Idiopathic Prolapsed Mitral Leaflet Syndrome

Angiographic-Clinical Correlations

N. Ranganathan, M.B.B.S., M.D. Silver, M.D., Ph.D.,

T. I. Robinson, M.D., and J. K. Wilson, M.D.

SUMMARY Angiographic clinical correlations were made in 59 patients with prolapsed mitral leaflet syndrome. Eight had nonejection systolic clicks (group I), 20 had early, mid or late systolic murmurs with or without a systolic click (group II), and 31 had pansystolic murmurs (group III). Isolated prolapse of posterior leaflet (PL) scallops occurred in 42 and 17 had combined leaflet prolapse. The study demonstrated the following:

(I) Group II patients usually had isolated PL prolapse with a predominant biscallop involvement while a high incidence of triple scallop prolapse and combined mitral leaflet prolapse occurred in group III.

(II) Severe mitral regurgitation and a greater incidence of atrial fibrillation were seen in patients with triscallop prolapse and combined mitral leaflet prolapse. Mitral regurgitation was milder in patients with single and biscallop prolapse and, when severe, was associated with ruptured chords.

(III) ST-T wave abnormalities in the inferior leads were most frequent in patients with isolated PL prolapse.

(IV) Systolic and diastolic asynergy occurred in 41 patients, most frequently in group II but also relatively frequently in group III (19 of 31). Segmental anterior dysfunction with normal ejection fraction was found in 18 patients, of whom 13 had early anterior wall relaxation.

(V) Patients without asynergy were slightly older than those with it. More in the former group had severe mitral regurgitation and were clinically disabled from it.

MITRAL VALVE PROLAPSE, a commonly recognized clinical entity, has been the subject of many recent studies. It is now clear that the prolapse can be idiopathic or associated with a variety of underlying conditions such as Marfan's syndrome, rheumatic heart disease, congestive or hypertrophic obstructive cardiomyopathy, secundum atrial septal defect, as well as ischemic heart disease. Idiopathic prolapsed mitral leaflet syndrome (PMLS) presents a varied clinical spectrum ranging from patients with nonejection systolic clicks, with or without a mid-late systolic murmur, to those with a pansystolic murmur of pure isolated mitral regurgitation.

Echocardiography and left ventricular angiography are useful techniques for confirming mitral valve prolapse. In particular, left ventricular angiography is invaluable for the proper anatomic delineation of the mitral structures involved. The angiographic features of posterior leaflet (PL) prolapse, which is the most common, have been established previously. However, delineation of anterior leaflet prolapse has been hampered by the lack of good angiomorphic correlation studies. Once angiographic-morphological correlations are established, satisfactory clinical correlations with the angiographic abnormalities can then be made. This paper presents our observations on such correlations in 59 patients with PMLS, 17 of whom had combined anterior and posterior leaflet prolapse.

Methods and Materials

Fifty-nine patients with PMLS in whom the mitral prolapse was confirmed by left ventricular angiography were studied. They were divided into three clinical subgroups. Group I contained eight patients who presented primarily with a nonejection systolic click confined to mid-systole. Group II consisted of 20 individuals with an early (six patients), mid or late systolic murmur (14 patients) with or without a systolic click. Group III contained 31 patients who presented with a pansystolic murmur of mitral regurgitation without a click. All had diagnostic heart catheterization and left ventricular cineangiographic studies. Selective coronary arteriograms were also done in 50 patients. Significant coronary artery disease was documented only in two patients in both of whom coronary disease was considered an associated finding. Hemodynamic measurements were made just prior to angiography. Cardiac output was measured by the Fick method. Pressure recordings were made using a Honeywell multichannel photographic recorder. Left ventriculograms were taken in the right anterior oblique (RAO) projection; in 41 patients, they were also taken in the left anterior oblique (LAO) projection. The latter projection is useful in defining involvement of the anterior leaflet in the prolapse. The left ventriculograms were studied carefully with regard to the following features: (1) the degree and timing of mitral regurgitation; (2) the bulging leaflet, its location, the presence or absence of scalloping of its margin; (3) the time course of events related to the prolapse; and (4) the sequential changes in the left ventricular wall motion to define the location and incidence of leaflet prolapse.

The recording of ECG rhythm strips during angiography, with markers to indicate the onset and end of each injection, facilitated analysis of the left ventriculograms and calculation of the ejection fraction (EF) and percent axis shortening. For these quantitative measurements, only sinus beats that did not occur immediately following an extrastyle were analyzed. The left ventriculograms were projected on a screen of convenient size. The outlines of the left ventricular silhouette both in systole and diastole were traced and used to calculate EF and percent axis shortening. EF was calculated using the formula

\[ EF = 1 - \frac{(As)^2/Ld}{(Ad)^2/Ls} \]

where A is the planimetered area of the left ventricular outline, L is the measured long axis, and d and s refer to end-
diastole and end-systole, respectively. Axis shortening was measured along the longitudinal and transverse diameter as well as along the radii bisecting the angles between them (fig. 1). The normal values for percent axis shortening in our laboratory are very similar to those described by others. Of the three posterior axes, the posterobasal (PB) one could be overlapped by prolapsed postero medial commissural scallop (PMCS) leading to an understimation of shortening along this radius. Thus, more reliance was based on posteromedial axis measurements to assess posterior wall motion.

The normal PL is usually a triscalloped structure. Its prolapse causes a typical triscalloped bulge in the left ventriculogram, with a central bulge corresponding to the middle scallop (MS) and two lateral bulges to the respective commissural scallops. Combined mitral leaflet prolapse was diagnosed by the use of the additional LAO projection when a combination of scallops of the PL and the anterior leaflet were involved in the prolapse. Pathological specimens were available in 15 patients, six of whom had combined leaflet prolapse angiographically. Morphologically, the mitral valve leaflets and scallops were defined by delineating the position of specific chordae tendineae that inserted into the commissures or clefts in the PL. The angiographic and morphologic observations were made independently and subsequently correlated as described in a previous paper.

Results

1. Angiographic Assessment of Mitral Prolapse

Isolated Posterior Leaflet Prolapse

Forty-two of 59 patients had isolated PL prolapse (fig. 2A). This diagnosis was substantiated by morphologic correlation in nine, and in 24 of the 33 remaining patients by the left ventriculogram taken in the LAO projection. This projection throws the anterior mitral leaflet into relief as it opens and closes during each cardiac cycle. In diastole, it is well visualized hanging down from the aortic root to which it is attached, and separating the contrast-filled left ventricular outflow tract from the nonopacified blood entering the inflow tract (fig. 2B). It moves like a hinge door during each cardiac cycle with its fulcrum at the aortic root. In these 24 patients, it assumed its normal closed position during systole showing that it was not prolapsed (fig. 2C).

The onset of prolapse occurred very early in systole in 38 of the patients. The scalloped outlines of the bulging PL were continuous and had equal radiodensity in all 42. In addition, the scallops of the PL moved toward the left atrium simultaneously.

Of the 42 patients with PL prolapse, 17 had prolapse of all three scallops of the PL while 20 had biscallop prolapse. In the latter instance, the MS and PMCS were particularly involved. Of five patients with single scallop prolapse, four had prolapse of the PMCS and only one had MS involvement. Thus, prolapse of the PMCS appears to be an almost invariable finding whenever the PL is involved, followed closely in number by prolapse of the MS. This seems to be at variance with our previous observations in patients with severe mitral regurgitation, in whom the prolapse of MS was the most common. The difference is probably explained on the basis that the present study comprises all three groups of patients with PMLS.

Combined Prolapse of Mitral Leaflets

Seventeen patients had combined anterior and posterior mitral leaflet prolapse. A left ventriculogram taken in the LAO projection was available for confirmation in all of them. In each ventriculogram, the anterior mitral leaflet was identified quite easily in diastole separating the inflow and outflow tracts. When its motion was followed into systole, it bulged into the left atrium in all 17 patients instead of remaining at its normal closed position (figs. 3A and 3B compared to figs. 2B and 2C).

Review of the left ventriculogram taken in the LAO projection in these patients showed distinctive features not present in patients with isolated PL prolapse. These included a temporal dissociation between the prolapsing leaflets with the prolapsing PL scallops moving toward the left atrium first in systole, followed by a second bulge that appeared centrally overlapping the prolapsed middle scallop of the PL. This feature was present in all 17 patients. In eight of them, a distinct cleft of radiodensity, suggesting a discontinuity in outline between the prolapsing leaflets was seen (fig. 4A). The prolapsed anterior leaflet invariably overlapped the middle scallop region of the PL; thus when both leaflets prolapsed, the central bulge appeared to have increased radiodensity compared to the lateral bulges caused by the prolapsing commissural scallops of the PL. This sign was noted in four patients (fig. 5). During end systole, when both leaflets prolapsed, the scalloping of their margins became indistinct. This was observed in eight patients whereas none with isolated PL prolapse demonstrated this sign. Of these 17 patients with combined prolapse, 13 had biscallop prolapse of the PL and four had triscallop prolapse.

\[\text{EJEC\slash TION FRACTION} = 75\%\]

\[\begin{array}{ll}
\text{AXIS} & \text{NORMAL} \\
\text{AB} & 43\% (49 \pm 4) \\
\text{AM} & 43\% (58 \pm 4) \\
\text{AA} & 47\% (56 \pm 4) \\
\text{L} & 37\% (25 \pm 2) \\
\text{PA} & 41\% (53 \pm 4) \\
\text{PM} & 47\% (51 \pm 4) \\
\text{PB} & 7\% (28 \pm 5) \\
\end{array}\]

\text{FIGURE 1. Outline of end-systolic and end-diastolic frames from RAO left ventriculogram in one patient showing the reference axes that were used in quantitation of wall motion.} L = \text{long axis; AB, AM and AA represent anterobasal, medial and apical axes; PB, PM and PA represent posterobasal, medial and apical axes. Note PB shortening is underestimated because of prolapsed leaflet. Normal values for different axes shortening are as shown.}
Morphologic Observations and Angiographic Morphologic Correlation

Morphologic observations were made in six of the 17 patients with angiographically diagnosed combined anterior and posterior mitral leaflet prolapse. Five valves showed an abnormal, hooded anterior leaflet and similar changes in PL scallops providing evidence of their prolapse (figs. 4B and 5C). The sixth had the posteromedial half of the anterior leaflet thickened but not hooded.

Ruptured chordae were observed in three valves (to both leaflets in one, to the PL in one, and to the anterior leaflet in the third patient, fig. 4B) and two had an anomalous arrangement of their chordal insertions (fig. 5C). Histologically, one patient had severe myxomatous degeneration of the affected leaflets. The other five showed increased amounts of mucopolysaccharide material in the leaflet substance but the changes were not florid as in the first. In nine

Figure 2. A) Systolic frame from RAO left ventriculogram from a patient with isolated posterior leaflet prolapse showing triscalloped bulge (arrows). B) Diastolic frame from LAO left ventriculogram in the same patient showing anterior leaflet (AL) in open position separating the inflow from the contrast-filled outflow tract. C) Systolic frame in the same projection as B showing the normal closed position of AL. Arrows point to prolapsed posterior leaflet (PL).

Figure 3. Diastolic (A) and systolic (B) frames from LAO left ventriculogram of a patient with combined anterior (AL) and posterior (PL) mitral leaflet prolapse. AL, identified easily in the open position during diastole, is seen to prolapse into the left atrium during systole along with prolapsed scallops of PL. (C) RAO left ventriculogram in the same patient showing a central bulge as well as a posteroinferior bulge (both indicated by arrows). The former is caused by overlapping prolapse of the AL and middle scallop of PL. The posteroinferior bulge is a prolapsed posteromedial commissural scallop.
patients with PL prolapse, morphologic observations confirmed the angiographic assessment.\textsuperscript{a0} Myxomatous degeneration was noted in the affected scallops in the majority while a few showed increased amounts of acid mucopolysaccharide in the leaflet substance. Ruptured chordae tendineae were noted in seven, three of whom had documented infective endocarditis.

II. Angiographic Clinical Correlation

Relationship to Clinical Subgroup and the Degree of Mitral Regurgitation

Table 1 shows the angiographic clinical correlations. Its top portion relates the clinical subgroups and the degree of mitral regurgitation to the prolapsed leaflets. While isolated

\begin{table}
\centering
\caption{Clinical and Angiographic Correlation in Patients with Prolapsed Mitral Leaflet Syndrome}
\begin{tabular}{llllll}
\hline
 & PL prolapse (scallops) & & & & \\
 & Tri & Bi\textsuperscript{a} & Single & Total & Combined \\
\hline
No. of patients & 17 & 20 & 5 & 42 & 17 \\
M/F sex ratio & 8/9 & 9/11 & 2/3 & 19/23 & 10/7 \\
Age (mean) (yr) & 54 & 44 & 42 & 47 & 43 \\
Clinical subgroups & & & & & \\
I. 8 patients & 2 & 2 & 1 & 5 & 3 \\
II. 20 patients & 4 & 12 & 2 & 18 & 2 \\
III. 31 patients & 11 & 6 & 2 & 19 & 12 \\
Mitral regurgitation & & & & & \\
Mild & 1 & 13 & 2 & 16 & 2 \\
Moderate & 5 & 3 & - & 8 & 4 \\
Severe & 9 & 3 & 2 & 14 & 8 \\
Ruptured chordae & 3 & 2 & 1 & 6 & 3 \\
Symptoms and signs & & & & & \\
Syncope & 2 & 9 & 1 & 12 & 4 \\
Palpitation & 8 & 13 & 2 & 23 & 7 \\
Chest pain & 6 & 9 & 1 & 16 & 7 \\
Marfanoid features & 7 & 4 & 1 & 12 & 6 \\
Funct. class (NYHA) & & & & & \\
III or more & 9 & 2 & 1 & 12 & 6 \\
Cardiomegaly & 11 & 6 & 2 & 19 & 10 \\
Arrhythmias & 10 & 8 & 3 & 21 & 10 \\
Atrial fibrillation/flutter & 8 & 3 & 2 & 13 & 5 \\
SVT & - & 2 & 1 & 3 & 2 \\
V. fibrillation & - & 1 & - & 1 & - \\
VPBs & 4 & 4 & 1 & 9 & 1 \\
Abnormal ST-T in II, III, aVF & 5 & 9 & 1 & 15 & 1 \\
Prolonged QTc & 5 & 7 & 3 & 15 & 4 \\
\hline
\end{tabular}
\textsuperscript{a}Middle scallop + posteromedial commissural scallop. \\
Abbreviations: VPBs = Ventricular premature beats; SVT = Supraventricular tachycardia.
nonejection systolic clicks occurred irrespective of the leaflet involved, the presence of early, mid, or late systolic murmur with or without nonejection systolic click indicated isolated PL prolapse in the majority of patients (18 of 20 in group II). It is of interest that two patients who had combined mitral leaflet prolapse in this group were males with Marfan habitus. Seven patients had an early systolic murmur with intermittent click. All had PL prolapse (biscallop in five and single scallop in two). The mitral regurgitation was trivial in four and mild in three. The onset of prolapse occurred very early in systole with maximum systolic bulge reached in mid-systole.

Of the 13 patients with mid-late systolic murmurs (clicks in ten patients), triscallop prolapse was found in four patients, biscallop prolapse noted in seven and combined prolapse in two. The mitral regurgitation was moderate in three, mild in eight and trivial in two. All 13 patients also had an onset of prolapse very early in systole. However, the maximum prolapse occurred in mid-late systole. The sequence was the same whether or not a nonejection systolic click was associated with the murmur. Of 31 patients in group III with a pansystolic murmur, 19 had PL prolapse (11 with triscallop prolapse) and 12 had combined leaflet prolapse.

Twenty-two patients had severe mitral regurgitation. Of these, nine had triscallop prolapse of PL, and eight had combined leaflet prolapse. On the other hand, biscallop or single scallop prolapse of PL was generally associated with a milder degree of mitral regurgitation. Three of five patients in this group who had severe mitral regurgitation had ruptured chordae tendineae. One patient with isolated MS prolapse did not, however, have ruptured chordae and yet had severe mitral regurgitation.

Thus, triple scallop prolapse of the PL or prolapse of both leaflets is more often associated with more severe degrees of mitral regurgitation. Furthermore, a significant degree of
mitral regurgitation occurring in patients with single or biscallop prolapse probably indicates ruptured chordae to the affected scallops.

**Correlation of Symptoms and Signs**

The symptoms and signs are indicated in the mid-portion of table 1. There was no significant difference in the age and sex distribution of the patients with regard to the prolapsed leaflet, although in the combined leaflet prolapse group there were more males than females. Symptoms of syncope, palpitation, and chest pain were noted irrespective of the leaflets or of the scallops of the PL involved. However, the incidence of cardiomegaly and number of patients disabled from severe mitral regurgitation was higher in those with triscallop PL prolapse and/or combined mitral leaflet prolapse.

**Electrocardiographic Findings and the Incidence of Arrhythmias**

These are shown in the bottom portion of table 1. Patients presenting with triscallop PL prolapse and combined mitral leaflet prolapse had a high incidence of atrial fibrillation (11 of 17 patients). This arrhythmia seems to be related to the severity and duration of mitral regurgitation. The mitral regurgitation was severe in 12, moderate in four, and mild in only one patient. Ventricular extrasystoles and recurrent ventricular and supraventricular tachyarrhythmias were particularly noted in patients with PL prolapse, although they were also noted on occasion in patients with combined leaflet prolapse. Sixteen patients had syncope as a symptom in this series (one in group I, ten in group II and five in group III). Supraventricular tachycardia was present in three (one occurred after exercise). Frequent ventricular extrasystoles were noted in seven patients, of whom two had episodes of ventricular tachycardia. One of them had severe mitral regurgitation and biscallop prolapse of the PL and was being treated at the time for infective endocarditis caused by *streptococcus viridans*. While recovering satisfactorily from the endocarditis, however, the patient died in the hospital with a sudden cardiorespiratory arrest. The terminal arrhythmia was not documented. The second patient with recurrent ventricular tachycardia had moderate mitral regurgitation, with a late systolic murmur. She had two documented episodes of ventricular fibrillation requiring defibrillation. The control of the arrhythmia was eventually achieved with propranolol and procainamide. Selective coronary arteriograms were normal in this patient and her heart murmur dated back about 18 years. Of the remainder, one patient had second degree A-V block and one had bifascicular block, but in none of the remaining four could the symptoms be related to any significant arrhythmia or ECG abnormality.

**Left Ventricular Wall Motion Abnormalities**

Left ventricular wall motion studies revealed left ventricular wall asynergy in both systole and diastole in a number of patients. Two main types were recognized, the first occurring in systole, and the second in diastole (fig. 6). A typical sequence of events was easily observed in the majority of patients, especially those with PL prolapse. Quite early in systole, the PL was seen to prolapse and then, as systole progressed, the posterior and inferior walls of the left ventricle contracted quite strongly forming an arched contraction ring. This movement has been described previously and been called the "inferior contraction ring"29, 30 (figs. 6A-D). Subsequently, at the onset of diastole, and even before blood flowed from the left atrium to the left ventricle, the anterior wall of the left ventricle relaxed prematurely (figs. 6E, F), causing an early diastolic bulge to appear anteriorly and superiorly. This sequence of prolapse of the leaflet followed by an inferior contraction ring and later early relaxation of the anterior wall was seen in 15 patients. Left ventricular asynergy was observed in 41 of the 59 patients studied (table 2A). The highest incidence was in group II patients with early, mid or late systolic murmur, with or without a nonejection systolic click (17 of 20 patients). Asynergy was also noted in patients from the other two groups. Considering the two types of asynergy, early relaxation of the anterior wall appeared to be more common (37 patients) than inferior contraction ring (19 patients).

**Quantitative Measurements of Left Ventricular Function and Wall Motion**

The ejection fraction and percent axis shortening could be calculated from the left ventriculograms in 52 patients. A normal ejection fraction and normal axis shortening were noted in 19 patients of whom 16 had early anterior wall relaxation. Another 1/3 of the patients had a normal ejection fraction (EF > 55%), but had segmental dysfunction primarily located in the anterior wall (18 patients). (The mean values for percent shortening of anterobasal, anteromedial, and anteropapical axes were 30 ± 2.4, 34 ± 1.8, and 28 ± 2.6, respectively, compared to normal shown in fig. 1.) Thirteen of these had diastolic asynergy. Segmental dysfunction of the posterior wall (two patients) and generalized hypokinesis (five patients with mean EF < 45%) were rare. (The mean values for percent shortening of posterobasal, posteromedial and posterobasal axes were 39 ± 6.0, 28 ± 7.5, 13 ± 7.5. Normal values shown in fig. 1.) In table 2B, the quantitatively demonstrated left ventricular function is related to the clinical subgroups and the leaflets involved in the prolapse. Patients such as those in groups I and II, who generally had isolated prolapse of scallops of the PL, tended to have normal contractility and/or anterior wall segmental dysfunction. Among them, hyperkinetic contraction (EF > 85%) was only noted in five. A spectrum of left ventricular function was noted in group III patients with pansystolic murmurs. They had a higher incidence of anterior wall dysfunction, as did those with combined mitral leaflet prolapse. Of 18 patients with severe mitral regurgitation, five had a normal EF and contractility, six had anterior segmental dysfunction, one had posterior dysfunction, four had generalized hypokinesis and two had hyperkinetic contraction.

**Comparison of Clinical Features of Patients with and without Left Ventricular Asynergy**

These results are presented in table 3. The patients without left ventricular wall asynergy were slightly older (P < 0.05) than those with left ventricular asynergy. Moreover, more were clinically disabled from mitral regurgitation (10 of 19). All patients with an electrical
Sequential frames of RAO left ventriculogram from end diastole (A) through the phases of systole (B-C). D, E, and F represent sequential frames from end-systole through phases of early diastole, where E occurs about 50 msec and F about 66 msec after D. Prolapse of posterior leaflet (arrows) begins very early in systole (B) becoming maximal in end systole (D). A marked posteroinferior contraction is evident in B, C, and D. At the very onset of diastole even before inflow of blood occurs from the left atrium, there is premature relaxation of the anterior wall (white arrow).

TABLE 2.

A. Incidence of LV Wall Asynergy

<table>
<thead>
<tr>
<th>Clinical groups</th>
<th>Pts</th>
<th>Inferior contraction ring</th>
<th>Early anterior relaxation</th>
<th>Both</th>
<th>Overall incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>8</td>
<td>2</td>
<td>5</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>II</td>
<td>20</td>
<td>11</td>
<td>15</td>
<td>9</td>
<td>17</td>
</tr>
<tr>
<td>III</td>
<td>31</td>
<td>6</td>
<td>17</td>
<td>4</td>
<td>19</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leaflet prolapse</th>
<th>Posterior</th>
<th>Triscallop</th>
<th>Biscallop</th>
<th>Single scallop</th>
<th>Combined prolapse</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>17</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>11</td>
<td>14</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>4</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>17</td>
</tr>
</tbody>
</table>

B. Quantitative LV Function and Motion Related To Leaflet Prolapse and Clinical Findings

<table>
<thead>
<tr>
<th>Clinical groups</th>
<th>Normal</th>
<th>Segmental dysfunction</th>
<th>Generalized hypokinesis</th>
<th>Hyperkinesis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anterior</td>
<td>Posterior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>1</td>
<td>3</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>II</td>
<td>10</td>
<td>4</td>
<td>—</td>
<td>1</td>
</tr>
<tr>
<td>III</td>
<td>8</td>
<td>11</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leaflet prolapse</th>
<th>Posterior</th>
<th>Triscallop</th>
<th>Biscallop</th>
<th>Single scallop</th>
<th>Combined</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10</td>
<td>6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>6</td>
<td>—</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>—</td>
<td>—</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Downloaded from http://circ.ahajournals.org/ by guest on April 20, 2017
TABLE 3. Clinical Features

<table>
<thead>
<tr>
<th>No. Pts.</th>
<th>With LV asynergy</th>
<th>Without LV asynergy</th>
</tr>
</thead>
<tbody>
<tr>
<td>M/F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18/22</td>
<td>11/8</td>
<td></td>
</tr>
<tr>
<td>Age (mean)</td>
<td></td>
<td>44.9 ± 11.3 (P &lt; 0.05)</td>
</tr>
<tr>
<td>(range)</td>
<td>17–69</td>
<td>25–67</td>
</tr>
<tr>
<td>Chest pain</td>
<td></td>
<td>14 ± 9</td>
</tr>
<tr>
<td>Palpitation</td>
<td></td>
<td>20 ± 11</td>
</tr>
<tr>
<td>Syncpe</td>
<td></td>
<td>11 ± 5</td>
</tr>
<tr>
<td>Functional class</td>
<td></td>
<td>III or more: 8 ± 10</td>
</tr>
<tr>
<td>Marfanoid features</td>
<td></td>
<td>13 ± 6</td>
</tr>
</tbody>
</table>

ECG Findings

- ST-T changes in II, III, and aVF: 16 ± 10
- Prolonged QTc: 14 ± 5
- Arrhythmias: atrial fibrillation: 10 ± 8
- SVT: 3 ± 2
- Ventricular premature beats: 7 ± 3
- Ventricular fibrillation: 1 ± 1

**Hemodynamic and Angiographic Features**

- LA/PW (mm Hg): Mean ± SEM 12 ± 1.7 (P < 0.025)
- PA (mm Hg): Mean ± SEM 16.8 ± 1.7 (P < 0.05)
- LVED (mm Hg): Mean ± SEM 11 ± 0.9 (P < 0.05)
- Mitral regurgitation: Mild-moderate, 23 pts; Severe, 13 pts

Abbreviations: LA = left atrium; PW = pulmonary wedge; PA = pulmonary artery; LVED = left ventricular end-diastole; SVT = supraventricular tachycardia.

A repolarization abnormality in the inferior leads had mechanical asynergy. Finally, the hemodynamic findings demonstrated that patients without left ventricular wall asynergy had more severe mitral regurgitation.

**Discussion**

The idiopathic variety of PMLS presents an interesting and varied clinical spectrum. Rarely, prolapse has been recognized angiographically while remaining silent clinically. The clinical symptomatology also varies. Generally the symptoms are benign, but problems with disabling chest pain, arrhythmias that are sometimes serious, infective endocarditis, and severe mitral regurgitation have been encountered. Many recent angiographic studies have drawn attention to the presence and importance of a left ventricular wall motion abnormality in PMLS. However, few patients presenting with pansystolic murmurs and significant mitral regurgitation have been studied. Furthermore, no study has presented clinical correlations with the angiographic abnormalities. Probably this stems from the controversy and confusion relating to the angiographic recognition of anterior leaflet prolapse. However, this can be done accurately if left ventriculograms in the LAO projection are studied in addition to the usual RAO projection. Because the anterior leaflet overlaps the posterior leaflet in the RAO left ventriculogram, prolapse of the former could be hidden or missed if this projection alone was used. In contrast, the LAO projection clearly delineates the anterior leaflet. Other authors have used additional LAO projections and have not differentiated angiographic features of combined mitral leaflet prolapse from those of isolated PL prolapse. Also, few angiographic morphologic correlative studies have been done. In the LAO left ventriculogram, the anterior leaflet is well visualized in diastole hanging down from the aortic root to which it is attached. In systole, if it should prolapse, it moves into the left atrium, the fulcrum of its movement being at the aortic root. Using this additional view, we were able to identify involvement of both the anterior and posterior leaflet in 17 of 59 patients. Morphologic confirmation was obtained in five of six patients.

The RAO left ventriculograms in our patients with combined leaflet prolapse demonstrated certain distinctive features not noted in those with isolated PL prolapse. They were: 1) actual discontinuity in outline between the prolapsing anterior leaflet and the prolapsing scallops of the PL producing a cleft of radionegativity seen in eight patients; 2) a temporal dissociation between the bulging leaflets as to the time of maximal prolapse; and 3) the overlapping middle scallop and the anterior leaflet prolapse producing a denser central bulge compared to the less dense lateral bulges caused by the commissural scallop prolapse. These signs also depend upon good quality angiograms. Thus, while they are suggestive and suspicious, their absence may not entirely exclude the diagnosis. Thus, confirmation should always be sought by examining the LAO left ventriculogram.

The clinical correlates of the angiographic abnormalities established in this study have certain important implications. Although the prognosis and clinical course of PMLS is generally benign, a number of patients tend to develop more severe degrees of mitral regurgitation over a period of time. In some patients this occurs with development of ruptured chordae tendineae, either spontaneous or secondary to infective endocarditis. It would be useful if one could identify individuals at high risk of developing more severe degrees of mitral regurgitation. Anatomic correlates of severity of mitral regurgitation are of interest in this respect. Severe mitral regurgitation was seen most commonly in patients with triscallop PL prolapse and combined mitral leaflet prolapse (17 of 22), while patients with biscallop and single scallop PL prolapse had mild or moderate degrees of mitral regurgitation. If mitral regurgitation was severe in this group it seemed to be related to ruptured chordae tendineae (three of five patients). Isolated prolapse of PMCS appears to be entirely benign unless rupture of chordae supervenes which is not the case with isolated MS prolapse. One patient in this series and five others in a previous study had severe mitral regurgitation and isolated MS prolapse without rupture of chordae.

The auscultatory features of this syndrome have been intriguing. Since they tend to alter with changes in heart rate, contractility, preload and afterload, simultaneous phonocardiography and angiography are needed to establish meaningful correlation. The present study has been limited in this respect. However, it has shown that the prolapse of the posterior mitral leaflet has invariably a very early onset in systole irrespective of the timing of the murmur or the presence or absence of a click. Maximal prolapse, however, tends to occur about the middle of systole in patients with
early systolic murmur and toward mid-late systole in those with late systolic murmurs. The timing of the mitral regurgitation when well seen angiographically tends to correlate well with the timing of the murmur. The early onset of prolapse has been confirmed in echocardiographic studies of DeMaria and others who have demonstrated the most common abnormality in PMLS to be a pansystolic bowing of the mitral leaflets.20

That prolapse occurs early means either that the leaflets are redundant and the chordae tendineae are lengthened or there is asynchronous and delayed contraction of the papillary muscle and/or the underlying left ventricular myocardium. Pathological evidence exists for the former20,28 and angiographic abnormalities of left ventricular wall motion and segmental dysfunction support the latter.29-31 Thus, both factors may have a role. Several recent angiographic studies have shown abnormalities in left ventricular wall motion in this syndrome, although methodology has varied between investigators. Leachman considered the mitral annulus not only dilated but also expanded paradoxically during systole.24 His studies were done using anteroposterior projection. Grossman et al.25 and Ehlers et al.26 drew attention to the increased contraction of the mid-ventricular segment especially noted in the inferior wall. Liedtke et al. described decreased proximal ventricular segment shortening in nine patients with clinical findings of the systolic click syndrome, but only two had angiographic evidence of mitral valve prolapse.26 Scampondis and associates demonstrated several patterns of wall motion abnormality, both in systole and in diastole, in 75 of 87 patients with PMLS.26 Of these, the most frequently observed were those associated with the vigorous contraction of the posterior inferior portion and an early diastolic relaxation of the anterior wall. Our own observations suggest that myocardial asynergy is prevalent in 41 of the 59 patients studied. The incidence of early anterior wall relaxation was higher than the incidence of the inferior contraction ring. Although the incidence of left ventricular wall asynergy was high in patients with early, mid or late systolic murmurs with or without click, it was relatively frequent also in patients with pansystolic murmurs and significant mitral regurgitation (19 of 31). It was of interest that all patients who had inferior wall ST-T wave abnormalities in the electrocardiogram had mechanical asynergy demonstrated angiographically. Segmental early relaxation has been considered a normal phenomenon by some authors since it has been demonstrated in patients with chest pain and normally contracting ventricles with or without coronary artery disease.40 However, our observations of its occurrence in the region of segmental dysfunction is at variance with their findings (13 of 18 patients with anterior segmental dysfunction). Increasing severity of mitral regurgitation probably brings its own modification of the wall motion. This is suggested by the fact that patients without left ventricular asynergy appeared to be slightly older than those with it while more in the former group had severe mitral regurgitation (table 3).

The myocardial wall motion abnormality in this syndrome, its relationship to leaflet pathology, and its significance in terms of electrocardiographic findings and a high incidence of arrhythmias and chest pain have still to be defined exactly. Nutter et al., in a study of 26 patients who had only a small incidence of abnormal contraction pattern, considered the regional ventricular dysfunction secondary rather than primary with the basic defect in an abnormal mitral apparatus.29 While this may be true in some patients, our observations suggest that it does not apply to all of them.

In a separate experimental study, we have examined the problem of the relationship of left ventricular asynergy and pathological changes in the mitral valve leaflets and chordae tendineae by inducing thermal injury to the papillary muscles and the underlying left ventricular wall in ten dogs. All dogs had late postoperative left ventriculograms prior to their sacrifice and their mitral leaflets and chordae tendineae were analyzed for acid mucopolysaccharide content. The mitral leaflets of dogs that had normal ejection fraction and asynergy as assessed by the axis shortening measurement had a higher acid mucopolysaccharide content than those of the control dogs and the dogs that had decreased ejection fraction and generalized hypokinesis (P < 0.05) (unpublished observations).

Acknowledgment

The authors thank sincerely Miss Bette Birnie and Miss Susan Jackson for their assistance in the preparation of the manuscript, and Mrs. M. Lorber and the Staff of Medical Arts & Photography Department of St. Michael’s Hospital for their assistance in preparation of the illustrations.

References


---

**Mitral Valve Prolapse**

**Two-dimensional Echocardiographic and Angiographic Correlation**

**BRIAN W. GILBERT, M.D., F.R.C.P. (C),**

**RICHARD A. SCHATZ, OLA F. VON RAMM, PH.D.,**

**VICTOR S. BEHAR, M.D., AND JOSEPH A. KISSLO, M.D.**

**SUMMARY** In order to define baseline descriptive criteria for the diagnosis of mitral valve prolapse with cross-sectional echocardiography, 49 patients undergoing catheterization were examined by a real-time, two-dimensional phased array echocardiographic imaging system. Angiography was used to separate patients into two distinct groups: 15 with normal mitral valve function and 34 with definite mitral valve prolapse. Systolic mitral leaflet and annulus motion were then observed in each patient and similarities and differences were noted between the two groups of patients. Correlative M-mode echocardiographic data were available in 37 patients.

IN RECENT YEARS, conventional time-motion echocardiography has become widely accepted as a useful method for the detection of mitral valve prolapse. Despite this promising application, some investigators have expressed concern over the sensitivity and specificity of the time-motion echocardiographic criteria that define this entity.

Two-dimensional, or cross-sectional, echocardiography, because of its unique ability to provide spatial information regarding cardiac structures, shows promise for the accurate noninvasive detection of patients with the mitral valve prolapse syndrome. At the present time, however, there are no reasonable descriptive criteria for the diagnosis of mitral valve prolapse using this technique. Most importantly, there is no existing information regarding the two-dimensional echocardiographic-angiographic correlates observed in patients with mitral valve prolapse.

Certain two-dimensional echocardiographic findings restricted to the angiographically proven mitral valve prolapse group were defined: 1) posteriorly displaced coaptation of the leaflets, 2) systolic superior movement of one or both mitral leaflets above the level of the mitral ring, and 3) a systolic curling motion of the posterior mitral ring on its adjacent myocardium. One or more of these abnormalities were found in all 34 patients with angiographic mitral valve prolapse. When mitral valve prolapse does occur, the results of two-dimensional echocardiography would suggest that both leaflets are usually involved.

**Patients**

One hundred eighty-three consecutive patients underwent complete clinical, 2-D echo, and angiographic examination in a three-month period for the diagnosis of various forms of heart disease. Of these, 49 patients were selected for this study on the basis of catheterization. These patients had either normal mitral valve function or mitral valve prolapse on cineangiogram and had 2-D echoes suitable for the analysis of mitral leaflet motion throughout the cardiac cycle. Twenty-eight patients were catheterized specifically for...
Idiopathic prolapsed mitral leaflet syndrome. Angiographic-clinical correlations.
N Ranganathan, M D Silver, T I Robinson and J K Wilson

Circulation. 1976;54:707-716
doi: 10.1161/01.CIR.54.5.707

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1976 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/54/5/707