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EDITORIAL COMMENT

Velocity Acceleration in Aortic Stenosis Revisited*

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Aortic stenosis (AS) carries significant morbidity and mortality, particularly with the ushering in of related symptoms. Traditionally, assessment of AS severity has relied on invasive measures of gradient across the valve and derivation of orifice area. However, over the past 3 decades, a gradual shift has occurred whereby currently the evaluation of AS severity and related management decisions rely initially and predominantly on Doppler echocardiography. With the reinvigorated focus on valvular heart disease brought about by catheter-based interventions and the larger number of patients being evaluated for such therapy, there is an increased attention to the accuracy and limitations of various techniques in the assessment of AS and the opportunities to advance our understanding and management of this valvular disease.

PARAMETERS OF AS SEVERITY

From the early days of Doppler echocardiography, the conventional parameters included in the assessment of severity of AS were the maximal AS jet velocity, mean gradient across the valve, and derived aortic valve area using the continuity equation (1-3). The stroke volume used in the calculation of valve area is usually derived from the left ventricular outflow tract (LVOT), the most reliable by echocardiography, requiring a measurement of LVOT diameter from which cross-sectional area of flow is calculated assuming a circular geometry. Because blood velocity in the LVOT and AS jet has the same duration during ejection, a simplification of the continuity equation using a velocity ratio (V_{lvot}/V_{jet}) was proposed approximately 30 years ago as an index of severity of AS (2,3). It has carried the names of "dimensionless index" (DI), "velocity ratio," and "Doppler velocity index." In a practical manner, the ratio reflects velocity acceleration from just before the valve to through the valve stenosis. It has the major advantage of avoiding calculation of cross-sectional area of flow in the LVOT, circumventing additional errors in calculating valve area and geometric assumptions. In general, an acceleration of flow velocity of more than 4 times through the valve (i.e., a DI <0.25) denotes significant AS (3). This cutoff corresponds to a valve area of approximately 0.8 cm^2 (3), which goes along with a 4-fold reduction in LVOT cross-sectional area (usual LVOT diameter of 2 cm or area of 3.14 cm^2). Although this ratio is simple and offers possible advantages over other parameters of stenosis severity, it is less frequently used in native valve stenosis but more often as an index of prosthetic aortic valve function (Doppler velocity index) (4,5), because the size of the implanted prosthetic aortic valve relates closely to the size of the LVOT and aortic annulus (5,6).

PROGNOSTIC IMPACT

Although the relation of the DI to the severity of AS has been explored many years ago, a paucity of data are available regarding its prognosis value in AS. In this issue of *iJACC*, Rusinaru et al. (7) report their experience in evaluating the prognostic impact of DI measurement in a large patient population with

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asymptomatic or minimally symptomatic AS and preserved left ventricular ejection fraction (7). Patients with a DI <0.25 had a worse outcome, defined as death or need for valve replacement, compared with those with a DI >0.25. Of note, a linear relation of worsening prognosis was found with gradually lower DI ratios <0.25. The inflection point at 0.25 for increased risk is important regarding the clinical significance of DI and gives further credence

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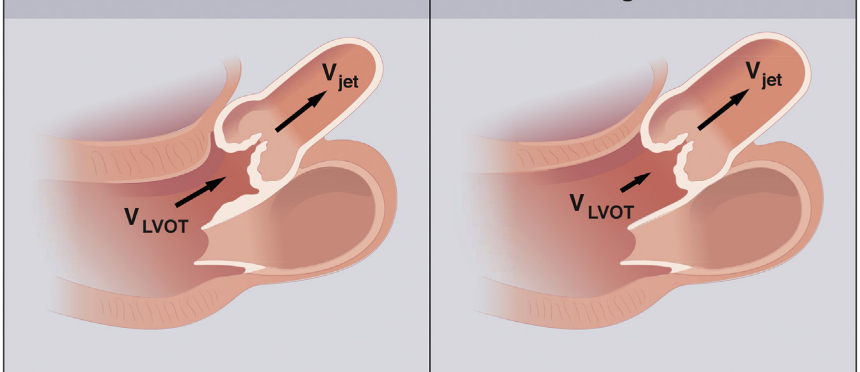
that severe AS with significant prognostic implications is at a valve area of ≤0.8 cm^2, which has been a matter of controversy (8); the current guideline-recommended valve area cutoff of 1 cm^2 is sensitive for severe AS, whereas the mean gradient of 40 mm Hg and peak velocity of 4 m/s are more specific for severe AS (8,9). The study by Rusinaru et al. (7) is an important investigation demonstrating the clinical value of velocity acceleration in AS, a line of evidence that has been missing in the literature. Because of the known relation of DI to other parameters of AS severity (2–4), the results observed are in general expected. However, what is surprising is that the DI ratio was additive to the prognostic information obtained with valve area and peak jet velocity, integral components of DI ratio, although a recent investigation did not show an incremental value of DI compared with gradients (10). Although the authors clearly demonstrate the prognostic impact of DI, one would have liked to see more details regarding its comparative value to that of the commonly used parameters of peak velocity, mean gradient, and valve area to weigh the significance of this ratio in the overall clinical assessment of AS with echo Doppler.

VELOCITY ACCELERATION: A CRITICAL APPRAISAL

It is important to reflect on velocity acceleration in the context of the overall Doppler echocardiographic evaluation of AS severity. Its advantage obviously is the avoidance of measurement of the LVOT diameter, eliminating a source of error in valve area calculation. Errors in determining valve area (combined interobserver and repeat study variability) usually average 15%, of which the least contributor is the jet velocity (5%); velocity in the LVOT and LVOT cross-sectional area accounts for 8% and 11% variability, respectively (data from our laboratory). Thus, positioning the pulsed Doppler adequately in the LVOT is a significant determinant of accuracy of both valve area and DI calculations. Ignoring measurement of LVOT area is likely accurate and acceptable in patients with a "normal" LVOT dimension. Although the DI is a good index of aortic valve function in health and stays stable from early life to adulthood in healthy persons, patients with AS, aortic root disease, or combined AS and regurgitation may have large variations in the LVOT cross-sectional area beyond that accounted for by body habitus (9); LVOT diameters

FIGURE 1 Effect of LVOT Size on DI



	Small LVOT	Large LVOT
$Diameter_{LVOT}$	≤ 1.8 cm	≥ 2.2 cm
$Velocity_{LVOT}$	≥ 20% Higher	≥ 20% Lower
V_{LVOT}/V_{jet}	≥ 20% Higher	≥ 20% Lower

Conditions of small and large LVOT size compared with the usual size of the LVOT (diameter average 2 cm; range 1.8 to 2.2 cm) and their effect on blood velocity in the LVOT and DI for the same flow condition and severity of AS. DI = dimensionless index; LVOT = left ventricular outflow tract; V = velocity.

possibly range from 1.4 cm (e.g., calcifications extending in the LVOT/anterior mitral valve, severe septal hypertrophy, small aortic root) to 3 cm (e.g., aortic root disease, dilated ventricles) (9). Because for the same flow, velocity is inversely proportional to cross-sectional area, the accuracy of DI in assessing AS severity can be affected by extremes in LVOT size and more so than valve area calculation, because the latter incorporates actual flow (stroke volume) and not just velocity in the LVOT. **Figure 1** illustrates such scenarios that affect DI measurements adversely, by ≥20% higher or lower depending on the size of the LVOT, compared with the majority of "normal" LVOT size (diameter average 2 cm; range 1.8 to 2.2 cm). Thus, in evaluating individual patients with native AS, the DI should be integrated with the usual parameters of peak velocity, mean gradient, and valve area in the overall assessment of AS severity, as suggested by the guidelines and by Baumgartner et al. (4) and Rusinaru et al. (7). To use the DI for decision making in AS along with the other parameters, one still needs to be cognizant of the overall size of the LVOT (small or large) and how it would affect the DI numerically and directionally. Of note is that considerations of LVOT size are less frequent when using velocity acceleration (Doppler velocity index) as an index of prosthetic aortic valve performance, because it is less influenced by valve size, as the inserted valve size relates to the dimension of the aortic root and LVOT (5,6).

Finally, one cannot ignore consideration of flow status in AS, because velocity of the AS jet and gradient across the valve are flow dependent. The advantage of echocardiography is that it allows an internal check of flow through other annular sites besides the LVOT (mitral/pulmonic) and through calculations of left ventricular volumes and ejection fraction from 2- or 3-dimensional echocardiography. In low-flow situations, the aortic valve may not open as wide as in normal flow, leading to a relative further reduction in valve area, and thus a relatively higher velocity and gradient across the valve—the reason to increase flow with inotropic agents or exercise and to reassess AS valve hemodynamics and area. An advantage of DI over sole measurements of peak velocity and gradients is the partial incorporation of flow in the assessment of AS severity. However, the DI would be affected similarly to derived valve area in low-flow states, by being relatively smaller compared with during normal flow. Whether the findings observed in this study, inclusive of cutoff values for DI, also are applicable in low-flow, low-gradient AS with depressed left ventricular function remains to be determined.

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