Mitral Valve Disease Complicated by Left-to-Right Shunt at Atrial Level

By Robert J. Marshall, M.D., M.R.C.P., and Herbert E. Warden, M.D., Ph.D.

The association of mitral stenosis with atrial septal defect (Lutembacher's syndrome) is well known but, when strict criteria of definition are applied, it is rare. For example, six, one, and no cases, respectively, were found in series of 2,000, 500, and 400 patients undergoing commissurotomy for mitral stenosis, and only two cases exist in the pathologic files of the Mayo Clinic. Green and Lambert were aware of only one case in the literature with adequate preoperative documentation by clinical and hemodynamic methods.

Mitr al regurgitation and an interatrial communication are two of the components of persistent common atrioventricular canal. We have been unable, however, to find a description of any adult patient with mitral regurgitation and a left-to-right shunt through a separate interatrial communication.

This paper describes clinical and hemodynamic features in two patients who had interatrial communications causing left-to-right shunts associated with severe acquired mitral stenosis and with severe congenital mitral regurgitation. The diagnoses were made at cardiac catheterization and confirmed at surgery. It is our belief that in both the interatrial communication was due to incompetence of the foramen ovale secondary to dilatation of the left atrium.

Case Reports

Case 1

A married woman age 31 years was admitted to West Virginia University Hospital on October 6, 1962. She gave a history of migratory arthralgia when aged 16 years and of quinsy when aged 23 years. For 6 months prior to admission, she noted increasing dyspnea on exertion, effort intolerance, and frequent chest colds; she had one episode of hemoptysis. On examination, there were accentuation of the first sound, an opening snap, and a rumbling diastolic murmur with presystolic accentuation in the mitral area. The pulmonary component of the second sound was increased. There were no basal murmurs. The electrocardiogram showed sinus tachycardia, evidence of left and right atrial enlargement, and incomplete right bundle-branch block. Fluoroscopy showed moderate enlargement of the left atrium and of the right ventricle, prominence of the main pul-

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mitral valve disease and atrial shunt

Table 1

Hemodynamic Data, Case 1

<table>
<thead>
<tr>
<th></th>
<th>Before operation</th>
<th>After operation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pressure (mm. Hg)</td>
<td>Per cent saturation</td>
</tr>
<tr>
<td>Superior vena cava</td>
<td>(4)</td>
<td>65</td>
</tr>
<tr>
<td>High right atrium</td>
<td>(4)</td>
<td>77</td>
</tr>
<tr>
<td>Mid right atrium</td>
<td>(4)</td>
<td>78</td>
</tr>
<tr>
<td>Low right atrium</td>
<td>(4)</td>
<td>79</td>
</tr>
<tr>
<td>Inferior vena cava</td>
<td>(4)</td>
<td>74</td>
</tr>
<tr>
<td>Right ventricle</td>
<td>40/0–3</td>
<td>81</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>40/20 (30)</td>
<td>81</td>
</tr>
<tr>
<td>Pulmonary artery wedge (right lung)</td>
<td>23/12 (17)†</td>
<td>97</td>
</tr>
<tr>
<td>Pulmonary artery wedge (left lung)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Femoral artery</td>
<td>105/66</td>
<td>95</td>
</tr>
<tr>
<td>Oxygen consumption (STP)†</td>
<td>240 ml. (index 133 ml.)</td>
<td>235 ml. (index 133 ml.)</td>
</tr>
<tr>
<td>Pulmonary blood flow</td>
<td>8.0 L./min. (index 4.4 L.)</td>
<td>5.1 L./min. (index 3.0 L.)</td>
</tr>
<tr>
<td>Systemic blood flow</td>
<td>4.7 L./min. (index 2.6 L.)</td>
<td>5.1 L./min. (index 3.0 L.)</td>
</tr>
<tr>
<td>Left-to-right shunt</td>
<td>3.3 L./min. (index 1.8 L.)</td>
<td>0</td>
</tr>
<tr>
<td>Pulmonary arteriolar resistance</td>
<td>130 dyne sec. cm.⁻⁵</td>
<td>80 dyne sec. cm.⁻⁵</td>
</tr>
<tr>
<td>Right ventricular stroke volume</td>
<td>80 ml. (index 44 ml.)</td>
<td>64 ml. (index 36 ml.)</td>
</tr>
<tr>
<td>Left ventricular stroke volume</td>
<td>47 ml. (index 26 ml.)</td>
<td>64 ml. (index 36 ml.)</td>
</tr>
</tbody>
</table>

* Three other series of saturations gave similar results.
† Prominent “a” wave.
‡ Standard temperature and pressure.

monary artery, and an inconspicuous aorta; pulmonary vascular markings were considerably increased, but Kerley lines were not seen.

At cardiac catheterization, the pulmonary artery wedge pressure was increased to 23/11 (mean 17) mm. Hg and the “a” wave was prominent (fig. 1a). This confirmed the diagnosis of mitral stenosis. In addition, measurements of oxygen saturation proved the existence of a left-to-right shunt at atrial level. Confirmation was provided by indicator-dilution curves (fig. 1a). The hemodynamic data are summarized in table 1.

Despite digitalization the heart rate remained rapid (110 to 120 per minute); the radioactive iodine uptake and the level of protein-bound iodine were normal. One month after the initial admission, the patient was found to have a systolic ejection murmur in the second and third left intercostal spaces. The dyspnea increased, the tachycardia persisted, and she had several spells of nocturnal orthopnea. She was readmitted on November 21, 1962. Operation was performed on November 27 with use of total cardiopulmonary bypass.

At operation the right atrium was distended and had an intense systolic thrill. A systolic thrill was also present over the pulmonary artery, and both artery and veins were moderately distended. There was a 1% by 1% cm. defect in the fossa ovalis. The atrial septum was incised from the margin of the defect toward the atrioventricular groove to permit access to the mitral valve. The annulus of the valve was of normal size and the leaflets were quite mobile; however, the free margins were rolled, thickened, and inelastic, the chordae tendineae were shortened, the commissures were fused, and the valve orifice just admitted the tip of the little finger (diameter 1 cm.). The valve was opened to a diameter of 4 cm, by means of a Tubbs dilator, and the interatrial communication was closed with horizontal mattress sutures of 3-0 arterial silk.

Following operation, the heart rate was 70 to 80 per minute; the electrocardiogram showed high nodal rhythm. Four days later atrial flutter appeared. Reversion to atrial fibrillation and sinus rhythm was achieved by additional doses of digitals and quinidine. On subsequent auscultation, a high-pitched musical systolic murmur was heard medial to the apex; the heart sounds were normal, and the opening snap and mitral diastolic murmur were inaudible at rest.

Cardiac catheterization was repeated on May 31, 1963 (table 1). The pressure in the pulmonary artery was normal, being 25/10 (mean 17) mm. Hg, and that in the pulmonary artery wedge was at the upper limit of normal, being 16/9 (mean 12) mm. Hg (fig. 1b). Indicator-dilution curves were also normal, confirming the absence of a left-to-right shunt and of significant mitral valve regurgitation (fig. 1b).

Case 2

A Negro girl aged 18 years was admitted to

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West Virginia University Hospital on August 4, 1962. At the age of 9 years she had an illness characterized by edema of the face and legs and was found to have an enlarged heart with loud murmurs; she was kept in bed for several months. There was no history suggestive of rheumatic fever. She complained of severe dyspnea on exertion for 10 days prior to admission, of orthopnea, and of cough accompanied by hemoptysis.

On examination, she was thin, anxious, and dyspneic. The jugular veins were distended to the angle of the jaw in the upright position and there were prominent “V” waves. The pulse was regular at 140 per minute and the blood pressure was 120/80 mm. Hg. There were moist rales at the bases of both lungs. The left side of the precordium was prominent due to enlargement of the heart. The apex was in the anterior axillary line, and there was a marked systolic thrill. There was a grade IV/IV pansystolic regurgitant murmur best heard in the mitral area and radiating widely over the entire precordium and also to the left scapula; there were also a prominent third heart sound and a faint diastolic rumble. The second sound was greatly accentuated in the pulmonary area and appeared normally split. There was a blowing early diastolic murmur along the left sternal border.

The electrocardiogram showed low voltage in the standard and unipolar limb leads; the P waves were prolonged and notched, there was an incomplete right bundle-branch block, and the QRS vector loop was clockwise in the frontal plane with a mean axis of +90°. The venous pressure was 25 cm. water and the arm-to-tongue circulation time (Decholin) was 26 seconds.

Fluoroscopy showed a greatly enlarged globular heart (fig. 2a). The enlargement appeared to involve all chambers. Pulmonary vascular markings were unusually prominent. Small effusions were noted at both lung bases and above them were Kerley lines. The diagnostic impression was rheumatic heart disease with regurgitation at the mitral, aortic, and tricuspid valves.

The findings at cardiac catheterization are summarized in table 2 and illustrated in figure 3a. The right atrial pressure was 24/14 (mean 18) mm. Hg, the conspicuous feature being a prominent “V” wave. The pulmonary artery pressure was 70/35 (mean 51) mm. Hg and the pulmonary artery wedge pressure was 33/21 (mean 27) mm. Hg, the “V” wave again being dominant. The diastolic pressure in the left ventricle was 18 to 30 mm. Hg; thus there was no significant diastolic pressure gradient across the mitral valve. Measurements of oxygen saturation proved the existence of a large left-to-right shunt at atrial level. An indicator-dilution curve showed severe distortion characteristic of the combination of (1) an arteriovenous shunt and (2) regurgitation at a valve between the injection site (pulmonary

![Figure 2](image_url)

*Figure 2*

X-ray films of the chest in case 2 before (left) and after (right) operation. Note decrease in the cardiac silhouette and in the degree of pulmonary vascular markings.
Table 2

Cardiac Catheterization Data, Case 2

<table>
<thead>
<tr>
<th></th>
<th>Before operation</th>
<th>After operation</th>
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</thead>
<tbody>
<tr>
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<td>Pressure (mm. Hg) Per cent saturation</td>
<td>Pressure (mm. Hg) Per cent saturation</td>
</tr>
<tr>
<td>Superior vena cava</td>
<td>24/12 (17)*</td>
<td>60</td>
</tr>
<tr>
<td>High right atrium</td>
<td>23/13 (17)*</td>
<td>69</td>
</tr>
<tr>
<td>Mid right atrium</td>
<td>(17)*</td>
<td>84</td>
</tr>
<tr>
<td>Low right atrium</td>
<td>(17)*</td>
<td>82</td>
</tr>
<tr>
<td>Inferior vena cava</td>
<td>(17)*</td>
<td>62</td>
</tr>
<tr>
<td>Right ventricle</td>
<td>72/15—24</td>
<td>83</td>
</tr>
<tr>
<td>Pulmonary artery</td>
<td>69/34 (50)</td>
<td>84</td>
</tr>
<tr>
<td>Pulmonary artery wedge (right lung)</td>
<td>(27)*</td>
<td>96</td>
</tr>
<tr>
<td>Pulmonary artery wedge (left lung)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Left ventricle</td>
<td>120/18—30</td>
<td>95</td>
</tr>
<tr>
<td>Ascending aorta</td>
<td>192/68 (84)</td>
<td>—</td>
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<td>Femoral artery</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>O₂ consumption (STP)‡</td>
<td>230 ml. (index 164 ml.)</td>
<td>215 ml. (154 ml.)</td>
</tr>
<tr>
<td>Pulmonary blood flow</td>
<td>9.8 L./min. (index 7.0 L.)</td>
<td>4.1 L./min. (index 3.0 L.)</td>
</tr>
<tr>
<td>Systemic blood flow</td>
<td>3.5 L./min. (index 2.5 L.)</td>
<td>4.1 L./m'n. (index 2.0 L.)</td>
</tr>
<tr>
<td>Left-to-right shunt</td>
<td>6.3 L./min. (index 4.5 L.)</td>
<td>0</td>
</tr>
<tr>
<td>Pulmonary arteriolar resistance</td>
<td>190 dyne sec. cm.⁵</td>
<td>250 dyne sec. cm.⁵</td>
</tr>
<tr>
<td>Right ventricular stroke volume</td>
<td>109 ml. (index 78 ml.)</td>
<td>50 ml. (index 36 ml.)</td>
</tr>
<tr>
<td>Left ventricular stroke volume</td>
<td>39 ml. (index 28 ml.)</td>
<td>50 ml. (index 36 ml.)</td>
</tr>
</tbody>
</table>

* “v” wave prominent.
† No dominant wave.
‡ Standard temperature and pressure.

Figure 3A

Case 2. Before operation. Above: pressures in right atrium and pulmonary artery wedge, with prominent “v” waves. Below: indicator-dilution curve with distortion due to combination of large left-to-right shunt and mitral regurgitation.
artery) and sampling site (left ventricle).

At this stage, the diagnosis rested between mitral regurgitation with left-to-right shunt at atrial level and left ventricle-right atrial canal. Persistent ostium atrioventriculare commune was unlikely because of the clockwise QRS vector loop. In order to decide between these two possibilities, and to assess the state of the aortic valve, selective angiocardiography was performed. An aortogram demonstrated competence of the aortic valve, absence of an aortic-cardiac shunt, and displacement of normal coronary arteries due to the cardiomegaly (fig. 4a). A left ventriculogram showed immediate filling of a huge left atrium; filling of the very large right atrium was less dense and slightly delayed (fig. 4b). There was also opacification of the pulmonary veins, and evidence of a moderate-sized pericardial effusion. These appearances established the diagnosis of mitral regurgitation and left-to-right shunt at atrial level.

At operation, the right atrium was severely enlarged and systolic thrills were palpable over both atria and the pulmonary artery. A 2 by 3 cm. opening was present in the fossa ovalis. The annulus of the mitral valve was dilated and three posterior chordae of the cusp were ruptured; the remaining chordae were elongated and redundant. The appearances did not suggest rheumatic disease. They were similar to those noted in mitral valve involvement in the Marfan syndrome. The atrial septum was incised at the upper and lower angles of the defect in order to provide adequate access to the left atrium. The anterior and posterior commissures of the mitral valve were plicated with silk sutures and the longest of the ruptured chordae was sutured to the posterior papillary muscle. On restoration of normal circulation it was clear that severe regurgitation persisted. Cardiopulmonary bypass was re-established and the left atrium was re-entered. The chorda, which had torn loose, was amputated, and the aortic cusp of the mitral valve was plicated in order to correct its redundancy. This resulted in some stenosis of the mitral valve orifice, which was now about 2 by 2 cm. The operation was tolerated well and convalescence was uneventful.

Postoperative x-ray films of the chest (fig. 2b) showed progressive diminution of heart size. The pansystolic murmur persisted but was less intense and unaccompanied by a thrill, the third sound was less pronounced, and the basal diastolic murmur was inaudible. The patient could sleep flat in bed and was free from dyspnea even on moderately severe exertion.

Cardiac catheterization confirmed the improve-

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**Figure 3B**

*Case 2. After operation. Above: pressures in right atrium, pulmonary artery wedge (right lung and lower lobe of left lung), and left ventricle (latter recorded at half sensitivity). Note the mild diastolic pressure gradient between the wedge (indirect left atrium) and the left ventricle resulting from mild stenosis produced during plastic repair of the mitral valve. Below: mild prolongation of the disappearance slope and increase in the CL/CR ratio (0.7) in the dilution curve, reflecting some persistent abnormality of the mitral valve.*
ment in hemodynamics (table 2 and fig. 3b). The right atrial pressure was 5/2 (mean 3) mm. Hg and the pulmonary artery pressure 38/18 (mean 26) mm. Hg. Pulmonary artery wedge pressure contours varied from site to site but the mean pressure in all three sites explored was 13 to 14 mm. Hg. There was an end-diastolic pressure gradient of 6 mm. Hg between the wedge and the left ventricle, reflecting mild mitral stenosis. Oxygen saturation data confirmed the absence of a shunt. A left ventriculogram showed no regurgitation into the left atrium. An indicator-dilution curve showed mild prolongation of the disappearance slope and a CL/CR ratio of 0.7, reflecting the persistent mitral valve lesion.

Discussion

When two congenital or acquired cardiac lesions coexist, the clinical and radiographic signs frequently reflect the predominant lesion, whereas evidence of the other is masked.

Case 1 provides an illustration of this principle. Initially the clinical signs and x-ray films of the chest were typical of uncomplicated severe mitral stenosis, although the incomplete right bundle-branch block raised the possibility of an associated left-to-right shunt at atrial level. After catheterization, an increasingly prominent ejection murmur was audible over the outflow portion of the right ventricle. This was interpreted as evidence for increasingly tight mitral stenosis, with a consequent increase in left atrial pressure and therefore in the magnitude of the left-to-right shunt.

At the preoperative study, the left-to-right shunt was calculated, both from oxygen saturation data and from the distortion of the indicator-dilution curve, to be about 40 per cent. The pulmonary artery wedge (indirect left atrial) pressure was 23/12 (mean 17) mm. Hg while the mean right atrial pressure was 4 mm. Hg. In patients with equally severe mitral stenosis and intact atrial septa, resting wedge pressures of about 30 mm. Hg are the rule. Thus, the interatrial communication was providing partial decompression of the left atrium. Further, the left atrium was less enlarged than is often the case in severe mitral stenosis.

The presence of an interatrial pressure gradient of 13 mm. Hg with only a moderate left-to-right shunt suggested that the defect must be small. This was confirmed at surgery. In patients with uncomplicated atrial septal defect, there is usually no demonstrable pressure gradient between the two atria, the direction of the shunt being determined by the greater distensibility of the right atrium\(^{11}\) and by the lesser resistance to filling of the right ventricle\(^{12,13}\) as compared with the left-sided chambers.

Wassermil and Hoffman\(^{14}\) recently described a patient with mitral stenosis who had an intact atrial septum but partial anomalous
pulmonary venous connection to the superior vena cava. The pulmonary artery wedge pressure (presumably in a portion of lung drained by normally connected veins) was 24 mm Hg, while the right atrial pressure was 5 mm Hg. They concluded that the finding of an increased wedge pressure in a patient with mitral stenosis and with arterialization at atrial level should favor diagnosis of partial anomalous venous drainage rather than an atrial septal defect, since the latter should lead to equalization of pressures in the two atria (and hence in the wedge). It is clear from case 1 of the present report, however, that the distinction cannot be absolute; the presence or absence of a pressure gradient between the atria depends on the size of the defect. In the case of Rapaport et al.,15 both an atrial septal defect and partial anomalous pulmonary venous connection were present.

Debate about the “protective” role of the septal defect4 appears to be of academic interest only. Although the shunt helps to “decompress” the left atrium, it does so at the expense of increasing the pulmonary blood flow. Early suggestions that the prognosis of mitral stenosis is better when a shunt is also present have not been confirmed.

The postoperative catheterization in case 1 provided objective support for the clinical improvement; there was no left-to-right shunt and the pulmonary artery wedge pressure was at the upper limit of normal.

In case 2, the clinical findings were interpreted as those of mitral and tricuspid regurgitation with congestive heart failure; the basal diastolic murmur could have represented either aortic or pulmonary regurgitation. An associated shunt was not suspected. Catheterization confirmed severe mitral regurgitation and demonstrated a large left-to-right shunt at atrial level. Reasons for making a diagnosis of mitral regurgitation with atrial septal defect rather than of atrioventricular canal defect or of left ventricle-right atrium canal have already been discussed. The globular cardiac silhouette was due to the presence of a pericardial effusion in addition to enlargement of all four cardiac chambers.

At operation the regurgitation was found to be due mainly to ruptured chordae tendineae. The reason for the rupture was not clear, since there was no history of trauma and no evidence of rheumatic disease or of healed bacterial endocarditis. However, the appearance of the entire valve was abnormal, being similar to valves that we have observed at operation in two patients with the Marfan syndrome and mitral regurgitation. A similar mesenchymal defect may have been responsible.

In both patients the interatrial communication was situated in the fossa ovalis. It appeared to have resulted from stretching of the margins of the foramen ovale as the left atrium became enlarged rather than to be a true atrial septal defect. It will be recalled that in about 25 per cent of persons the foramen ovale fails to become sealed off, and remains as a potential communication between the atria.8 Conditions such as valvular pulmonary stenosis, idiopathic pulmonary hypertension, and pulmonary embolism, which cause increased pressure in the right heart chambers therefore are sometimes complicated by a right-to-left shunt through an incompetent foramen ovale. Hence, it appears reasonable to expect that conditions such as mitral stenosis and mitral regurgitation, which lead to increased pressure in the left atrium and to considerable stretching of its walls, could become complicated by left-to-right shunting through an incompetent foramen ovale. In fact, evidence for left-to-right shunting of blood through an incompetent foramen ovale has been found at necropsy in some infants with mitral and aortic atresia.16 To our knowledge, the cases described here provide the first evidence of this mechanism in adults with obstructive or regurgitant lesions of the mitral valve.

**Summary**

The clinical features and the changes in hemodynamics are described before and after operation in two patients with mitral valve disease associated with left-to-right shunt at atrial level.

The first patient had severe rheumatic mitral stenosis, which masked the associated moder-
ate shunt. Since the interatrial communication was small, there was a moderate gradient in pressure between the two atria. Thus, the finding of an elevated left atrial or pulmonary artery wedge pressure in a patient with mitral stenosis and an increase in the saturation of blood at atrial level does not eliminate the possibility of a small interatrial communication.

The second patient had severe mitral regurgitation due to a structurally abnormal valve with ruptured chordae tendineae, and had also functional pulmonary and tricuspid valve regurgitation. These lesions also masked the associated large left-to-right shunt. Electrocardiographic and angiocardiographic criteria were used to exclude the possibilities of persistent atioventricular canal defect and of left ventricle-right atrium shunt.

After operation, cardiac catheterization demonstrated a return of the hemodynamic changes toward normal in both patients. There was also a striking clinical improvement.

In both, the interatrial communication was situated in the fossa ovalis. It appeared to be a foramen ovale that had become patent due to stretching of the walls of the left atrium, rather than a true atrial septal defect. Although left-to-right shunting may occur through a patent foramen ovale in infants with mitral or aortic valve atresia, we are unaware of previous hemodynamic or surgical evidence of a similar phenomenon developing as a consequence of severe mitral valve disease in adults.

**ADDENDUM**

Since this paper was submitted for publication, Ross et al. (Circulation 28: 853, 1963) described three patients with mitral stenosis or atresia associated with very small interatrial communications, all of whom had a continuous murmur due to persistence of an interatrial pressure gradient throughout the cardiac cycle. Burchell (Circulation 28: 1153, 1963) described a patient with mitral stenosis and valve-incompetent foramen ovale who at operation had a continuous thrill over the right atrium, and also a patient with mitral regurgitation due to ruptured chordae tendineae associated with a valve-incompetent foramen ovale. Acar and Plainfossé (Coeur med. int. 2: 447, 1963) have also emphasized that there may be a continuous pressure gradient when an interatrial communication complicating mitral stenosis is small.

**References**

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