EDITORIAL COMMENT

Assessment of Mitral Stenosis: Role of Real-Time 3D TEE*

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The need to identify patients with important mitral stenosis (whose condition might be improved by closed commissurotomy) and to separate them from those with predominant mitral insufficiency (who could be made worse) was the motivation for the development of ultrasound cardiography by Edler and Hertz in the 1950s and remained a central focus of M-mode echocardiography for the next 2 decades (1,2). With the development of each new

echocardiographic technique, the assessment of mitral stenosis has been an early and often pivotal application. The 1975 report by Henry et al. (3) that 2-dimensional (2D) echocardiography could directly visualize the mitral valve orifice (MVA_{2D}) and permit measurement of its area was the first quantitative application of this technique and the first example of a noninvasive method that could provide a direct quantitative measure that could only be calculated at cardiac catheterization. The demonstration by Hatle et al. (4) of a good correlation between the mitral valve area (MVA) determined by the continuous-wave Doppler pressure half-time (MVA_{PHT}) and the MVA at catheterization was one of the earliest quantitative applications of this method and persists as one of the standard echocardiographic Doppler measures of the MVA. Since that time, a number of additional echocardiographic methods for measuring the MVA have been reported including continuity-based approaches (MVA_{CON}) (5,6), estimation of the elliptical orifice size based on the diameters of the color

flow jet exiting the valve (7), and transthoracic 3-dimensional (3D) measurement of the MVA (8–12).

The report by Schlosshan et al. (13) in this issue of *iJACC* examines the feasibility of mitral valve morphology and valve area assessment using real-time 3D transesophageal imaging. The authors found that 3D transesophageal echocardiography (TEE) measurements of the mitral valve orifice area (MVA_{3D}) could be obtained in 95% of patients. MVA_{3D} measurements were slightly but significantly lower than similar measurements by transthoracic 2D imaging (mean difference, −0.16) and the MVA by the pressure half-time (mean difference, −0.23) but not significantly greater than the MVA by the continuity equation (mean difference, 0.05; p = 0.82). These differences are consistent with the known physics and hemodynamics of the system being studied. When viewed from the esophagus using real-time 3D echocardiography, the mitral valve orifice will be recorded using the lateral resolution of the system. In this projection, the relatively sparse line density of the 3D system necessitates greater interpolation and smoothing, which, together with the point spread function of the scanning beam, results in a displayed area that is smaller than the actual valve orifice size. In contrast, the line density of 2D images from the chest wall is greater and the elliptical valve orifice is recorded using primarily the axial resolution of the system, which is superior to its lateral resolution. These effects combine to yield a larger valve area that should be closer to the true anatomic area and in studies comparing MVA_{2D} with excised mitral valves, the correlations have been excellent, ranging from 0.92 to 0.95 (3,14,15). The MVA by the continuity equation is based on the basic flow equation (flow = area × velocity or area = flow/velocity) and thus yields the area at the vena contracta (effective valve area). This, by definition,

must be smaller than the anatomic area, and the fact that the MVA_{3D} is not significantly different from the MVA_{CON} again points to the effect of the more limited lateral resolution of the 3D system in reducing the MVA. Although a flow-based equation, the constant in the Doppler mitral valve pressure half-time (220) was defined relative to the Gorlin valve area, which seeks to correct for the coefficient of contraction and therefore approximates the anatomic valve area (because excised valves were Gorlin's standard of reference) and should also approximate the anatomic area. Thus, as the authors found, the MVA_{PHT} should be larger than the MVA_{3D} and closer to that of the 2D measurement. Thus, if one assumes that all the data are accurately recorded, the results of this study are consistent with what one would predict from the physics of the ultrasound imaging systems and the physiology of the lesion.

In a classic illustration in the original article by Henry et al. (3), the authors compared a mitral valve orifice recorded by 2D echocardiography (0.68 cm^2) with that of an excised mitral valve (0.64 cm^2). Unfortunately, none of these methods are accurate to 0.01 cm^2, and in most cases are not accurate to the 0.1-cm^2 level. An examination of the Bland-Altman plots for the interobserver and intraobserver variability from the Schlosshan et al. (13) study shows that even when the same data are planimetered by the same or different observers, differences >0.1 cm^2 can occur. Even the generally accepted gold standards have problems. The most accurate standard is the directly measured valve area at surgery, either in situ or after removal of the valve. However, the number of studies using this standard is limited, the number of valves actually measured is small, and more severely distorted valves are difficult to remove en bloc or to measure in situ, and hence validation is generally based on more pliable valves. The more commonly used standard is the valve area measured at catheterization using the Gorlin formula. However, although the Gorlin "constant" is intended to correct for the coefficient of contraction, the coefficient of contraction is not a constant but varies with the size and shape of the orifice and the inlet (16,17). The Gorlin constant also fails to correct for the conversion of cm H_2O to mm Hg. Furthermore, just as the mean gradient calculated by the Bernoulli equation is based on the mean of the squares of the instantaneous velocities, the Gorlin equation should use the mean of the square roots of the instantaneous pressure gradients rather than the square root of the mean gradient. Finally,

the cardiac output measurement in patients with mitral stenosis may introduce even greater error, particularly in those with significant valvular insufficiency. Thus, in comparative studies, although the overall correlations are generally excellent and the mean differences usually small, it is not surprising that there is scatter in the values reported by different methods, and when multiple methods are applied in the same patient, it is extremely rare for the results to be identical.

Several other points in this study are worthy of comment. First, 2D images of the mitral orifice were recorded in only 27 of 43 patients (63%) compared with a success rate in most reported studies of ~90% or greater. As additional and often simpler methods for measuring the MVA have become available (e.g., the pressure half-time), the time and effort invested in recording the MVA_{2D} in clinical studies has decreased. However, in reviewing our clinical database for the past 10 years, a MVA by 2D planimetry in patients with rheumatic mitral stenosis was reported in 89% of 302 patients with mean gradients ≥10 mm Hg. Second, the MVA could only be recorded by the continuity equation in 60% of patients because of aortic or mitral regurgitation. The inaccuracy of the aortic outflow as a reference for MVA in these conditions is why most authors use the mitral inflow area and velocity (proximal isovelocity surface area method) as the reference for mitral flow because it is independent of aortic insufficiency and corrects for mitral regurgitation. Using this approach, Faletra et al. (14) reported a correlation of 0.87 for MVA_{CON} when compared with the directly measured valve area. Finally, the authors emphasize the importance of 3D TEE in assessing valve morphology, particularly the degree of commissural fusion, which they classify as minimal, partial, or complete. Unfortunately, the criteria for these grades are never given, either in this paper or in the authors' reference making it difficult for readers to validate or use this system. For example, one might presume that if both commissures are completely fused, there would be no residual valve area. Furthermore, because there is an inverse relationship between the degree of commissural fusion and MVA, the independent importance of these observations remains to be demonstrated, particularly because, as the authors note, commissural calcification, which does affect the success of balloon valvuloplasty, is difficult to appreciate by 3D TEE.

Thus, the central message of the study by Schlosshan et al. (13) that the mitral valve orifice

can be accurately recorded by 3D TEE is undoubtedly correct. The additional value of morphological evaluation will need to be documented in future studies by its independent effect on procedure outcome and restenosis. It appears that all the patients in this study had been determined to have critical mitral stenosis before TEE, and, given the invasive nature of this procedure, it is unlikely that it would ever be seen as a primary method for assessing MVA. However, if TEE is being performed for another reason (e.g., to exclude left atrial appendage thrombi, as in this case), then it is clear that the MVA and valve morphology can also be assessed.

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