Determining Aortic Stenosis Severity: What to Do When Measuring Left Ventricular Outflow Tract Diameter Is Difficult

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Contemporary decision-making in aortic stenosis (AS) is based on clinical assessment in conjunction with echocardiographic determination of AS severity and left ventricular ejection fraction. The primary hemodynamic parameters recommended for clinical evaluation of valvular AS are AS peak jet velocity, mean transaortic gradient, and aortic valve area (AVA) by continuity equation.1

Each of these measures has limitations, and it is essential to integrate all Doppler and two-dimensional echocardiographic data to determine AS severity accurately. AVA determined by the continuity equation has the advantage of being less flow dependent than the other parameters. For a reliable estimation of the AVA (or more accurately, the effective orifice area [EOA]), an accurate estimate of stroke volume must be obtained. In current practice, this depends on the ability to determine a left ventricular outflow tract (LVOT) area. This in turn depends on the assumption of a circular (or cylindrical) LVOT shape, in conjunction with the ability to obtain an accurate linear LVOT diameter (LVOTd). The LVOT area should be determined at a location within the LVOT that closely corresponds to the region where a technically adequate pulsed-wave Doppler signal is obtained. Because the linear dimension (LVOTd) is squared to obtain LVOT diameter, it is easy to see how the inability to measure the LVOT diameter accurately remains the Achilles’ heel of this technique. So how should AVA be determined when the LVOTd cannot be accurately measured?

The careful study by Leye et al2 presented in this issue of the Journal seeks to address this conundrum. The authors are to be congratulated on performing a large study with both validation and test populations. In the validation cohort, the authors explore the relationship among LVOTd, gender, height, and body surface area (BSA). By using an LVOTd derived from the BSA, they determined AVA in their test population (AVAcalc) and compared it with AVA measured (1.20 ± 0.42 vs 1.23 ± 0.40 cm², P = .08; mean difference −0.03 ± 0.19 cm²; r = 0.89, P < .0001).

This study does provide an interesting and novel approach to the conundrum in a patient with AS in whom the LVOTd is difficult to measure, but further investigation is required. Leye et al2 did validate a size-adjusted estimation of the LVOTd, but more research needs to be done to enable use of this approach. It should be remembered that the authors’ validation set was derived from patients without aortic valve disease, and specifically those without AS or bicuspid aortic valve. It is known that LVOTd tends to be larger in patients with bicuspid aortic valve (BAV). In addition, remodeling of the aortic annulus (thus conceivably the LVOT) may also occur in some patients with severe AS and trileaflet valves.3 Although we know that 30% of the testing set had severe AS, it would have been interesting to know the proportion who had BAV. It would be hoped that the authors’ technique for deriving AVA would hold up in larger groups containing significant populations of both severe AS and BAV. An important limitation of this study, acknowledged by the authors, is that a higher body mass index may falsely affect the relationship between LVOTd and BSA. The author’s equation tended to overestimate the AVA in obese patients (body mass index > 30 kg/m²), a population in whom it can be difficult to measure an accurate LVOTd on transthoracic echocardiography (TTE). Previous authors have found that the aortic annulus related linearly with height, whereas the relation with BSA was best explained by a quadratic equation.4 The current article reports a slightly better correlation between LVOTd and height in the overall validation set than between LVOTd and BSA.

So what can be done when the LVOTd is hard to measure in patients with valvular AS? Two broad strategies are available: 1) Try a different measurement on TTE. 2) Try a different imaging modality.

OTHER MEASURES USING TRANSTHORACIC ECHOCARDIOGRAPHY

Both AS jet velocity and mean transaortic gradient are common measures of AS severity. Calculation of the AVA is helpful when flow rates are either very high or very low.1 Of greatest clinical concern, AS jet velocity and the mean transvalvular gradient tend to underestimate AS severity when forward stroke volume is low.

The dimensionless severity index (velocity ratio) = LVOT (VTI or V)/AV (VTI or V) is useful when LVOTd is not assessable. To an extent, this ratio is normalized for body size, forward stroke volume, and Doppler interrogation angle (the latter especially when both the LVOT velocity and transaortic velocity are determined from the same continuous wave Doppler tracing where a LVOT velocity,
envelope is sometimes seen). Unlike AVA, however, the dimensionless index lacks extensive prospective validation.

Alternate ways of determining stroke volume (the numerator in the continuity equation) may be explored. Occasionally, imaging quality is sufficient to determine left ventricular stroke volume accurately using the two-dimensional apical biplane method of discs. In a younger population, the right ventricular outflow tract dimension can often be accurately measured, allowing right ventricular stroke volume to be determined and used in the calculation assuming the absence of a significant intracardiac shunt or pulmonary regurgitation.

Aortic valve planimetry can be used (especially with transesophageal echocardiography [TEE]). There is a conceptual advantage in this: It should be remembered that anatomic orifice area more closely approximates EOA as calculated by the Gorlin formula, which in turn is thought to be more representative of the burden imposed on the left ventricle by the stenotic valve than continuity equation-derived AVA. It should be remembered that planimetry can be prone to error, given the three-dimensional nature of the aortic orifice, and may be compromised by poor imaging quality.

**USING A DIFFERENT MODALITY**

TEE usually provides a better acoustic window for measurement of the LVOTd if there is a poor window on TTE. Although the study by Ley et al showed that TEE did not provide significantly different LVOTd measurements than TTE, in patients with severe AS, aortic annulus dimension (closely related to the LVOT dimension) measures larger by TTE. Accordingly, this relation requires further exploration. Real-time three-dimensional TTE planimetry has been shown to be a feasible and reproducible method for measuring AVA. Because real-time three-dimensional TTE image quality tends to be lower than that of two-dimensional TTE, this approach may not provide the answer when a poor transthoracic acoustic window is the primary issue.

AVA by planimetry on multidetector computed tomography and cine magnetic resonance imaging has been compared with TEE and TTE measurements. Both modalities have been shown to provide an accurate assessment of the AVA. Cardiac catheterization with pressure measurements and calculation of the AVA using the Gorlin formula can provide accurate data when performed with appropriate attention to technique and detail.

If an accurate measured LVOTd cannot be obtained, can one simply substitute the predicted LVOTd from one of the equations in the article of Ley et al? As noted earlier, the AVAcalc did not differ significantly from the AVA measured in the test cohort. However, in an individual patient, the measured LVOTd can vary ±3 to 4 mm from the predicted value, resulting in the AVA differing by up to ±0.4 cm². Thus, we do not believe that AVAcalc is sufficiently accurate in individual patients to base decisions on this information alone. As the authors suggest, it is important to measure the LVOTd accurately, when possible, and to use the predicted LVOTd derived from the equations provided as a safeguard.

In the last decade, the importance of avoiding patient–prosthesis mismatch of the prosthetic aortic valve is increasingly recognized, particularly in the setting of left ventricular dysfunction. Could advanced knowledge of a patient’s projected LVOTd help the surgeon avoid patient–prosthesis mismatch? If the patient’s BSA is multiplied by 0.85 cm²/m², the result should approximate the minimum EOA of the prosthesis required to avoid patient–prosthesis mismatch. If a significant discrepancy exists between the projected LVOT dimension and the anticipated size of the prosthesis needed to avoid mismatch, then the surgeon may want to consider the options: These might include using a valve with superior hemodynamic characteristics (e.g., a prosthetic valve in the supravalvar position or a homograft) or an aortic annular enlargement procedure. At a minimum, the finding should trigger the need for an intraoperative TEE to carefully measure the LVOT/aortic annulus.

**CONCLUSIONS**

When LVOT cannot be accurately measured, reasonable strategies exist to assess valvular AS severity, and the present study adds to this armamentarium. In the final analysis, however, it is the integration of the information derived from clinical assessment, echocardiography, and advanced modality imaging that provides the best safeguard against errors and ensures optimal patient outcomes.

**REFERENCES**