Progressive narrowing of the aortic valve orifice eventually leads to limitations in cardiac output and myocardial blood flow, particularly during exercise or other physiological stress. The pressure gradient across the stenotic aortic valve is a useful and reproducible measure of the severity of the stenosis in most patients. The mainstay of therapy for aortic stenosis is the fixed obstruction that has traditionally been accomplished with surgical aortic valve replacement (SAVR). However, during the past decade, transcatheter aortic valve replacement (TAVR) has rapidly evolved as an alternative therapy. Despite improvements in valve design and delivery, all prostheses are hemodynamically inferior to healthy native valves and, therefore, valve replacement results in the exchange of de novo valve disease for prosthetic valve disease. Because the gradient across most prosthetic valves is directly related to their size, a paradigm of aortic valve surgery is to implant the largest valve possible to minimize the transvalvular pressure gradient and maximize the ability to generate increased cardiac output in times of increased demand.

The potential placement of a prosthetic valve that is relatively too small for a patient is a significant concern (Figure A and B). This condition, which has been referred to as patient–prosthesis mismatch (PPM), results in persistent imbalance between the hemodynamic abilities of the aortic prosthesis and the required cardiac output of the patient. Resting cardiac output and transvalvular flow increase proportionally with body surface area; therefore, the recommended parameter for diagnosis of PPM is the indexed effective orifice area (effective orifice area divided by body surface area). Traditionally, the presence of PPM is defined as an indexed effective orifice area of <0.85 cm²/m² and severe PPM is <0.65 cm²/m².1 PPM is the most common cause of elevated post-operative transvalvular gradients after aortic valve replacement and has a reported prevalence as high as 20% to 70% and 2% to 20% for moderate and severe mismatch, respectively.2 In the modern era of increasingly prevalent and more severe obesity,3 the potential problem of PPM is frequently encountered because the aortic annulus does not expand in response to adiposity, and yet the demand for cardiac output is chronically increased. The presence of PPM is of particular clinical interest because it is associated with increased perioperative and late mortality, worse functional status, and reduced post-operative left ventricular remodeling. There is a spectrum of risk in PPM with worse outcomes being associated with lower indexed effective orifice area values.4 These observations conceptually reiterate the importance of adequate gradient reduction and, hence, the need for optimal valve sizing and implantation.

In practice, the tools used for choosing the size of a surgically implanted valve are rather crude and have changed little during several decades. Manual insertion of a series of vendor-specific sizing devices into the aortic annulus at the time of the valve surgery is the standard method of choosing SAVR size. Of note, these devices are round because they are intended to mimic the profile of the implanted valves (Figure C), whereas the true aortic annulus is oval shaped or elliptical (Figure E through H).4 In contrast to the method of sizing SAVR, TAVR prosthetic size is chosen based on measurements done from reconstructed images of the aortic annulus derived from gated multirow detector computed tomography (MDCT) of the heart (example shown in Figure E through H). These images give a clear visual representation of the elliptical shape of the annulus. The use of a round sizing device to plan the implantation of a rigid, round prosthetic valve into an oval shaped orifice leads to the obvious potential for undersizing of the SAVR prosthesis. In contrast, the flexible and expandable nature of TAVR prostheses offers a better opportunity to use more of the real estate that is available in the aortic annulus to achieve the best effective orifice area and lowest gradient.

In this issue of Circulation: Cardiovascular Imaging, George et al5 analyze the potential for using preoperative MDCT annular sizing and prosthesis selection versus standard intraoperative SAVR sizing. In this retrospective series of 78 patients undergoing elective SAVR, the intraoperatively determined valve size was compared with what would have been chosen if a preoperative MDCT were used. Secondarily, the theoretical valve area of both SAVR and TAVR using the different valve sizing approaches was compared. This study is timely in that there is a growing body of literature reporting superior hemodynamics and lower rates of PPM with TAVR compared with SAVR. PPM was more frequent (60% SAVR and 46% TAVR) and more frequently severe (28% SAVR and 20% TAVR) in surgical patients than in patients undergoing TAVR with a balloon expandable valve in cohort A of the PARTNER-I trial.6 Similarly, severe PPM was more common (20.7% versus 7%) in patients who underwent SAVR...
compared with TAVR with a self-expanding valve in the CoreValve US Pivotal trial.\textsuperscript{7}

The observed hemodynamic benefit of TAVR over SAVR is undoubtedly because of several limitations of the surgical approach, including suboptimal valve sizing and prosthetic design limitations. Most surgically implanted valves have a relative thick valve ring and struts that take up part of the orifice (Figure C) whereas TAVR’s have much thinner, expandable frames and no struts (Figure D). In this study, less than half of the total cohort would have received equivalently sized valves based on intraoperative sizing versus sizing by preoperative MDCT, and 41% of patients received a smaller surgical valve than predicted by MDCT. The authors conclude that intraoperative sizing via traditional methods is limited by several patient and operator-dependent factors. Although technical limitations of the surgical approach for valve sizing and implantation may be difficult to overcome, this study provides evidence that MDCT is a readily available tool that has the potential to optimize valve sizing by providing a more physiological assessment of annular dimensions and geometry. As previously stated, the annulus is not a round and static structure, and its intraoperative assessment during full arrest is inherently limited. MDCT seems to be capable of providing a better understanding of the capacity of the annulus to accommodate a maximally sized prosthesis. Because MDCT is increasingly being used to evaluate coronary anatomy before valve surgery, it requires little extra effort to also use the available information to quantify annular geometry and dimensions.

Interestingly, the authors sought to compare the geometric orifice areas (GOAs) achieved with implanted surgical valves to the theoretical values achievable with an MDCT sized, maximally deployed, balloon expandable TAVR (Edwards SAPIEN 3). Not surprisingly, the theoretical GOAs associated with the TAVR valves were larger when compared with identically sized surgical valves. The difference in GOAs is due, in part, to the presence of a valve ring and struts within the surgically placed bioprosthetic valves, which limits the theoretical GOA (Figure C). Although large GOAs are attractive intuitively, several limitations of this analysis should be mentioned. The authors assumed full expansion of the TAVR valve to the preoperative annulus size, something that may...
not always occur in clinical practice, especially in cases with increased risk of annular rupture.\textsuperscript{9} Perhaps, more importantly, GOA has not been validated as a clinically relevant assessment of valve hemodynamics or prognostic marker of clinical outcomes. This decoupling of ideal GOA and post-operative hemodynamics is apparent in that all 3 groups in this study (SAVR valves that were appropriately sized, undersized, and oversized compared with computerized tomographic (CT)–predicted valve sizes) had nearly identical post-operative transvalvular gradients. Although several studies have detailed lower post-operative gradients with TAVR when compared with SAVR, the theoretical nature of this study precludes comparable functional assessment between the 2 strategies beyond reference to the post-operative hemodynamics described in historical TAVR cohorts.

Gated CT is one of the most powerful and exciting imaging technologies to impact clinical cardiology practice in recent years. Its application in the assessment of cardiac structure and function has become paramount in the diagnosis of disease and in procedural planning. In this study, George et al\textsuperscript{4} explored the application of MDCT to an area of clinical interest where it is not routinely used. Although the data presented do not necessarily demonstrate that CT is ready to be used today for sizing surgical valves, we commend the authors on this interesting study and recognize the potential for continued implementation of cardiac CT in this and other new clinical settings. Emerging technologies, such as CT-derived fractional flow reserve and CT myocardial perfusion imaging, are both currently under investigation as tools to better characterize the hemodynamic significance of coronary stenoses. Although the clinical use of the above techniques remains to be determined, the rapidity of image acquisition, high-spatial resolution and anatomic detail, and the true 3-dimensional nature of cardiac CT make it particularly well suited for guidance of structural interventions. Novel applications, such as in the assessment of the left atrial appendage size and geometry before insertion of closure devices, will likely favor CT over conventional transesophageal echocardiographic measurements, as previously occurred with TAVR.\textsuperscript{5} Finally, volumetric data sets acquired by ECG-gated CT have been used in the 3-dimensional printing of anatomic models of cardiac structures of interest, an area of explosive growth and interest. The role of 3-dimensional modeling for training purposes, in procedural planning, and device innovation is an active area of investigation.\textsuperscript{6,7} For the foreseeable future, all aspects of structural heart disease interventions will likely evolve in parallel with advances in CT imaging.

Disclosures

None.

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Round Valve in an Oval Hole: Right-Sizing Prosthetic Aortic Valves With Preoperative Computed Tomography
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