Aortic Stenosis: The Quest for a Noninvasive Gold Standard*

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The high mortality rate associated with symptomatic aortic stenosis makes the accurate clinical assessment of this lesion essential (1). However, the classic clinical descriptors of significant aortic stenosis are less accurate in patients with hypertension, aortic insufficiency and coronary heart disease. Moderate degrees of aortic stenosis may be difficult to assess, and a systolic ejection murmur is prevalent in the elderly, in whom the clinical assessment of the severity of aortic stenosis is more difficult. These diagnostic uncertainties have led to a quest for a noninvasive "gold standard" with which to evaluate both the presence and the severity of aortic stenosis (2).

Invasive study standards. Early invasive studies emphasized the peak to peak aortic gradient; 50 mm Hg was considered a "surgical gradient" (3). Later, the Gorlin formula (4) allowed for the calculation of the aortic valve area. The formula utilized the mean aortic gradient and therefore took into consideration the differences in the contour of the aortic pulse tracing as aortic stenosis became more severe. Furthermore, the Gorlin formula emphasized the inverse relation between gradient and flow in the assessment of valvular stenosis. Currently, aortic valve area determined by the Gorlin formula is the invasive gold standard against which noninvasive methods must be judged.

Historical perspective of the noninvasive assessment of aortic stenosis. M-mode echocardiography identified thickened aortic valve leaflets with restriction of opening as well as accompanying left ventricular hypertrophy (5). An aortic leaflet separation of ≥8 mm was associated with significant aortic stenosis (6). Direct measurements of the aortic valve area used cross-sectional imaging of the aortic orifice in systole (7). However, imaging of the valve was confounded by the irregular shape of the orifice, cardiac motion and operator-dependent factors such as gain settings. Other assessments of aortic stenosis relied on variables of left ventricular function. The systolic and diastolic slopes of the posterior left ventricular wall were compared, reflecting the slower filling and emptying of the pressure-overloaded ventricle (8). Another calculation used systolic wall thickness (an indirect estimation of gradient) and systolic left ventricular dimension (an indirect indicator of ventricular function) (9). This relation was reasonably accurate in children and young adults. However, in older adults the prevalence of aortic regurgitation, hypertension and ischemic heart disease independently influenced left ventricular diameter, hypertrophy and wall motion. In summary, imaging techniques were reasonably reliable to identify the presence, but not the severity, of aortic stenosis (5,10).

The introduction of Doppler echocardiography revived the noninvasive evaluation of aortic stenosis (11). Doppler flow velocities were converted to pressure gradients using a modification of the Bernoulli law. The Doppler gradient was neither a peak to peak nor a mean gradient but the peak instantaneous gradient. A variety of physiologic variables (12) as well as operator dependence in obtaining peak maximal velocities produced potential inaccuracies. Furthermore, gradient alone was an imprecise way to evaluate stenosis; initially, corrections were made using cardiac output determined by thermodilution or Doppler techniques (13,14). The jet width using Doppler color flow imaging was correlated to the severity of aortic stenosis (15). The most accepted technique for correcting gradient for flow was the continuity equation (16–19). This method measured the flow velocity ratio across the aortic valve and therefore corrected for high and low flow states. The continuity equation performed well, with correlation coefficients and predictive accuracies averaging about 0.85.

The current study. In this issue of the Journal, Mann and colleagues (20), recognizing the practical limitations of the continuity equation, introduce another entry to the quest for the noninvasive gold standard: "the fractional shortening velocity ratio." This ratio was retrospectively derived and prospectively tested against the current invasive gold standard—cardiac catheterization and the Gorlin formula. Additional strengths of this calculation include: 1) It indexes gradient to a left ventricular function variable. 2) the Doppler gradient is the continuous wave gradient already in use with its known strengths and limitations, and 3) fractional shortening is an accepted variable of left ventricular function that requires minimal computation and no mathemathic assumptions. This ratio appears to perform well: a fractional shortening velocity ratio of ≥1.1 had a sensitivity of 90% to 96% and a positive predictive accuracy of 90% to 92% for identifying patients with significant aortic stenosis (aortic valve area ≤1.0 cm²), whereas a fractional shortening veloc-
ity of \( \leq 0.8 \) had a sensitivity of 100% and a predictive accuracy of 74% to 88% for identifying patients with critical aortic stenosis (aortic valve area \( \leq 0.7 \text{ cm}^2 \)). The ratio outperformed mean aortic valve gradient and peak aortic velocity in the patient group studied by the authors.

Although Mann et al. (20) accurately state that the "simplicity of this new noninvasive method readily lends itself to routine clinical use," several issues remain problematic: 1) The continuous wave measurements retain pitfalls, as cited previously. 2) Although the fractional shortening is a good to excellent indicator of left ventricular function, it is not equivalent to flow as such. This becomes apparent in patients with mitral regurgitation, for whom this method may be severely limited. 3) Whether corrections of fractional shortening in patients with regional contraction abnormalities (21) will be adequate needs to be tested in larger populations. Finally, more patients need to be studied with intermediate valve areas and abnormal cardiac output to determine the performance of this technique in borderline situations (the standard deviation of the findings in the middle range remains significant).

Conclusions. The fractional shortening velocity ratio, which incorporates, at least indirectly, the requisite flow to gradient concept, appears to be a legitimate contender as a noninvasive gold standard. It is simpler to apply than the continuity equation. Independent evaluations should be performed by prospective users. If the ratio proves itself, it may be applied initially. However, like many of our noninvasive approaches, the method operates best in mild and severe degrees of stenosis; in the moderate range, the inevitability of cardiac catheterization may remain (22).

References