Cross-sectional Echocardiographic Study on the Mitral Valve Prolapse Associated with Secundum Atrial Septal Defect
— Pre- and post-operative comparison —

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Cross-sectional echocardiography was performed on 77 patients with secundum atrial septal defect (ASD). Mitral valve prolapse (MVP) was recognized in 41 out of the 77 (53.2%); anterior MVP was found in 36 patients, three cases revealed posterior MVP, and two were diagnosed as having both anterior and posterior MVP. Pre- and post-operative study was carried out on 53 cases; anterior MVP decreased in incidence from 28 patients to 17 following closure of ASD, whereas posterior MVP remained unchanged, as did both anterior and posterior MVP.

The left ventricular distortion ratio (LVDR) was measured in the short axis view in 45 cases. After the repair of ASD, the LVDR decreased both in end-systole and end-diastole (p < 0.01), that is, the left ventricle became more circular in configuration. Pre- and post-operatively, MVP patients revealed a significantly greater LVDR than those without it in end-systole, and post-operatively in end-diastole as well (p < 0.01). Prior to operation, the short axis area of the left ventricle (LVSAa) was statistically larger in patients with MVP than without it in end-diastole (p < 0.05).

However, there existed no relationship between the presence of MVP and the pulmonic to systemic flow ratio, right ventricular dimension index, right ventricular systolic pressure and size of ASD at the time of operation.

MITRAL valve prolapse (MVP) is a relatively common cardiac valvular abnormality. Since the initial descriptions of the time-motion echocardiographic appearance of this lesion by Shah and Dillon, echocardiography has become widely accepted as a useful tool for the detection of patients with MVP. Despite this promising application, several authors have expressed concern over the sensitivity and specificity of the M-mode echocardiographic criteria that define this entity.

Since its advent, cross-sectional echocardiography has shown promise for the accurate non-invasive detection of patients with MVP, because of its unique ability for spatial orientation of the cardiac structures. MVP has been reported to be frequently associated with secundum atrial septal defect (ASD). Gilbert and associates have re-
Fig. 1. Criteria of MVP on two-dimensional echocardiogram. The diagnosis was made by the systolic protrusion of one or both mitral leaflets into the left atrium above the mitral valve ring.
Abbreviations: AML = anterior mitral leaflet; PML = posterior mitral leaflet; MVP = mitral valve prolapse; LV = left ventricle; AV = aortic valve; LA = left atrium.

Fig. 2. Long axis view of the left ventricle in an 8-year-old female with anterior MVP associated with secundum ASD. The anterior mitral leaflet (AML) protrudes into the left atrium (LA) as indicated by a white arrow.
Abbreviations: RV = right ventricle; LV = left ventricle; IVS = interventricular septum; AV = aortic valve.

ported on the two-dimensional and angiographic correlations in MVP associated with ASD.

The purpose of the present study is: 1) to survey the prevalence of MVP in ASD using cross-sectional echocardiography; 2) to compare the incidence of MVP before and after surgical closure of the defect; and 3) to elucidate the mechanism responsible for the production of MVP from the standpoint of the anatomical distortion of the left ventricle.

METHODS

Cross-sectional echocardiography was carried out on 77 patients with secundum ASD. Twenty-eight were male and the remainder were female, ranging in age from three to 53 years. The diagnosis of ASD was made by cardiac catheterization in all patients. In 53 out of the 77 cases, the diagnosis was verified by surgical closure of ASD. And no residual shunt was noted after the operation.

Two-dimensional images were obtained approximately two weeks before and two to twelve weeks after operation using a Sonolayergraph of Toshiba with an electronic sector scanner (SSH-11A) or mechanical sector scanner (SSL-51H). The subjects were examined in the supine position.

The sweep of the cross-sectional probe was aligned with the scanning plane along the long and short axes of the left ventricle. An ordinary 35 mm camera and a commercially available 8 mm cinecamera were employed for the recording of the cross-sectional images.

Using 8 mm cinematography, the diagnosis of MVP was made by the systolic superior movement of one or both mitral valves into the left atrium above the mitral valve ring in the long axis view of the left ventricle\textsuperscript{5,7}.

Fig. 1 shows a schematic description of criteria of various types of MVP into the left atrium, anterior MVP, posterior MVP, and both anterior and posterior MVP.

RESULTS

Fig. 2 shows a long axis view of the left ventricle from an 8-year-old girl with secundum ASD (M.K.). The anterior mitral leaflet (AML) protrudes into the left atrium (LA) above the plane of the mitral valve ring. The white arrow indicates the prolapsed anterior mitral leaflet.

Fig. 3 presents long axis view from a 48-year-old female secundum ASD (K.H.). The posteromedial scallop (panel A) and the middle scallop (panel B) of the anterior mitral leaflet (AML) are prolapsed into the left atrium (LA) as indicated by arrows, whereas anterolateral scallop (panel C) shows no prolapse.

1. **Prevalence of MVP in ASD**

In order to survey the prevalence of MVP in ASD, two-dimensional images were obtained preoperatively from 77 patients with secundum ASD. Fig. 4 describes the prevalence and the age distribution of MVP in these patients. The MVP was detected in 40% of the 25 cases younger
than 10 years, 56% of the 16 teenagers, 40% of the 10 patients in their twenties, 69% of the 16 cases in their thirties and 70% of the 10 subjects older than 40 years. In total, 41 of the 77 patients (53.2%) revealed MVP on cross-sectional images along the long axis of the left ventricle.

In addition, the ASD patients older than 30 years showed a higher incidence of MVP than younger adults and children. Furthermore, 26 females out of the 77 patients showed MVP against 15 males.

2. Effect of surgical closure of ASD on MVP

Table I shows an incidence of MVP before and after the surgical repair of ASD in the pre- and post-operatively examined 53 patients. Prior to the closure of ASD, 33 out of the 53 cases revealed MVP on two-dimensional echocardiograms along the left ventricular long axis; the anterior mitral leaflet was prolapsed into the left atrium during systole beyond the mitral valve ring in 28 of the 33 patients, whereas the posterior mitral leaflet was prolapsed only in three instances. The remaining two revealed both anterior and posterior mitral valve prolapses.

Post-operatively, the incidence of MVP decreased to 41.3% from 62.1%; the anterior MVP disappeared in 11 out of the 28 patients, whereas the posterior MVP remained along with both anterior and posterior MVP.

3. Left ventricular distortion ratio and short axis area

Next, the left ventricular distortion ratio (LVDR) was obtained in the 45 patients from
TABLE 1 EFFECT OF CLOSURE OF ASD ON MVP

<table>
<thead>
<tr>
<th></th>
<th>Before Operation</th>
<th>After Operation</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Cases (%)</td>
<td>Cases (%)</td>
</tr>
<tr>
<td>MVP (+) AML</td>
<td>28 (52.8)</td>
<td>17 (32.0)</td>
</tr>
<tr>
<td>MVP (+) PML</td>
<td>3 (5.6)</td>
<td>3 (5.6)</td>
</tr>
<tr>
<td>MVP (+) AML + PML</td>
<td>2 (3.7)</td>
<td>2 (3.7)</td>
</tr>
<tr>
<td>Total</td>
<td>33 (62.1)</td>
<td>22 (41.3)</td>
</tr>
<tr>
<td>MVP (-)</td>
<td>20 (37.9)</td>
<td>31 (58.7)</td>
</tr>
</tbody>
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Pre- and post-operative study was carried out on 53 patients; anterior MVP disappeared in 11 cases following closure of ASD, whereas posterior MVP remained unchanged, similar to the cases of prolapse of both mitral leaflets.

Abbreviations: MVP (+) or (−) = presence or absence of mitral valve prolapse; AML = anterior mitral leaflet; PML = posterior mitral leaflet.

the cross-sectional echocardiograms along the left ventricular short axis both in end-systole and end-diastole. Fig. 5 shows a schematic description of the major (A) and minor (B) diameters in the short axis view of the left ventricle. The quotient A/B was defined as the left ventricular distortion ratio. Moreover, the shaded area described in Fig. 5 was also measured by planimetry using NAC Cardias 3500, and it was defined as the left ventricular short axis area (LVSSA).

Fig. 6 shows the short axis views of the left ventricle from a 38-year-old female with ASD (H. M.). Pre-operatively, panel A was recorded during diastole and panel B during systole. As shown in panel A, there is a diastolic flattening in the left

Fig. 5. Measurement of the left ventricular distortion ratio and short axis area. The major diameter A/the minor diameter B in the short axis view of the left ventricle was defined as the left ventricular distortion ratio (LVDR). Moreover, the shaded area was defined as the left ventricular short axis area (LVSSA).

Abbreviations: RV=right ventricle; IVS=interventricular septum; LV=left ventricle.

Fig. 6. Short axis views of the left ventricle from a 38-year-old female with anterior MVP with ASD (H.M.). In diastole (panel A), the left ventricle is markedly distorted, whereas in systole (panel B), it assumes a more circular configuration.

Abbreviations are the same as in Fig. 5.
ventricular contour without normal curvature of the interventricular septum. However, the systolic contraction leads to the formation of a relatively circular configuration in the short axis view as shown in panel B.

As shown in Fig. 7, the LVDR was pre-operatively $1.32 \pm 0.12$ and post-operatively $1.22 \pm 0.11$ in end-systole. In end-diastole, it was $1.39 \pm 0.16$ prior to operation and $1.27 \pm 0.18$ after operation. Following surgical correction of ASD, the LVDR significantly decreased in end-systole ($p < 0.01$) and in end-diastole as well ($p < 0.01$), that is, the left ventricle post-operatively became more circular in shape throughout the cardiac cycle.

Furthermore, Fig. 8 shows the relationship between the LVDR and the presence of MVP before and after the closure of ASD in the 45 cases. Pre-operatively, in end-systole, the ratio was $1.41 \pm 0.12$ in the 24 patients with MVP, whereas in 21 without MVP, it was $1.23 \pm 0.06$. There was a significant difference in the LVDR between those with and without MVP ($p < 0.01$). Post-operatively, the ratio was $1.30 \pm 0.12$ in 13 cases with MVP, and $1.19 \pm 0.08$ in 32 without MVP; the LVDR in patients with MVP was significantly greater than in those without MVP after operation.

In end-diastole, pre-operatively, there was no significant difference in the LVDR between the two groups of MVP (+) and MVP(−). In contrast, post-operatively, the ratio in 13 patients with MVP was $1.39 \pm 0.25$, but $1.22 \pm 0.12$ in 32 without MVP (Fig. 9). A significant difference was found between the two groups ($p < 0.01$).

Moreover, the short axis area of the left ventricle (LVSA) was obtained pre-operatively and corrected for the body surface area (BSA) in 45 ASD patients. In end-diastole, the left ventricular short axis area was closely related with the

*Fig. 8. In end-systole, there was a significantly greater LVDR in MVP patients than those without MVP before and after operation. Abbreviations: MVP (+) or (−)=presence or absence of mitral valve prolapse; LVDR=left ventricular distortion ratio.*
presence of MVP (p < 0.05); it was 8.7 ± 3.1 cm²/BSA in those with MVP, and 6.5 ± 2.7 cm²/BSA in the absence of MVP (Fig. 10). In contrast, there was no significant relationship between them in end-systole.

4. Right ventricular dimension index (RVDI)

The right ventricular dimension index was pre-operatively measured from M-mode echocardiogram and corrected for the body surface area in 43 patients. The RVDI in the MVP patients was 2.6 ± 0.8 cm²/BSA and 2.2 ± 0.6 cm²/BSA in those without MVP, respectively. There was no significant difference in the right ventricular dimension index between the two groups.

5. Catheterization findings and the size of ASD

The pulmonic to systemic flow ratio (Qp/Qs), right ventricular systolic pressure (RVSP) and the size of ASD at the time of operation were not related to the presence of MVP. Moreover, the LVDR had no relation to these parameters.

DISCUSSION

MVP was first reported to be frequently associated with secundum ASD by McDonald and others. Their descriptions were based on the angiographic studies and identified prolapse only in the posterior mitral leaflet. Victorica and associates also reported the association of anterior MVP with ASD. Moreover, Betriu reported a higher incidence of posterior mitral...
leaflet using left ventriculography. The discrepancy among these angiographic data of MVP is thought probably due to the difference in methods of X-ray projection.

In recent years, two-dimensional echocardiography has been shown to provide spatial orientation of cardiac structures and movement not readily available by conventional M-mode echocardiography. Gilbert and associates suggested that cross-sectional echocardiography may also be superior to angiography for the detection of certain types of mitral prolapse.

In the present study, the majority of the patients examined showed a prolapse of the anterior mitral leaflet, whereas the posterior leaflet was involved in only a limited number of patients. Because the anterior mitral leaflet has a greater height than the posterior leaflet, it is more easily observable in cross-sectional echocardiography. Despite the larger size of the anterior mitral valve, it is frequently difficult to define by angiography due to the superimposition on the opacified silhouette of the left ventricle.

In contrast, the posterior mitral leaflet is visualized to be short in the long axis view, and occasionally, the superior arching of the valve may be obscured by the swift up-and-down movement of the posterior mitral valve ring. However, the posterior mitral leaflet has a wider attachment to the atrioventricular ring than the anterior oblique projection by angiography. Furthermore, recent advances in axial cineangiography facilitate the detection of the MVP.

In order to fully visualize the prolapsed leaflets, the cross-sectional plane should be oriented toward the posteromedial to anterolateral scallops in addition to the middle portion of the mitral leaflets.

As for the age distribution of MVP, Yoshikawa and associates have already reported that adult patients revealed a higher incidence of MVP than children. In our series, we also noted the same tendency although neonates and senile patients older than 70 years were not included in this study for the lack of catheterization data. The higher prevalence of MVP in adults would be explained by an increase in the right ventricular overload.

The etiology of MVP has not been fully unraveled, but overwhelming evidence points to the myxomatous transformation of the mitral valve as the underlying pathology. In the presence of ASD, the left ventricular distortion is thought to be closely related to the production of the MVP.

In 1971, the right ventricular enlargement and abnormal movement of the interventricular septum have been recognized by Diamond et al as the characteristic findings. Meyer suggested that the mechanism of systolic anterior septal motion was related to dilatation of the right ventricular chamber and exaggerated anterior displacement of the main body of the left ventricle during systole. Furthermore, Hagan reported that the hinge or pivot point was either displaced downward or eliminated completely in patients with right ventricular volume overload.

Fukui and associates mentioned that the backward deviation in the interventricular septum in ASD is due to a right ventricular enlargement. Weyman reported that the interventricular septum was flattened at end-diastole in right ventricular volume overload and during systole returned to the normal, circular configuration. This change in left ventricular shape from diastole to systole resulted in the net motion of the interventricular septum toward the right ventricle.

Mirro and associates recently have reported on the clockwise rotation of the left ventricular body by measuring the angular displacement of the papillary muscles in ASD.

Schreiber and associates hypothesized that the abnormal left ventricular shape might affect the closure of the mitral valve, producing a pattern similar to MVP. They, therefore, related the degree of abnormal left ventricular shape or eccentricity by two-dimensional echo to MVP. Post-operatively, MVP was either decreased or abolished. Improvement in left ventricular geometry following ASD repair is accompanied by a decrease in the degree of MVP.

Similarly, in our study, we noted a significant relationship between the left ventricular distortion and the presence of MVP. In addition, the left ventricular deformity was markedly decreased following the surgical repair of ASD, resulting in the diminution in the incidence of anterior MVP. Thus, surgical intervention of ASD is thought to be beneficial for the patients with MVP.

Also, in the present study, the end-diastolic short axis area of the left ventricle was larger in patients with MVP than in those without it. As a result, it is concluded that the left ventricular distortion leads to inappropriate coaptation of mitral leaflets and may be one of the predisposing factors responsible for the production of MVP in secundum ASD.

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Thus, far, the prognosis for MVP has been regarded as good except for the associated mitral regurgitation or infective endocarditis. Our study was confined to patients examined shortly before and after operation. In order to survey the progression of MVP, it is of paramount importance to follow the course of abnormal mitral valve movement for years using cross-sectional echocardiography.

The advantage of this technique is that it can noninvasively repeat the real time observation of the mitral valve movements. Finally, cross-sectional echocardiography is thought to be a useful method for detecting MVP.

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