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Editorial

# Contemporary Practice of Echocardiography in Transcatheter Aortic Valve Replacement

THE CONTEMPORARY practice of perioperative imaging and procedural guidance for transcatheter aortic valve replacement (TAVR) has evolved greatly in recent years. This has been both a cause and an effect of changes in the way clinicians provide anesthesia for these procedures. Although valve sizing with multidetector computed tomography (MDCT) has decreased the use of general anesthesia (GA) chosen solely to facilitate intraprocedural transesophageal echocardiography (TEE), a shift toward greater use of monitored anesthesia care (MAC) and transthoracic echocardiography (TTE) already was underway. Although change to a less-invasive anesthetic largely due to the development of low-profile device sheaths and the near-universal use of transfemoral access has been well-described in anesthesia literature, evolving trends in interventional echocardiography for structural heart procedures including TAVR deserve additional attention.[1]

Increasing indications for structural heart disease (SHD) interventions have led to a greater volume for programs and created a new field of SHD echocardiography, with a formal training and certification process now in development.[2] Currently, both cardiologists and cardiac anesthesiologists are involved in interventional echocardiography for TAVR using both TEE and TTE, and future pathways to demonstrate proficiency are expected to exist for both disciplines.[3,4] Whether or not the cardiac anesthesiologist is the individual performing the examination during a TAVR procedure, their role on the heart valve team necessitates the ability to interpret images and provide procedural guidance, just as he or she would in any other heart room. With increasing momentum to formalize the role of the imager in TAVR, it is important to review the current practices and future trends in echocardiography for TAVR and how this may affect the role of the anesthesiologist.

## Goals of Intraprocedural Echocardiography for TAVR

As the trend toward a less-invasive approach for TAVR continues, a minimally invasive real-time, high-resolution technique with three-dimensional (3D) capability for imaging of aortic valve pre- and postimplantation would be ideal. However, sonographic engineering is yet to develop such a modality. In the meantime, both TEE and TTE are reasonable methods for intraprocedural imaging. Given that the majority of TAVR now is performed under MAC in the United States, TTE is likely the more frequently used modality, although these data are not collected specifically by national registries.[5]

Current technology and procedure competence in TAVR have improved to such an extent that valve deployment, once dependent on both fluoroscopy and TEE guidance, is now possible largely with fluoroscopic guidance alone.[6] However, echocardiography remains a best practice at high-performing centers in assessment before and after implantation.[7] Predeployment, the goals of echocardiography include the final confirmation of baseline cardiac function, valvular stenosis, and risk assessment of subvalvular dynamic left ventricular outflow track (LVOT) obstruction after deployment. Each of these findings already should be known and discussed by the valve team before the patient is scheduled for TAVR. Postdeployment echocardiography is used to evaluate prosthetic valve positioning and function and to detect causes of hemodynamic instability. Both TEE and TTE can accomplish these goals when performed by an individual proficient in image acquisition and a team capable of appropriate interpretation.

Markers of successful valve implantation include assessment of seal, velocity, and device shape. A satisfactory valve seal indicates no significant paravalvular or transvalvular aortic regurgitation.[8] This can be confirmed by obtaining both short- and long-axis views, including the midesophageal aortic valve short-axis, midesophageal aortic valve long-axis, deep transgastric five-chamber, and transgastric long-axis views with TEE; and the parasternal long-axis, parasternal short-axis, apical five-chamber, and apical three-chamber views with TTE. Assessment based on an incomplete examination can lead to errors in diagnosis. For example, supravalvular aortic root flow seen on short-axis views alone may be confused for paravalvular aortic regurgitation (PAR), and transvalvular regurgitation due to the left ventricular wire before removal can be confused with more concerning PAR. Proper identification of

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aortic regurgitation is important because greater-than-mild aortic regurgitation has been associated with worse mortality and morbidity after TAVR.[9]

The etiology of PAR, whether from suboptimal valve position, valve asymmetry, underexpansion, or ectopic annular or subannular calcifications, will determine what, if any, action is needed.

The desired postimplantation peak velocity is generally <2.0 m/s when measured by a continuous-wave Doppler in any long-axis view. The Doppler envelope should be early peaking. The LVOT velocity also should be measured with pulse-wave Doppler because if both values are elevated, a dimensionless index >0.6 also is considered appropriate. When a suboptimal gradient exists, the valve may be undersized, underdeployed, or improperly positioned. Valves should be circular rather than ovoid on short-axis and be seated a few millimeters into the LVOT on long-axis. Rapid assessment may be required if hemodynamic instability exists.

Because most TAVR today proceeds relatively uneventfully, there may exist a false notion that echocardiography is unimportant. Particularly as the shift toward TTE and MAC continues, one may wrongly believe that a high-quality examination is not necessary, and some programs may settle for suboptimal imaging or no echocardiography at all. Centers may neglect both the financial investment and time commitment required to staff a case with a properly trained individual, whether that be a cardiologist, cardiac anesthesiologist, or echocardiography technician, working in conjunction with individuals competent to make rapid interpretations. Although the best practices of high-volume, top-performing centers support the continued use of echocardiography, quality data supporting this are lacking.

## Considerations for Imaging Modality

TAVR programs use multiple imaging modalities, including MDCT, cardiac magnetic resonance imaging, and fluoroscopy, in addition to echocardiography. Although 2D- and 3D-TEE once were used for annular sizing during the early days of TAVR, the introduction for MDCT has transformed preprocedural imaging by providing more detailed and precise evaluation of aortic root anatomy and annular dimensions.[10] Supplanting echocardiography as the gold standard for TAVR workup, a complete MDCT study also assesses the risks of coronary occlusion or rupture due to LVOT calcification and provides co-planar fluoroscopic angle prediction prior to the intervention.[11] Furthermore, MDCT is used to evaluate the suitability of transfemoral access, can rule out coronary disease, and eliminate the need for a diagnostic cardiac catheterization.[12]

In current practice, there are very few reasons not to obtain a complete preprocedural MDCT study. Most adverse reactions due to contrast allergies can be mitigated with pretreatment of steroids and an antihistamine. Sedatives can help restless patients remain motionless. Although contrast-induced nephropathy remains a concern, modern high-power, 160-mm dual-source scanners now are capable of performing a complete cardiac and vascular examination with low-contrast protocols that reduce dye requirements by >50%.[13]

When TEE is required for valve sizing, annular dimensions may be comparable to MDCT. Rong et al performed a meta-analysis comparing 3D-TEE to MDCT for aortic annular area, aortic annular perimeter, and LVOT area measurements.[14] Results showed a strong correlation between the two imaging modalities and nonsignificant mean differences in all three parameters. Whatever modality is used for anatomic evaluation, it is imperative that the study is performed in advance of the procedure to ensure availability of the correct valve type. Heavy LVOT calcium should lead to the use of a self-expanding valve, whereas patients with an extra-large annular size may benefit from a balloon-expandable valve.[15,16]

Intraprocedurally, MAC alone is not an absolute indication for TTE; however, a deeper level of sedation may be necessary for TEE, which increases the risk of hemodynamic and airway compromise. Rates of these complications will increase with longer procedure times and certain patient characteristics. The only significant indication for intraprocedural TTE is esophageal pathology that precludes TEE probe placement. For TEE, there are four broad indications for intraprocedural use:

1 *Whenever GA is selected*: TEE affords higher overall 2D and 3D image quality and the ability to continuously image without interrupting the surgical procedure or exposing the sonographer to significant radiation.[17] For all but the most skilled echocardiographers, this will result in a more rapid assessment. When a single individual is responsible for both acquiring images and providing anesthesia, a position at the head of the bed near essential equipment is preferred. Common reasons for selecting GA include the use of alternative access sites requiring cutdown, patient preference, or the preference of the heart team.
2 *When poor acoustic TTE windows exist*: The TTE examination during TAVR is particularly challenging due to factors including a requisite supine position, the presence of the fluoroscopic system, the potential lack of patient cooperation with breathing commands, and the dynamic environment of the procedure suite. Patient characteristics, such as obesity, chest wall deformities, and chronic obstructive pulmonary disease, also may contribute to a technically difficult study. When a suboptimal TTE examination leaves an unanswered clinical question, aortography and invasive catheter pressure measurement may help; however. if these methods are inconclusive, TEE should be considered.
3 *Uncertainty in valve sizing*: As stated, there remain few contraindications for MDCT. However, in cases when 3D-TEE is used for sizing, it should be performed before scheduling a patient for TAVR. If any uncertainty remains on the day of procedure, TTE should not be relied upon exclusively for measurement of annular dimensions.
4 *When concurrent procedures dictate use*: Future directions in TAVR may lead to concomitant procedures that rely on advanced imaging, such as the bioprosthetic aortic scallop intentional laceration, to prevent the coronary artery obstruction procedure, which is performed to avoid

coronary obstruction after TAVR. In this procedure, TEE facilitates the accurate positioning of catheters in real-time.[18]

## Competencies in Echocardiography for SHD Interventions

To date, formal postgraduate training in interventional echocardiography, including training program guidelines, standards, credentialing, and board examination, have not been developed or adapted officially by any professional society. However, a 2019 multisociety expert consensus document discussed the need for specialized training and proposed a framework for interventional echocardiography training pathways for both cardiology and adult cardiothoracic anesthesiology (ACTA) fellows.[3] Core competencies that help define this subspecialty include medical knowledge, patient care and procedural skills, advanced imaging, and communication. Medical knowledge competency reaches beyond simple familiarity with devices, imaging acquisition, and analysis. Interventional echocardiographers need to be familiar with MDCT and other imaging modalities typically used. They must understand intraprocedural complications, their hemodynamic manifestations and echocardiographic appearance, and the most efficient ways to demonstrate these findings. The importance of image integration into the heart team cannot be underestimated.

Interventional imaging trainees should be under supervision of an experienced interventional echocardiographer who has been performing unsupervised structural imaging for a minimum of five years, with volumes similar to that of an experienced proceduralist. Fellowship training program requirements for the cardiac anesthesiologist should focus on periprocedural examinations only, because anesthesiologists generally do not participate in screening and postprocedure follow-up. A baseline proficiency in perioperative TEE should be a prerequisite to establishing competence in providing imaging guidance for structural heart interventions. To gain competence in interventional echocardiography, ACTA fellows should participate in at least 75 structural heart cases, of which 40 must be performed personally, and the remaining 35 may be interpreted with a supervising echocardiographer to meet the requirement. These examinations can be included in or exceed the 300 required by the National Board of Echocardiography certification criteria. In addition to hands-on training, it also is expected that fellowship programs adapt formal didactics and curricula based on SHD interventions. In the near future, it is possible that ACTA fellowship programs will need to be individually accredited as structural heart training programs, marking the first step to introduction of a certification in structural imaging for anesthesiologists.

## Considerations for the Interventional Echocardiographer

As more anesthesiologists and cardiologists gain expertise in interventional echocardiography, the question of who should lead periprocedural echocardiographic imaging for TAVR needs to be given some thought. Although cardiac anesthesiologists have incorporated perioperative TEE into routine practice successfully, TTE historically has been the domain of cardiologists and sonographers. It has been suggested that cardiac anesthesiologists can add value to their TAVR programs by performing intraprocedural TTE.[19] Integrating TTE into routine TAVR practice can improve institutional efficiencies as well as the increase the cardiac anesthesiologist's scope of practice and anesthetic management abilities.[20] Image acquisition may be performed by an echocardiography technician, but, regardless, anesthesiologists have the responsibility to understand and interpret the TTE examination, particularly when serving in the role of lead interventional echocardiographer.

Although the addition of TTE for TAVR to the cardiac anesthesiologist's repertoire is possible, integrating interventional TEE into routine practice may be more challenging. Since its introduction in 2015, current procedure terminology code 93355 refers to TEE guidance during advanced structural heart procedures. To receive reimbursement for this code, echocardiographers must meet the minimum threshold of placing the probe and performing the study, including guidance, with real-time acquisition and documentation. The Centers for Medicare and Medicaid Services allow for an anesthesiologist to bill for current procedure terminology code 93355, but only when an anesthesia service is not being concurrently performed. In an ideal world with unlimited resources, two anesthesiologists or an anesthesiologist and a cardiologist may be involved in every SHD procedure. However, few centers can afford such a luxury. In reality, one anesthesiologist may be expected to perform both the anesthetic and interventional TEE services while billing for only half of their duties. The best approach in terms of patient care, staffing flexibility, and improved work flow in this situation remains to be discerned.

Over the last two decades, advancements in TAVR technology and procedure experience have necessitated a shift in patient selection, imaging approaches, and anesthetic technique.[21]

Echocardiography for TAVR has adapted in kind and remains an indispensable tool for procedural success from beginning to end. Reflecting on perpetual innovation, the most feasible echocardiographic approach to TAVR going forward should continue to focus on patient care and efficient workflow while adjusting to the economic needs of the healthcare system.

## Conflict of Interest

Peter J. Neuburger is a consultant for Medtronic.

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