Abnormal Mitral Valve Motion in Patients with Elevated Left Ventricular Diastolic Pressures

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SUMMARY
In order to see whether or not the echocardiographically recorded mitral valve could reflect alterations in left ventricular pressure, simultaneous mitral valve echograms and left ventricular pressures were obtained on patients undergoing diagnostic cardiac catheterization. Attention was given to the left ventricular initial diastolic pressure (LVIDP), left ventricular end-diastolic pressure (LVEDP), and the atrial component of the left ventricular pressure (LVa). The echocardiographic measurements included the opening velocity of the mitral valve in early diastole (D-E slope) and the interval between the A point, which is the onset of closure of the mitral valve following atrial systole, and the C point, which represents closure of the mitral valve as indicated by the meeting of the anterior and posterior mitral leaflets. In order to compensate for variations in atrioventricular conduction, the A-C interval was subtracted from the electrocardiographic P-R interval. In 19 patients, the LVIDP was less than 14 mm Hg, the LVEDP was less than 20 mm Hg, and the LVa was less than 8 mm Hg. In these patients, the D-E slope was greater than 25 cm/sec and the PR-AC interval was greater than 0.08 sec. Six patients who had an LVIDP of 14 mm Hg or greater had a D-E slope of less than 25 cm/sec. There were 14 patients with an LVEDP greater than 20 mm Hg and an LVa of 8 mm Hg or greater. All of these patients had a PR-AC interval of less than 0.06 sec. There were an additional three patients who had an LVEDP above 20 mm Hg, but whose LVa was less than 8 mm Hg. In these three patients, the PR-AC interval was greater than 0.06 sec. Thus, the shortened PR-AC interval correlated primarily with an elevated LVa. This study indicates that the echocardiographic pattern of mitral valve motion is altered in patients who have markedly elevated left ventricular diastolic pressures.

Additional Indexing Words:
Left ventricular end-diastolic pressure
Left ventricular compliance
Echocardiography
Ultrasound cardiology
Mitral valve echograms

ECHOCARDIOGRAPHY permits a noninvasive means of recording mitral valve motion. The pattern of mitral valve motion has proved to be of value in the detection of mitral stenosis,1-4 hypertrophic subaortic stenosis,5,6 aortic insufficiency,7,8 and prolapsed mitral valve.9,10 An earlier study demonstrated that closure of the mitral valve was influenced by atrial contraction and relaxation.11 It was noted that motion of the mitral valve was a result of an interplay between left atrial and left ventricular pressures. Another study showed that closure of the mitral valve was interrupted in patients who had markedly elevated left ventricular end-diastolic pressures as a result of an increased atrial component to the left ventricular diastolic pressure.12 Other investigators noted premature closure of the mitral valve in patients with severe aortic insufficiency and markedly elevated left ventricular diastolic pressures.13 Some preliminary observations formed the basis of a theory that mitral valve motion was influenced by pressures on the left side of the heart.14 The purpose of this study was to evaluate further the relationship between mitral valve motion and left ventricular diastolic pressure.

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Received April 10, 1972; revision accepted for publication December 26, 1972.
Method

Echocardiograms were obtained of the anterior and posterior mitral valve leaflets together with simultaneous left ventricular pressures on 36 patients undergoing diagnostic cardiac catheterization. None of these patients had thickening or fibrosis of the mitral leaflets. The echograms were recorded utilizing a commercial echograph which had a repetition rate of 1,000/sec. The transducer had a half-inch crystal which was focused at 7.5 cm. The frequency rate was 2.25 MHz. Both the echocardiogram and the left ventricular pressures were recorded simultaneously on an Electronics for Medicine strip-chart recorder. A simultaneous electrocardiogram was also recorded. The mitral valve echogram was obtained in a fashion described in previous publications. The transducer position was adjusted in order to record the posterior as well as the anterior mitral leaflets.

On the left ventricular pressures particular attention was given to the left ventricular initial diastolic pressure (LVIDP), left ventricular end-diastolic pressure (LVEDP), and the atrial component of the left ventricular pressure (LVa) (fig. 1). The left ventricular pressures were recorded through a fluid-filled catheter. In some patients this recording system produced marked artifacts early in diastole and no measurement of LVIDP could be obtained. As a result there were fewer measurements of LVIDP than LVEDP, which was not influenced as much by the fluid-filled catheter. The echocardiographic measurements included the opening velocity of the mitral valve in early diastole (D-E slope) and the interval between the A point, which is the onset of closure of the mitral valve.

Figure 1

Simultaneous recording of left ventricular pressure, mitral valve echogram, and ECG. PR = interval between onset of electrocardiographic P wave and QRS; D-E = slope or velocity of opening of mitral valve in early diastole; AC = interval from onset to termination of mitral valve closure following atrial systole; LVa = amplitude of rise in left ventricular pressure following atrial systole; LVIDP = left ventricular initial diastolic pressure; LVEDP = left ventricular end-diastolic pressure.
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valve, and the termination of valve closure or C point, indicated by the meeting of the anterior and posterior mitral leaflets (fig. 1). Since the interval between the A and C points was a function of atrioventricular conduction, this interval was subtracted from the electrocardiographic P-R interval, which was measured from the onset of the P wave to the onset of the QRS. The PR-AC interval was compared with the left ventricular end-diastolic pressure (LVEDP) and the amplitude of the atrial component of the left ventricular diastolic pressure (LV\(A\)). The left ventricular initial diastolic pressure (LVIDP) was related to the D-E slope of the mitral valve.

Results

Figure 2 demonstrates a mitral valve echogram from a patient with low left ventricular diastolic pressures. The opening velocity of the valve (D-E slope) is rapid and the closing interval (A-C) is short and uninterrupted. The graph in figure 3 compares the D-E mitral slope with the LVIDP in

\[ \text{LVIDP > 12mm Hg} \]

\[ \text{LVIDP 12mm Hg OR LESS} \]

Graph comparing the opening velocity of the mitral valve with the left ventricular initial diastolic pressure (LVIDP).

Figure 2

Mitral valve echogram from a patient with low left ventricular diastolic pressures. The mitral opening velocity (D-E slope) is rapid, and mitral closure (A-C interval) is short and uninterrupted.
20 patients in whom satisfactory left ventricular pressures and mitral valve echograms were obtained. In 13 patients the LVIDP was less than 14 mm Hg and the D-E slope was greater than 25 cm/sec. In six patients the LVIDP was 14 mm Hg or greater and the D-E slope was less than 25 cm/sec. Figure 4 demonstrates the mitral valve echocardiogram of one of the patients with an elevated LVIDP. As noted, the D-E slope-opening velocity is diminished as compared with that demonstrated in figure 2. This patient also had an accentuated A wave which was present in four of the six patients with an elevated LVIDP. In this particular patient the mitral valve-opening velocity or D-E slope was 9.7 cm/sec; LVIDP was 32 mm Hg.

Figure 4
An echogram from a patient whose left ventricular initial diastolic pressure is 32 mm Hg. The opening velocity of her mitral valve is diminished and measures 9.7 cm/sec. An accentuated A wave is also present.
Figure 5 is a graph correlating the PR-AC interval with the LVEDP. There were 19 patients whose LVEDP was less than 20 mm Hg (black dots). All 19 patients had a PR-AC interval greater than 0.06 sec. Fourteen patients (triangles) had an LVEDP of 20 mm Hg or greater and had an LV\(_a\) greater than 8 mm Hg. In all 14 patients the PR-AC interval was 0.06 sec or less. There were three patients who had an LVEDP of 20 mm Hg or greater but whose LV\(_a\) was less than 8 mm Hg. In these patients the PR-AC interval was greater than 0.06 sec. Figure 6 is a mitral valve echocardiogram of a patient who had an LVEDP of greater than 20 mm Hg and LV\(_a\) greater than 8 mm Hg. The A-C interval was 0.14 sec. The P-R interval was 0.16 sec giving a PR-AC difference of 0.02 sec. Another characteristic finding was interruption of closure of the mitral valve with a plateau between the A and C points. This interrupted closure or plateau was noted in an earlier study\(^{12}\) and occurred in all but three of the patients who had an LV\(_a\) over 8 mm Hg.

Figure 7 is a diagram demonstrating the three types of valve motion noted in this study. The P-R interval of the electrocardiogram is constant. Figure 7A illustrates a simulated normal left ventricular pressure and a normal mitral valve echogram. Both the LVIDP and the LVEDP are low with a very small LV\(_a\). The opening mitral valve velocity, D-E slope, is rapid and the duration of closure of the mitral valve, A-C interval, is short and uninterrupted. In figure 7B the LVIDP is normal, however, the LVEDP is markedly elevated as a result of a large LV\(_a\). The opening velocity of the mitral valve remains normal; however, the distance between the onset and termination of mitral valve closure is prolonged. In addition, closure is interrupted as indicated by a plateau or notch between the A and C points. The diagram in figure 7C shows a left ventricular pressure with an elevated LVIDP. The LVEDP is also elevated, however, there is a relatively small LV\(_a\). The mitral valve opening velocity, D-E slope, is reduced. The amplitude of the A wave is increased, but the interval between the A and C points is normal.

**Discussion**

The observations made in this study are essentially empirical. However, there are some possible explanations for the relationship noted between the pattern of mitral valve motion and left ventricular function as reflected by the diastolic pressure. In the nondiseased, nonrestricted mitral valve, the pattern of motion should be influenced by the pressure gradient between the left atrium and left ventricle\(^{16}\) and by the amount of blood flowing through the mitral orifice. Even in the diseased, fibrotic mitral valve as occurs with mitral stenosis, the pattern of motion during diastole has proven to be a function of the pressure gradient as well as the flow through the mitral orifice.\(^4\) Pridie has demonstrated how a markedly elevated left ventricular diastolic pressure due to aortic insufficiency can close the mitral valve prematurely.\(^{13}\) Zaky demonstrated the relationship between closure of the mitral valve and changes in left atrial pressure following atrial systole.\(^{11}\) Thus, it should not be surprising to find a relationship between changes in left ventricular diastolic pressure and mitral valve motion.

Normally the left ventricular diastolic pressure is relatively low throughout diastole. The initial diastolic pressure is near 0 mm Hg. The left atrial pressure is only slightly higher than the left ventricular pressure since the mitral orifice is relatively large and presents very little if any obstruction to the flow of blood. With this very low initial diastolic ventricular pressure, blood flows very rapidly from the left atrium into the left ventricle, and the mitral valve literally flies open with a very fast D-E slope (fig. 7A). In patients with failing left ventricles, poor ejection fractions and high end-systolic volumes, the LVIDP may be quite elevated. With the onset of ventricular diastole, the blood from the left atrium must now flow into a chamber with a higher than normal pressure and the mitral valve may open at a slower rate (fig. 7C). This diminished velocity of valve
Figure 6

Echogram of a patient whose left ventricular end-diastolic pressure is elevated with an increased left atrial component. In addition to demonstrating an abnormal PR-AC interval, interruption to mitral closure is seen as a plateau between the A and C points.

opening and apparent diminished flow rate could be due, in part, to the high end-systolic volume. Although the left atrial filling pressure increases and the filling gradient remains normal, this large residual left ventricular volume might impede the flow of additional blood from the left atrium since the left ventricle may be reaching a point of reduced distensibility. It should be pointed out, however, that although none of the patients in this series had constrictive or restrictive heart disease, the initial left ventricular diastolic pressure is also usually elevated in these patients as a result of impaired ventricular filling. Whether or not the mitral D-E slope is abnormal in these patients remains to be seen.

It is interesting to note that most of the patients with a diminished D-E slope had a large atrial component to the mitral valve echogram. This
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Schematic diagram of the three different types of mitral valve motion demonstrated in this study. Also included are simulated simultaneous left ventricular (LV), left atrial (LA) pressures, and the ECG.15 (Courtesy of Lea and Febiger, Philadelphia.) See text for discussion.

finding suggests that with forceful atrial contraction the atrium is able to force more blood from the left atrium into the left ventricle. This finding is consistent with a preliminary observation suggesting that the distance between the anterior and posterior mitral leaflets is a function of mitral valve flow.17 If these observations are correct, then these patients seem to have a higher percentage of their mitral flow as a result of atrial systole. These patients theoretically would have a marked reduction in cardiac output were they to go into atrial fibrillation and lose their active atrial contraction.

Normally following atrial systole there is a slight rise in atrial pressure (fig. 7A). This elevated left atrial pressure reopens the mitral valve and forces blood from the left atrium into the left ventricle. As blood enters this normally compliant left ventricle, the chamber accepts this additional blood with relatively little change in pressure. With atrial relaxation the left atrial pressure begins to fall. Meanwhile the left ventricular pressure continues to rise gradually, and the left atrial pressure drops below the left ventricular pressure before ventricular systole. At this point the mitral valve begins to close. With ventricular systole there is a rapid rise in left ventricular pressure and the valve closes completely. The end result is a relatively short, uninterrupted closure of the mitral valve from its onset (A) to its termination (C) (fig. 7A).

Many patients have an elevated LVEDP as a result of a marked increase in left ventricular pressure following atrial systole (fig. 7B). These patients characteristically have diminished left ventricular compliance as a result of hypertrophy or fibrosis. These patients frequently have aortic stenosis, hypertension, or coronary artery disease. The end-systolic volume usually remains normal until overt heart failure ensues. As a result, LVIDP remains normal, and the D-E slope may remain normal (fig. 7B). There may or may not be some diminution in E-F slope of the mitral valve as blood flows into this poorly compliant ventricle. With atrial systole the left atrial pressure rises rapidly (fig. 7B). As blood is driven from the left atrium into the left ventricle, there is a rapid rise in left ventricular pressure. It parallels the rise in left atrial pressure and equalizes or exceeds the left atrial pressure earlier than normal. As a result, the mitral valve may be interrupted with a plateau in the mitral valve echogram. Closure of the mitral valve is completed with ventricular systole. The termination of mitral closure (point C, fig. 7B) frequently is delayed. It may take longer to generate the higher left ventricular pressure necessary to exceed the left atrial pressure and close the mitral valve. The end result of the earlier onset and delayed termination of mitral closure is prolongation of the AC interval.

It should be pointed out that the abnormal mitral valve motion occurred in patients with markedly abnormal left ventricular pressures (LVIDP > 13 mm Hg, LVEDP > 20 mm Hg). Obviously some patients may have abnormal left ventricles and elevated pressures, but the pressures may not be high enough to influence mitral valve motion. Thus the sensitivity of the echocardiographic technic remains to be seen. Nonetheless, the ability of the mitral valve echogram to reflect even gross changes in left ventricular diastolic pressure has obvious clinical implications since the left ventricular diastolic pressure has been an important measurement in the overall assessment of left ventricular performance. Thus despite the possible limitation of sensitivity these echocardiographic findings should be a valuable addition to the growing list of noninvasive methods for evaluating left ventricular function.

References

Circulation, Volume XLVII, May 1973
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Circulation. 1973;47:989-996
doi: 10.1161/01.CIR.47.5.989
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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