Editorial Comment

Quantitative Assessment of Mitral Regurgitation*

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Accurate quantitation of mitral regurgitation offers a major clinical dilemma. The clinical clues depend largely on cardiac auscultation, the accuracy of which needs to be rigorously tested (1). Mitral regurgitation may not be associated with a clinically audible systolic murmur, and the auscultatory features of severity of regurgitation are generally based on increased volume of diastolic flow across the mitral valve. The echocardiographic methods (2) used before widespread adoption of Doppler techniques provided indirect clues related to left ventricular and atrial chamber size and evidence of ventricular diastolic volume overload.

Diagnosis of mitral regurgitation. The advent of Doppler methods has permitted detection of mitral regurgitation with a level of sensitivity not previously obtained (3–5). A systolic flow disturbance on the atrial side of the mitral valve, detected by pulsed Doppler technique, is used to diagnose the presence of mitral regurgitation. The potential errors of false positive diagnosis of mitral regurgitation by this approach may be avoided by placing the sample volume ≥1 cm behind (i.e., posterosuperior) the plane of the mitral anulus and requiring a pansystolic or late systolic flow disturbance generally associated with aliasing. Specifically, a brief early systolic flow disturbance at the time of closure or doming of the mitral valve leaflets can be a normal occurrence. The incidence of mitral regurgitation in normal subjects or in the absence of disease or dysfunction of the mitral apparatus appears to be <5%.

Quantitation of mitral regurgitation. The pulsed Doppler method has also been used to provide information regarding quantitation of mitral regurgitation. The regurgitation jet may be mapped by moving the Doppler sample volume progressively deeper into the left atrium. The atrium can be divided into nine compartments by considering divisions approximating one-third in the two dimensions of a cross-sectional plane. Careful mapping of a regurgitant jet with use of orthogonal planes from parasternal and apical two-dimensional echocardiographic images can provide assessment of size of a regurgitant jet. Although the largest area in any imaging plane may be used to quantitate the severity of regurgitation, a theoretically sounder approach would use a three-dimensional reconstruction of a flow disturbance map to avoid under- or overestimation. The latter approach, however, is time consuming and may be influenced by reduced sensitivity in Doppler interrogation at depth when examination is performed from the apical window. It is also subject to attenuation as a function of the angle between the Doppler beam and the flow jet.

An alternate approach to quantitation utilizes the ability of the pulsed Doppler technique to quantitate stroke volume at multiple sites. The volume of blood flow across the mitral orifice during one diastole can be obtained by measuring cross-sectional area of the orifice and an integral of the diastolic flow velocity curve. The diastolic volume flow across the mitral valve orifice comprises forward stroke volume as well as regurgitant volume. The forward stroke volume can similarly be obtained by interrogation of the flow velocity profile across a valve or a vessel that does not have a regurgitant component to its flow volume. Thus, the aortic valve or left ventricular outflow tract can be used to obtain forward stroke volume in the absence of aortic regurgitation. Regurgitant volume and regurgitant fraction can then be simply calculated from these data. Although theoretically sound, this approach has not been routinely adopted because of the potential for large errors based on small inaccuracies in cross-sectional area derivations. Thus, an error in estimation of regurgitant fraction may be exaggerated from small errors in stroke volume determinations across the two orifices.

The present study. The development of Doppler color flow imaging provided real time visualization of the regurgitation flow velocity map. It was not surprising that the size of the regurgitant jet was correlated with the severity of regurgitation. The initial report (6) correlated severity as assessed by selective left ventricular angiography with the depth behind the mitral orifice to which the jet was visualized. Realizing that the severity reflected by long narrow jets may be different from that reflected by large wide jets (even if both extend to a similar distance behind the mitral orifice), Helmcke et al. (7) correlated maximal jet area with severity. They observed a better correlation with angiographic grade of severity when the regurgitant jet area was corrected for the left atrial area. If one were to exclude cases of acute mitral regurgitation (without significant left atrial enlargement), it is not intuitively apparent how the left atrial area would contribute (in an inverse relation!) to severity of

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regurgitation. The findings of a correlative study by Spain et al. (8) in this issue of the Journal are reassuring because they demonstrate a good correlation between maximal jet area and angiographic severity of mitral regurgitation; the expression of this jet area as a percent of left atrial area did not improve on this correlation. Spain et al. further demonstrate that, when the jet area is averaged from two orthogonal planes, specificity for the prediction of severe mitral regurgitation is improved without reducing sensitivity. This finding would suggest that, when technically feasible, a three-dimensional reconstruction of the flow jet would provide a better correlation with severity.

Doppler color flow imaging is a multigated pulsed Doppler system using a variety of algorithms to detect flow velocities and distinguish them from wall motion. The system suffers from all the limitations of a pulsed Doppler technique and has some additional limitations, including variability of frame rate, sector angle, pulse repetition frequency and gain settings. This makes the method highly operator dependent. Nevertheless, clinical techniques to derive reproducible data have been developed and should be carefully adopted by those experienced in the conventional Doppler technique but starting afresh in color flow imaging.

Technical considerations. An important basic consideration is that the Doppler systems, no matter how sensitive and reproducible, provide information on velocity of flow rather than volume of flow. The velocity may reflect kinetic energy of flow, which is a product of mass and acceleration. On the basis of the Bernouilli equation, velocity is closely related to pressure gradient. The transmitral systolic pressure gradient is greatly influenced by arterial systolic pressure, thus, changes in arterial pressures would greatly affect the velocity profile of mitral regurgitation (9,10). The actual volume of regurgitation, regurgitant fraction and regurgitant orifice are all altered by changes in systemic vascular resistance or afterload. Even a modest decrease in arterial blood pressure induced by vasodilators results in dramatic decrease in mitral regurgitation. It is therefore essential that comparisons of techniques to assess severity of regurgitation be made at similar levels of arterial pressure and resistance. Doppler color flow imaging and contrast ventriculography should be carried out under nearly identical hemodynamic conditions and preferably simultaneously. Some of the lack of correlation in the reported studies may be related to comparisons in some patients at dissimilar hemodynamic states.

In any comparative evaluation of a new technique, the accuracy of the standard against which it is examined must also be considered. Although contrast left ventriculography has been widely utilized in clinical practice for quantitative assessment of mitral regurgitation, its limitations include variability of the position of the catheter within the left ventricular cavity, volume and rate of injection of contrast medium, left atrial volume in which the regurgitant contrast is diluted and the volume of forward flow that partly determines its clearance. Ventricular ectopic activity induced by the catheter and peripheral arterial pressure at the time of contrast injection are additional factors that influence quantitative assessment of regurgitation. Finally, the so-called quantitative assessment provides, at best, semiquantitative categories (mild, moderate and severe) rather than actual volumetric assessment of regurgitation. The concept of regurgitant fraction suffers not in theory but in practice from imperfect methods to assess stroke volumes (i.e., angiographic evaluation of left ventricular stroke volume and indicator-dilution method of assessing forward stroke volume).

Hemodynamic correlates. The hemodynamic or pressure correlates of severity of mitral regurgitation have been overemphasized. It has been taught traditionally that a large *V* wave in the left atrial pressure pulse is indicative of severe regurgitation. The height of the *V* wave is influenced by many factors including left atrial size and compliance, cardiac output and left atrial pressure at end-diastole. Thus a high output state in the presence of mild or moderate mitral stenosis may be associated with a large *V* wave with little or no regurgitation. Similarly, severe mitral regurgitation into a markedly dilated left atrium may be associated with a *V* wave of only modest amplitude. It is therefore not in the least surprising that Spain et al. (8) were unable to predict likelihood of hemodynamic abnormalities from Doppler color flow imaging or mitral regurgitation. Indeed, continuous wave Doppler recordings provide better insight into hemodynamics as they relate to instantaneous pressure differences between the left ventricle and the left atrium. Recent work in our laboratory (11) has demonstrated a good correlation between the rate of left ventricular pressure increase in the pre-ejection phase of systole (derived from continuous wave Doppler recordings of the mitral regurgitation signal) with traditional variables of left ventricular function, and this index has been further utilized to predict ventricular function after surgical correction of mitral regurgitation (12).

Today's clinicians must be aware of the imprecision of all available techniques as well as the dependence on various physiologic and technical factors. In patient management, therefore, they must use judgment based on many variables and not be unduly swayed by the results of one approach, whether it is contrast ventriculography or Doppler color flow imaging.

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