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EDITORIAL COMMENT

Imaging the Future of Transcatheter Aortic Valve Replacement*

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In this issue of *JACC: Cardiovascular Imaging*, Moss et al. (1) describe their experience with echocardiography in 50 patients who underwent transcatheter implantation of an aortic valve replacement (TAVR) via the femoral artery. If it continues to show reasonable safety and reliability in further experience, this procedure may revolutionize the field of valve replacement (2–6).

Like intraoperative echocardiography (7), ultrasound guidance of TAVR characterizes valve morphology, quantitates the severity of valve stenosis and regurgitation, and enables immediate on-line decisions to plan and define the success of the mission. Echocardiography will likely contribute to better outcomes of TAVR, provided it is used optimally. But the field is new, and there is much to learn. Echocardiographic imaging is useful in several stages of transcatheter valve procedures, some of which are mentioned in the article by Moss et al. (1).

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Before TAVR, echocardiography was used to estimate annular size, which in some patients is too small or too large for currently available percutaneous devices. The aortic valve morphology is assessed; bicuspid valves may or may not be less amenable to percutaneous valve replacement. The preoperative transthoracic echocardiography (TTE) defines the severity of aortic stenosis and aortic regurgitation. Both TTE and transesophageal echocardiography (TEE) visualize the distribution of calcium on and adjacent to the valve, the distance from the valve to the left main coronary ostium, the angle of the left ventricular outflow tract to the aorta, and the baseline severity of left ventricular size, function, and hypertrophy. In some cases, pre-operative computerized tomography (CT) visualizes some of these features, such as calcification, better than echocardiography. Computerized tomography is also very useful for assessing the size of and tortuosity of the abdominal and thoracic aorta, and the iliac and femoral arteries used for access. The discovery by CT or TEE of severe atheroma in the aorta, which are likely to embolize with manipulation of these large catheters, can also have an impact on the plans for TAVR. For example, protruding atheroma might mandate a trans apical AVR (8), rather than a femoral procedure. Defining the size of the sinuses of Valsalva and the sinotubular junction may also be important if the TAVR device available is one that anchors to the sinotubular junction (9).

During the TAVR procedure, TEE is used, more or less constantly, to achieve numerous goals, analogous to the constant ultrasound guidance of transcatheter treatment of mitral stenosis (10), atrial–septal defect (11), hypertrophic cardiomyopathy (12), and other lesions. In the procedure room or operating room before the intervention, the patient's annular diameter is remeasured with TEE to allow choice of the most appropriate AVR size. In cases of per apical TAVR, transthoracic (TTE) and epicardial echocardiography may be used. Transthoracic echocardiography from the apical window defines the optimum site for the incision. A sleeved TTE probe, placed directly on the left ventricular apical epicardium, defines the exact needle trajectory and depth to reach the center of the left ventricular cavity, which is often small and hypercontractile in these patients.

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During balloon valvotomy of the stenotic aortic valve, but before implantation of the AVR, the location of the indentation on the balloon is noted by TEE and fluoroscopy, in comparison to adjacent landmarks. Immediately after balloon dilation, TEE rechecks the severity of aortic stenosis and regurgitation. If acute severe regurgitation develops, fluid and vasopressor resuscitation can be made easier by imaging left ventricular size by TEE. The crimped AVR and stent are then positioned inside the aortic annulus, but this crucial placement is difficult even when using TEE and fluoroscopic guidance. Because of the expected 2 to 4 mm of superior migration during implantation (1), the starting position should be with 70% of the valve inferior to the plane of the annulus and 30% above it.

After verifying capture of rapid ventricular pacing, the valve prosthesis is expanded within the aortic annulus, verified by fluoroscopy and TEE. Pacing must be continued until the balloon is deflated because premature cessation of pacing may allow left ventricular ejection to push the balloon-filled AVR to a more superior position than is desired.

Immediately after the AVR is expanded into place, TEE is used to assess the severity and location of aortic regurgitation. Most patients have mild perivalvular regurgitation, but if TEE shows it to be more severe, repeat balloon dilation of the AVR can be helpful (6% in the experience of Moss et al. [1]). The TEE imaging should assess leaflet motion of the AVR, define dislodgement and migration of the prosthesis, and look for impingement of the device on coronaries. The transgastric views are used to measure prosthetic valve gradients and to check for left and right ventricular dysfunction. New regional wall motion abnormalities may be the most reliable way to detect obstruction of a coronary orifice by the prosthesis. Other complications, such as pericardial tamponade, aortic dissection, or new mitral regurgitation, also are detectable by echocardiography. Some vascular catastrophes, such as bleeding adjacent to the aorta (1), can be diagnosed by TEE, although the sensitivity is probably low.

After the TAVR procedure, the goals of echocardiographic imaging for TAVR include follow-up measurement of valve and ventricular function and re-assessing the function of other valves.

For successful TAVR, high-quality imaging is needed. The best option seems to be a combination of ultrasound and fluoroscopy, which are complimentary in guiding TAVR. Fluoroscopy and TEE have different strengths. Assessment of the location of wires and catheters is done better with fluoroscopy because the echocardiographer cannot determine whether the portion of the wire or catheter seen in an imaging plane is its tip or its middle portion. However, TEE is more able than fluoroscopy to assess valvular regurgitation rapidly and repeatedly, to constantly image movement of wires and catheters, and to do so without radiation. Ultrasound imaging becomes more helpful in patients with less intracardiac calcium, where fluoroscopy is less effective. Conversely, fluoroscopy becomes more helpful in patients who have more calcification, because cardiac motion becomes more apparent, whereas TEE becomes more difficult because of shadowing. At the time of expansion of the crimped bioprosthesis into its final location, fluoroscopy visualizes well the calcified native valve, the crimped bioprosthesis, and the stent. The smart fluoroscopist uses any adjacent calcified structures as landmarks identified during previous angiography, but the technique lacks depth perception. Using echocardiography at the time of expansion of the bioprosthesis, the crimped valve and stent are difficult to see, whereas the surrounding structures show up well. It is important for the interventionalist, whose habit is fluoroscopy, to learn the value of echocardiography and to marry the 2 modalities.

To function as a team, a common vocabulary is needed between health care professionals of different backgrounds. Imagers, interventional cardiologists, and cardiac surgeons often use differing names for cardiac structures, imaging planes, and directions within those planes. Communication is essential to optimally choose the proper imaging window and plane, visualize the area in question, and interpret what is shown. Manipulation of the device should be narrated using a common vocabulary discernible by all of the team.

There are numerous areas in need of further research. Moss et al. (1) found an unexplained underestimation of annular size by TTE compared with TEE. Perhaps blooming of structural thickness results from harmonic imaging, as mentioned, or perhaps the annulus is not really round. This systematic difference might result from measuring a different plane or from foreshortening that could be defined by computed tomographic or magnetic resonance imaging.

We do not yet understand any predictive value in the TEE images and whether they can forestall procedural complications, whether the extent or location of calcification impact outcome, and what is the response of the left ventricle and the aortic leaflets to the balloon inflation and valve implantation. It is uncertain whether intracardiac imaging (13) will be of sufficient guidance to substitute for TEE. Although it would seem to be better to cross the native valve with this large device in the very center of the leaflets rather than at the commissures, it is not certain whether TEE will provide sufficient guidance to do this. Correlations with computed tomography, magnetic resonance imaging, or 3-dimensional echocardiography might allow prediction of difficulty in crossing the valve or development of a larger paravalvular leak. The shape and angle of the ascending aorta may be helpful in choosing the apical versus femoral approach to TAVR, whether the wire will easily cross the valve or how it will lay in the commissure. Is there a role of balloon sizing? How should periprosthetic regurgitation be quantitated? Are there structural features of some aortic valves, like in mitral stenosis (14), that would predict success or failure of TAVR? How do we recognize and treat immediate failure of TAVR (15)? All of these issues demand further study.

The development of TEE guidance of TAVR is very similar to its use in patients undergoing surgical valve repair (16). In that field, the pre-pump echocardiography provides accurate online diagnosis of valve dysfunction, both its severity and mechanism. Like the post-pump intraoperative study, TEE provides a safety net on the success of percutaneous valve interventions, and can immediately detect complications and suboptimal results.

Some interventional cardiologists, who are mostly accustomed to fluoroscopy alone, have advocated that TAVR can be done as well without echocardiography guidance. This again is similar to intraoperative echocardiography in the early days, before showing that its use reduces subsequent reoperation, for example after surgical mitral repair (17). In the article by Moss et al. (1), the Vancouver group is now using TEE routinely in all cases, whereas they used it in only 74% of the first group of patients.

Regarding percutaneous valve procedures, this editorial illustrates the importance of: 1) cooperation between individuals from several specialties who partner their efforts; and 2) the role of echocardiographic imaging, together with fluoroscopy, to guide the procedural success of TAVR.

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