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**Echocardiographic Evaluation of Mitral Stenosis Using Diastolic Posterior Left Ventricular Wall Motion**

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**SUMMARY** The slope of the posterior left ventricular wall motion in diastole (LVDS) was determined by echocardiography in 25 normal subjects and 21 patients with mitral stenosis. Patients with mitral stenosis had reduced LVDS that was related to the degree of mitral stenosis determined by calculated mitral valve area ($r = 0.92$). The mitral valve area correlated more closely with LVDS than with the left atrial emptying index derived from the posterior aortic wall motion. Three patients with mitral stenosis had an increased LVDS after mitral valvotomy or mitral valve replacement. One patient with a stenotic mitral valve prosthesis had reduced LVDS. The results of this study suggest that analysis of the LVDS would be useful in predicting the severity of mitral stenosis and may be beneficial in evaluating patients with suspected prosthetic mitral valve malfunction.

**SINCE EDLER'S DESCRIPTION in 1955, M-mode echocardiography has been used to verify the presence of mitral valve stenosis with a high degree of accuracy.** Estimates of the severity of mitral stenosis using the diastolic closure rate of the anterior mitral valve leaflet (E-F slope) have not been accurate. Strunk et al. suggested that because the motion of the posterior aortic wall in diastole reflects changes in the left atrial volume, analysis of this motion might allow more accurate assessment of the degree of mitral stenosis. Hall et al. found no correlation between the degree of mitral stenosis and the left atrial emptying index derived from the posterior aortic wall motion.

Volume changes within the left ventricle can be determined echocardiographically from analysis of the left ventricular wall motion. Alterations of the posterior left ventricular wall motion in diastole have been found in patients with impaired left ventricular filling from a variety of causes, including constrictive pericarditis, cardiac tamponade and hypertrophic cardiomyopathy. Mitral stenosis, a condition with a reduced rate of left ventricular filling, might also be expected to show alterations of the posterior left ventricular wall motion on echocardiography. Accordingly, this study was undertaken to determine if patients with mitral stenosis had abnormal posterior left ventricular wall motion by echocardiography, and if so, whether analysis of this motion could be used to predict the severity of the stenosis.

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Methods

The echocardiograms of patients with echocardiographic and clinical evidence of mitral stenosis recorded at Eastern Maine Medical Center since 1975 were reviewed. Patients with unsatisfactory recordings and those with more than minimal mitral or aortic regurgitation or left ventricular dysfunction were excluded. Eight of the 21 patients had atrial fibrillation when the echocardiogram was performed. Included in the study group were three patients who had an echocardiogram recorded before and after mitral valvulotomy or mitral valve replacement and one patient with obstruction of a Starr-Edwards prosthetic mitral valve. Eight patients had cardiac catheterization data obtained within a few days of the reference echocardiogram. Mitral valve areas were calculated using the Gorlin formula. The echocardiographic recordings of 25 randomly selected normal patients were reviewed for comparison.

All echocardiograms were recorded using a Smith Kline Ekoline 20A ultrasonoscope and Honeywell strip-chart recorder. The aorta, mitral valve and left ventricle were examined using standard techniques. Patients were examined in the supine or 30° left lateral position. The transducer was placed perpendicular to the chest wall at the interspace, usually left fourth, where the mitral valve echoes were best seen. To record the left ventricular posterior wall motion, the transducer was angled inferiorly and laterally to visualize the posterior left ventricular wall just below the level of the mitral valve leaflets, taking care to record the best endocardial echo. The movements of the posterior aortic wall were recorded by first identifying the mitral valve echo and then rotating the transducer medially and cephalad until the aorta and left atrium were identified. In addition to the usual measurements, the excursion of the posterior aortic wall in diastole was measured and left atrial emptying index was calculated by the method of Strunk et al. The slope of the posterior left ventricular wall motion was determined by constructing a line parallel to the maximum diastolic slope of the left ventricular wall (fig. 1). Values were average for 10 consecutive cardiac cycles.

Results

For normal subjects, the posterior left ventricular wall slope in diastole averaged 153 mm/sec (range 90–190 mm/sec). Twenty-one patients with mitral stenosis had reduced posterior left ventricular wall slope that averaged 66 mm/sec (range 41–101 mm/sec). A representative echocardiographic tracing of posterior wall motion for normal patients and those with mitral stenosis is shown in figure 2.

Values for the posterior left ventricular wall diastolic slope were compared with the left atrial emptying index developed by Strunk et al. (fig. 3). There is some correlation between these two indirect measurements of the severity of mitral stenosis (r = 0.56, p > 0.01). When the measurements of posterior left ventricular wall slope are arranged corresponding to left atrial emptying index of greater or less than 0.4, there is a somewhat better separation (fig. 4). The values for 25 normal subjects are included for comparison.

In eight patients with mitral stenosis, pulmonary capillary wedge pressure and left ventricular end-diastolic pressure were used to estimate mitral valve area (Gorlin formula). Comparison of the measured posterior left ventricular wall slope and the mitral valve area shows a direct correlation (r = 0.92, p = 0.01) (fig. 5). This correlation was not improved by correcting the left ventricular wall slope for left ventricular diastolic volume. Four of the five patients with calculated mitral valve areas of 1.1 cm² or less had a left atrial emptying index of less than 0.4.

Three patients with mitral stenosis had echocardiograms before and after either mitral valvulotomy (one patient) or porcine mitral valve replacement (two patients). The values for posterior left ventricular wall slope increased from an average of 52 mm/sec before surgery (range 51–54 mm/sec) to an average of 104 mm/sec after surgery (range 90–112 mm/sec) (fig. 6). The echocardiograms of one patient recorded before and after mitral valvulotomy are presented for comparison (fig. 7).

One patient with prosthetic tricuspid and mitral valves was suspected of having stenosis of the #4 Starr-Edwards mitral valve prosthesis (model 6320). The posterior left ventricular wall slope was reduced to 74 mm/sec, suggesting some reduction of left ventricular filling. Cineradiography showed a reduction in

FIGURE 1. Echocardiogram from a normal subject. The diastolic posterior left ventricular wall slope (mm/sec) is determined from a line drawn parallel to the maximum rate of change of posterior left ventricular wall motion in diastole (A-B). PLVW = posterior left ventricular wall; LV = left ventricle; IVS = interventricular septum.
the excursion of the mitral valve poppet, which did not reach the end of the cage in diastole. The excursion of the tricuspid valve poppet was normal (fig. 8). The calculated mitral valve area at the time of catheterization was 1.1 cm². This patient died before surgery and at autopsy there was evidence that the left ventricular muscle bundles had impinged on the prosthesis, preventing full opening of the poppet in diastole.

Discussion

The posterior left ventricular wall motion reflects changes in volume within the left ventricle. Since the posterior left ventricular wall is viewed echocardiographically from a single, fixed point on the chest wall, the slope of this posterior wall motion is affected to some extent by the overall swinging of the heart as well as intrinsic left ventricular wall motion. In normal subjects left ventricular filling is brisk and the slope of the posterior left ventricular wall in diastole is steep (average 153 mm/sec). In normal subjects and in those with mitral stenosis, the posterior left ventricular wall slope was not related to heart rate (range 52–130 beats/min).

Patients with pericardial constriction have very rapid initial filling of the left ventricle. This early rapid filling period is reflected echocardiographically by a very steep slope of the posterior left ventricular wall motion in diastole and then a subsequent flattening, suggesting that the left ventricular filling takes place in early diastole only.

Removal of the constriction restores more normal posterior left ventricular wall motion. Cardiac tamponade also restricts the filling of the left ventricle, but seems to do so throughout diastole so that the slope of the posterior left ventricular wall motion is slowed and prolonged. Some of the illustrative echocardiograms used to show the abnormal septal motion in patients with cardiac tamponade also show very slow diastolic posterior left ventricular wall slope, compatible with slow left ventricular filling. The change from a normal to a reduced posterior left ventricular wall slope in diastole has been shown by echocardiography during the development of acute pericardial tamponade.

Patients with mitral stenosis have slowed left ventricular filling, particularly in the first third of diastole, when left ventricular filling is normally most rapid. This slowed filling of the left ventricle is reflected on the echocardiogram as a reduced posterior left ventricular wall slope in diastole. The data comparing the posterior left ventricular wall slope with the calculated mitral valve area show that the posterior left ventricular wall slope is a good
predictor of the severity of mitral stenosis. Although only three patients with mitral stenosis were studied before and after surgery, the improvement in the posterior left ventricular wall slope after surgical relief of the mitral valve obstruction tends to confirm the value of this measurement.

The left atrial emptying index, derived from the echocardiographic tracing of the posterior aortic wall motion, has been suggested as a measure of the severity of mitral stenosis.\textsuperscript{4} Using the left atrial emptying index for comparison, those patients in this study with severe mitral stenosis (atrial emptying index less than 0.4) had a reduced mean posterior left ventricular wall slope in diastole (55 mm/sec) com-

**Figure 4.** Left ventricular wall slope in diastole (LVDS) and atrial emptying index (AEI) calculated after Strunk et al.\textsuperscript{3} AEI in normal subjects and those with severe (AEI < 0.4) and moderate (AEI > 0.4) mitral stenosis are shown. Open circles indicate sinus rhythm; closed circles, atrial fibrillation.

**Figure 5.** Comparison of the posterior left ventricular wall slope in diastole (LVDS) and the mitral valve area (MVA) in eight patients with mitral stenosis.

**Figure 6.** Posterior left ventricular wall motion in diastole (LVDS) before and after mitral valvulotomy (open circles) and porcine mitral valve replacement (closed circles).
pared with that of normal subjects (153 mm/sec). Those with less severe mitral stenosis (left atrial emptying index greater than 0.4) had a mean posterior left ventricular wall slope of 75 mm/sec.

Hall's study suggested that the left atrial emptying index may not be as helpful in predicting the severity of mitral stenosis as previously suggested. In his study of 18 patients with mitral stenosis, he could not find any correlation between the mitral valve area and the left atrial emptying index. However, in this same group of patients he could separate those with mitral stenosis from normal subjects on the basis of echocardiographically determined peak rate of increase in left ventricular dimension. The slope of the posterior left ventricular wall motion in diastole is a simple determination that may reflect the degree of mitral stenosis as accurately as more complicated estimates of the rate of ventricular volume change.

Factors other than mitral stenosis may affect the rate of left ventricular filling and alter the posterior left ventricular diastolic slope. Reduced left ventricular filling rates have been found in some patients with coronary artery disease and severe hypertrophic cardiomyopathy. Faster-than-normal left ventricular filling occurs in patients with diastolic volume overload, such as mitral regurgitation, aortic regurgitation and left-to-right intracardiac shunts, and these conditions might be expected to affect posterior left ventricular wall motion. If these conditions are excluded, the posterior left ventricular wall motion in diastole correlates with reduced left ventricular filling rate due to mitral stenosis.

The echocardiographic evaluation of patients with suspected prosthetic mitral valve obstruction is difficult. Although two-dimensional echocardiography appears to provide the most accurate assessment of mitral valve area, this technique is not useful for evaluating prosthetic valves because the prosthetic orifice may not be visualized. Other noninvasive techniques used to evaluate these patients include the echocardiographic assessment of the prosthetic annulus movement and the duration and variation of the S2 opening-click interval as determined by phonocardiography. The results of this study suggest that the rate of left ventricular filling, as reflected by
the posterior left ventricular wall slope in diastole, 
would reflect stenosis of the valve prosthesis and 
would be of some use in these patients, particularly if
an earlier study were available for comparison.

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