging Modalities for Structural Heart Disease Interventions

Imaging Modality	Advantages	Disadvantages
MDCT	Comprehensive cardiac and vascular assessment Blood–tissue interface well-defined Calcium well imaged/quantified High reproducibility Noninvasive	Artifacts of imaging Iodinated contrast requirement Radiation exposure Cardiac cycle–dependent Poor temporal resolution on most systems
TEE	High temporal resolution Pulsed, continuous, and color-flow Doppler Real-time/multibeat imaging High safety profile of ultrasound No contrast required Portable	Semi-invasive Acoustic shadowing and other artifacts of imaging Higher operator dependence

MDCT indicates multidetector row computed tomography; and TEE, transesophageal echocardiography.

cardiac cycle (Figure). The impact of this phenomenon on sizing of transcatheter mitral valves is unclear. All of the analyses by Mak et al[16] were performed in diastole, where typically the annulus plane is easier to appreciate. However, existing studies of mitral annular dynamism based on 3D-TEE have shown the largest dimensions in late systole.[12,17,18] Systolic annular measurements are more challenging in the setting of closed mitral leaflets, where the hinge points may not be easily discerned. It stands to reason that there may be a significant impact of leaflet dynamics and anatomy on seating of transcatheter mitral devices, which has yet to be defined. Although an early comparative study by Shanks et al[19] showed excellent agreement between MDCT and 3D-TEE for mitral annular measurements as well as leaflet morphology, until MDCT analysis of leaflet morphology can be consistently duplicated, detailed leaflet analysis falls clearly into the realm of echocardiography. Left ventricular outflow tract obstruction, on the contrary, is an additional concern in transcatheter mitral replacement; measurement of a neo-left ventricular outflow tract which is formed by the displacement of the anterior mitral leaflet by the transcatheter mitral valve is easily performed on MDCT.

In this same issue, Suh et al[20] compare MDCT to transthoracic echocardiography and 2-dimensional (2D) TEE analysis of mitral PVL severity and location. In 78 patients who had undergone reoperation, MDCT had a not surprisingly better (although not statistically significant) diagnostic accuracy for detection of PVL. MDCT had a similar diagnostic accuracy for detection of PVL to 2D-TEE. The authors should be congratulated on the efforts to push the limits of the diagnostic abilities of MDCT. The correlation between PVL severity planimetered by MDCT and assessed by 2D-TEE methods was statistically significant but weak. Imaging quality for MDCT was nondiagnostic in 12/204 patients due to beam-hardening artifacts, all in mechanical valves.

The use of 2D-TEE imaging, however, is a significant limitation of this study. Real-time 3D-TEE has been used extensively during percutaneous PVL closure procedures[21–23] and can depict not only the relevant cardiac landmarks adjacent to the sites of PVLs, but also wires, delivery catheters, and closure devices.[24] Real-time 3D-TEE imaging results in a more accurate localization of paravalvular defects and an estimation of the size of the defect that correlates better with surgical findings when compared with 2D-TEE.[25] Thus, one would expect better correlation between 3D-TEE multiplanar reconstruction with or without color Doppler, to MDCT planimetry of paravalvular defects. The analysis begs the question of what additional benefits MDCT provides over TEE if intraoperative 3D-TEE guidance will be used for closure of leaks. Patient preference is a significant consideration in the preprocedural assessment; however, further cost-benefit as well as accuracy studies may be needed before recommending MDCT as an equivalent technology to 3D echocardiography for mitral PVL assessment. A greater argument could be made for the use of MDCT for the assessment of aortic PVLs, where acoustically shadowing of distal structures may mask PVL. Again, one cannot ignore the potential harm of MDCT radiation and iodinated contrast which must be balanced against the benefits. Coregistration is another

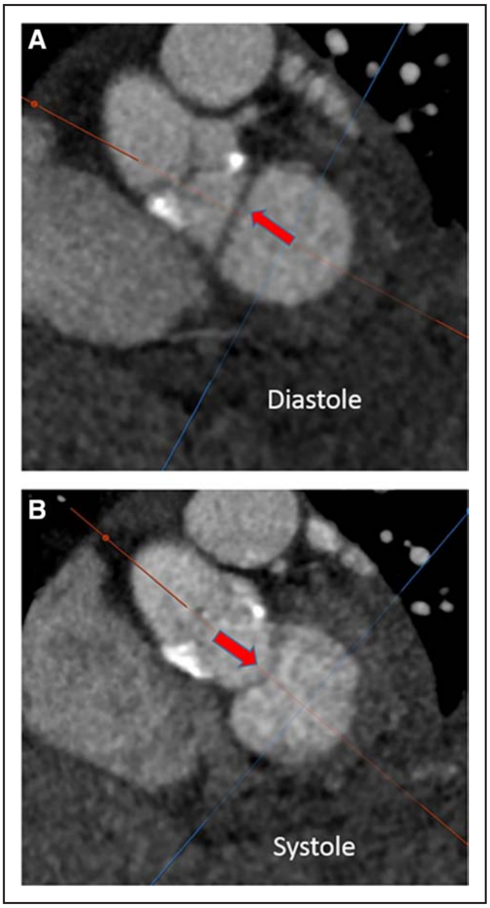

Figure. The aortic–mitral continuity. The inflow and outflow regions of the left heart are in direct continuity. The aortic–mitral continuity is a complex, dynamic portion of the saddle-shaped structure of the mitral annulus, which changes shape from diastole (**A**) to systole (**B**).

technology in its early stages, which may add more value to MDCT preprocedural planning; however, similar coregistration can be performed with intraprocedural 3D-TEE.[26] Nonetheless, imaging advancements in MDCT spatial resolution and reconstruction techniques which have made this discussion possible are truly exciting.

As if all of the challenges outlined above were not enough, an additional challenge arises after devices are placed. Native mitral valve regurgitation assessment by echocardiography is well established. Methods of assessment include quantitative Doppler and direct planimetry of effective regurgitant orifice area by 3D reconstruction.[27,28] However, after transcatheter devices are placed, these methods become less accurate or invalid because of Doppler flow acceleration and acoustic artifacts from devices. In the post-transcatheter edge-to-edge repair setting, multiple mitral regurgitation jets may be difficult to assess on TEE color Doppler imaging because of artifacts from the device(s). Additionally, if jets are entrained by the devices, excessive jet spray could cause an overestimation of mitral regurgitant severity. Following MitraClip, assessment of residual regurgitation can be assessed by 3D color Doppler.[29] Cardiac magnetic resonance (CMR) is also promising in the assessment of regurgitant volume by both volumetric and velocity-encoding methods, showing excellent reproducibility in the post MitraClip setting.[30] CMR has shown prognostic value in diagnosing PVL after transcatheter aortic valve replacement.[31] A promising area of further study would be the similar utility to measure mitral regurgitant volumes after mitral PVL closure or after transcatheter mitral valve replacement. Although often used as the gold standard for volumetric measurement, CMR suffers from motion, arrhythmia gating, and magnetic artifacts from metal-containing prostheses. Additionally, there is often the question of consistency of application of measuring the basal slice for inclusion in volumetric measurements.[32] Magnetic distortion from a mitral prosthesis (whether surgical or transcatheter) may be a particularly problematic artifact in the basal slice depending on the patient. Nonetheless, CMR consistently shows excellent reproducibility and may be the best option for overall quantification. When carefully performed, 3D-transthoracic echocardiography has been shown to have similarly excellent reproducibility to CMR[33] and could theoretically be used to calculate regurgitant volumes as well, with the considerations of acoustic artifacts from prostheses. Luckily, we do not have to depend only on one modality.

We are fortunate to have multimodality imaging available as a true modern-day toolbox. As both Mak et al[16] and Suh et al[20] have shown, advances in imaging technology result in multiple imaging options, which allow us to best assess our patients. This will be crucial not only in structural interventions but in other areas of cardiology. It is up to us to leverage these technologies and use our collective expertise to drive the field forward to obtain the best outcomes for our patients.

Disclosures

None.

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