Isolated Congenital Mitral Insufficiency with Particular Reference to Left Heart Volumes

By Graham A. H. Miller, B.M., B.Sc., Richard Brown, M.D., and H. J. C. Swan, M.B.

Mitral insufficiency is well recognized in association with certain congenital cardiac anomalies. Reports of congenital mitral insufficiency as an isolated anomaly, however, are rare; 1-3 a review of the literature reveals only 20 such cases. The pathologic anatomy of the condition has been described by Edwards and Burchell.4

This report concerns clinical, hemodynamic, and angiocardiographic findings in seven patients in whom the age of onset and the absence of a history of carditis indicate isolated congenital mitral insufficiency. In each of the cases reported here, left ventricular angiograms were made. The volumes of the left atrium and ventricle were calculated according to the method of Arvidsson,5 and the degree of regurgitation has been quantitated. Absolute measurement of chamber volumes and regurgitant flow extends significantly the description of the hemodynamics in such conditions and allows for more meaningful interpretation of the criteria used for diagnostic purposes.

Methods

Cardiac Catheterization

Cardiac catheterization was performed as described by Wood and Swan6 with premedication as described by Moffitt and associates.7 The right axillary vein and artery were isolated under local anesthesia. The left ventricle was entered by passing the catheter retrograde through the aortic valve from the axillary artery. Calculations of the Ry/v ratio were made from the wedged pulmonary artery tracings according to the method of Owen and Wood.8

Angiocardiography

During angiocardiography, patients were anesthetized with nitrous oxide and oxygen. Halothane, in concentrations of less than 1 per cent, was used for brief periods. In all cases, 100 per cent oxygen was administered for at least 60 seconds prior to angiocardiography. Contrast medium—sodium and methylglucamine diatrizoate (Renovist), 1.3 to 1.7 ml. per Kg.—was injected mechanically through a no. 6, 7, or 8 Rodriguez catheter in 0.9 to 3.4 seconds. The injection was made into the sinus of the left ventricle in each case, but an additional angiogram was made with injection into the right ventricle in case 7. Simultaneous anteroposterior and lateral exposures were made at six frames per second during left heart opacification, with a roll-film or cut-film changer.9 The electrocardiogram, arterial pressure, and the time of x-ray exposures were recorded simultaneously to permit correlation of the radiographic appearance with the events of the cardiac cycle.

Measurements of Angiocardiograms for Calculation of Volumes

Only those films showing complete opacification of the left ventricle were measured. Measurements were made as indicated in figure 1, and read to the nearest 1 mm. Estimation of chamber volume was carried out by the method of Arvidsson.5 The volume of the left atrium (V1a) is

\[ V_{1a} = \frac{a}{f_1} \times \frac{b}{f_2} \times \frac{c}{f_3} \times 4 \pi \]

and of the left ventricle (V1v) is

\[ V_{1v} = \frac{1}{2} \times \frac{L}{2f_1} \times \frac{B}{2f_2} \times \frac{C}{2f_3} \times 4 \pi \]

where L, the true long axis of the ventricular ellipsoid, is

\[ L = \sqrt{\left(\frac{D \cos \beta}{f_2}\right)^2 + \left(\frac{A}{f_1}\right)^2} \]

and f1 and f2 are the anteroposterior and lateral


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Figure 1
Paired angiograms (anteroposterior and lateral projections). Calculations of heart volumes are made from the dimensions indicated on the line drawings. Lowercase symbols refer to semi-axes and uppercase symbols to axes.

Figure 2
a. Example of left ventricular (solid circles) and atrial (open circles) volumes calculated from paired angiographic exposures plotted in sequence during three cardiac cycles (case 7, angiogram made with injection into main pulmonary artery). b. Composite left ventricular (solid circles) and atrial (open circles) volumes plotted against time expressed in fractions of a second after the R wave of the electrocardiogram. Constructed from the data in a.

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### Table 1

**Summary of Clinical Findings**

<table>
<thead>
<tr>
<th>Clinical history</th>
<th>Case</th>
</tr>
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<tbody>
<tr>
<td>Age</td>
<td>1</td>
</tr>
<tr>
<td>9 yr.</td>
<td>5½ yr.</td>
</tr>
<tr>
<td>Sex</td>
<td>M</td>
</tr>
<tr>
<td>Age at onset of exercise intolerance</td>
<td>3 yr.</td>
</tr>
<tr>
<td>Age when murmur first detected</td>
<td>3 yr.</td>
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<td>Physical examination</td>
<td></td>
</tr>
<tr>
<td>Height, percentile₀²</td>
<td>&lt;3</td>
</tr>
<tr>
<td>Weight, percentile₀²</td>
<td>Edema</td>
</tr>
<tr>
<td>Apical systolic thrill</td>
<td>+</td>
</tr>
<tr>
<td>Pulmonic valve closure</td>
<td>Accentuated</td>
</tr>
<tr>
<td>Pansystolic murmur</td>
<td>Grade</td>
</tr>
<tr>
<td>Position</td>
<td>Apex</td>
</tr>
<tr>
<td>Transmission</td>
<td>Axilla</td>
</tr>
<tr>
<td>Mid-diastolic murmur, position</td>
<td>Apex</td>
</tr>
<tr>
<td>Thoracic roentgenogram</td>
<td></td>
</tr>
<tr>
<td>Cardiokoracic ratio</td>
<td>0.82</td>
</tr>
<tr>
<td>Enlargement of pulmonary artery</td>
<td>+</td>
</tr>
<tr>
<td>Enlargement of left atrium</td>
<td>+</td>
</tr>
<tr>
<td>Electrocardiogram</td>
<td></td>
</tr>
<tr>
<td>Rhythm</td>
<td>Atrial fibrillation</td>
</tr>
<tr>
<td>AQRS, degrees</td>
<td>+120</td>
</tr>
<tr>
<td>Left atrial enlargement</td>
<td>+</td>
</tr>
<tr>
<td>Left ventricular hypertrophy</td>
<td>+</td>
</tr>
<tr>
<td>Remarks</td>
<td>Heart surgery*</td>
</tr>
</tbody>
</table>

* Cardiomyotomy by Dr. J. W. Kirklin; attempted replacement of mitral and tricuspid valves by Starr-Edwards ball valve prostheses.
† Cardiomyotomy by Dr. D. C. McCoon was successful in the repair of a cleft of the anterior mitral valve leaflet.
‡ Electrocardiogram showed inverted T waves in leads II, III, and aV<sub>6</sub>, and slight elevation of the ST segment in V<sub>6</sub>. 
### Summary of Hemodynamic and Volume Data

<table>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>Normal*</th>
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<tr>
<td><strong>Surface area, M.²</strong></td>
<td>0.87</td>
<td>0.73</td>
<td>1.02</td>
<td>0.85</td>
<td>0.74</td>
<td>1.10</td>
<td>0.72</td>
<td>–</td>
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<tr>
<td><strong>Cardiac output, L./min./M.²</strong> (awake)</td>
<td>2.9</td>
<td>3.6</td>
<td>3.7</td>
<td>4.4</td>
<td>3.8</td>
<td>3.6</td>
<td>3.6</td>
<td>–</td>
</tr>
<tr>
<td><strong>Pressures, mm. Hg:</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>Left ventricle</td>
<td>115/10-30</td>
<td>110/10-13</td>
<td>110/12</td>
<td>100/5-11</td>
<td>90/6-10</td>
<td>104/10</td>
<td>90/7</td>
<td>–</td>
</tr>
<tr>
<td>Pulmonary artery wedge</td>
<td>–</td>
<td>32/20</td>
<td>18/11</td>
<td>13/7</td>
<td>15/10</td>
<td>12/4</td>
<td>14/9</td>
<td>–</td>
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<tr>
<td>Pulmonary artery</td>
<td>125/60</td>
<td>38/24</td>
<td>32/19</td>
<td>22/7</td>
<td>25/15</td>
<td>18/5</td>
<td>30/10</td>
<td>–</td>
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<tr>
<td><strong>Pulmonary resistances, units/M.²:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>6.5</td>
<td>6.3</td>
<td>2.7</td>
<td>4.8</td>
<td>2.6</td>
<td>4.6</td>
<td>–</td>
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<tr>
<td>Vascular</td>
<td>–</td>
<td>2.4</td>
<td>2.5</td>
<td>0.45</td>
<td>1.7</td>
<td>0.35</td>
<td>1.8</td>
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<tr>
<td><strong>Regurgitation indices:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>Ry/Vt</td>
<td>–</td>
<td>4.3</td>
<td>–</td>
<td>2.2</td>
<td>1.6</td>
<td>3.5</td>
<td>3.07</td>
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<tr>
<td>C₁₁/R₁₁</td>
<td>0.68</td>
<td>&gt;1.0</td>
<td>0.36</td>
<td>0.33</td>
<td>0.35</td>
<td>0.26</td>
<td>0.44</td>
<td>–</td>
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<tr>
<td><strong>Volumes from angiocardio-gram, ml./M.²:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
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<tr>
<td>Left atrium, maximum</td>
<td>170</td>
<td>573</td>
<td>–</td>
<td>71</td>
<td>55</td>
<td>–</td>
<td>90</td>
<td>24 ± 4.7</td>
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<tr>
<td>Left atrium, minimum</td>
<td>78</td>
<td>319</td>
<td>–</td>
<td>21</td>
<td>22</td>
<td>–</td>
<td>67</td>
<td>12 ± 4.2</td>
</tr>
<tr>
<td>Change in volume, ml./M.²</td>
<td>92</td>
<td>254</td>
<td>–</td>
<td>50</td>
<td>33</td>
<td>–</td>
<td>23</td>
<td>12 –</td>
</tr>
<tr>
<td>Change in volume, per cent</td>
<td>46</td>
<td>44</td>
<td>–</td>
<td>70</td>
<td>60</td>
<td>–</td>
<td>26</td>
<td>50 ± 14.7</td>
</tr>
<tr>
<td>Left ventricle:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>Vₑₑ</td>
<td>320</td>
<td>367</td>
<td>147</td>
<td>149</td>
<td>130</td>
<td>132</td>
<td>171</td>
<td>85 ± 11.7</td>
</tr>
<tr>
<td>Vₑₑ</td>
<td>132</td>
<td>131</td>
<td>61</td>
<td>55</td>
<td>49</td>
<td>66</td>
<td>74</td>
<td>28 ± 8.8</td>
</tr>
<tr>
<td>Vₑₑ⁻⁻⁻⁻⁻⁻⁻ Vₑₑ</td>
<td>188</td>
<td>236</td>
<td>86</td>
<td>94</td>
<td>81</td>
<td>66</td>
<td>97</td>
<td>56 ± 8.9</td>
</tr>
<tr>
<td>Vₑₑ</td>
<td>181</td>
<td>231</td>
<td>80</td>
<td>86</td>
<td>72</td>
<td>59</td>
<td>88</td>
<td>49 –</td>
</tr>
<tr>
<td>Vₑₑ⁻⁻⁻⁻⁻⁻⁻ as per cent of Vₑₑ</td>
<td>59</td>
<td>64</td>
<td>59</td>
<td>63</td>
<td>62</td>
<td>50</td>
<td>57</td>
<td>67 ± 8.2</td>
</tr>
<tr>
<td>Stroke volume, SV, from dye dilution curve, ml./M.² (asleep)</td>
<td>8</td>
<td>27</td>
<td>34</td>
<td>42</td>
<td>41</td>
<td>34</td>
<td>59</td>
<td>43 ± 10.2</td>
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<tr>
<td><strong>Regurgitation, Vₑₑ:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>–</td>
</tr>
<tr>
<td>As ml./M.²/beat</td>
<td>173</td>
<td>204</td>
<td>46</td>
<td>44</td>
<td>31</td>
<td>25</td>
<td>29</td>
<td>6†</td>
</tr>
<tr>
<td>As per cent of Vₑₑ</td>
<td>96</td>
<td>88</td>
<td>58</td>
<td>51</td>
<td>43</td>
<td>42</td>
<td>33</td>
<td>12†</td>
</tr>
</tbody>
</table>

* Means and standard deviations of data from 18 subjects with no abnormality of the left heart.
† See text for discussion.
Volumes for seven patients with congenital mitral insufficiency plotted against calculated regurgitant flow expressed as percentage of left ventricular stroke volume. a. left atrium. b. Left ventricle.

A correction factor has been derived:
\[ V_E = 1.01 \times (V_{ED} - V_{ES}) - 7.37 \]
where \( V_E \) is the corrected left ventricular ejection volume. This correction factor was applied to all values for \( V_{ED} \) and \( V_{ES} \) obtained angiographically.

Arterial Indicator-Dilution Curves

Arterial indicator-dilution curves for calculation of cardiac output were recorded, 1 to 3 minutes prior to angiocardiography, at the femoral artery after injection of 2.5 or 5 mg. of indicator* into the same chamber used for injection of contrast medium. Cardiac output was calculated according to the method of Hamilton10 and was divided by the heart rate during inscription of the curve to give the stroke volume, SV, which was subtracted from the corrected left ventricular ejection volume, \( V_E \), to give a value for regurgitant flow, \( V_R \).

Cardiac output with the patient awake was obtained from indicator-dilution curves performed with injection into the main pulmonary artery. These curves were also used to obtain \( C_L/C_R \) ratios as an index of valvular insufficiency as described by Wood and Woodward.11

Results

The principal clinical features are given in table 1 and the hemodynamic and angiocardiographic data are summarized in table 2. The mean pulmonary arterial wedge pressures was elevated in case 2 and at the upper range of normal for children in case 3. For cases 2 and 4, the \( \text{Ry/v} \) ratio was in the range found in cases of mitral insufficiency. Calculation of the \( \text{Ry/v} \) ratio in the remaining cases has little meaning, since the wedge pressures were not elevated. Pulmonary vascular resistance was normal in all instances in which it could be measured.

In cases 3 to 7, the contour of the indicator-dilution curve was within the range of normal, but, in cases 1 and 2, there was significant prolongation of the disappearance phase of the curve consistent with the presence of valvular insufficiency.

Maximal and minimal left atrial volumes were increased above the range of normal in all cases in which measurement was possible, as was the difference between maximal and minimal volumes (fig. 3a and table 2). Left atrial opacification was inadequate for measurement purposes in cases 3 and 6.

Left ventricular volumes \( (V_{ED} \) and \( V_{ES} \) were calculated in all cases and all were increased significantly above the normal range (fig. 3b and table 2). The left ventricular ejection volume \( (V_{ED} - V_{ES}) \) was grossly increased in cases 1 and 2 and moderately in-

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* Cardio-green, from Hynson, Westcott and Dunning, Baltimore, Maryland.
creased in the remaining cases. Expressed as a percentage of end-diastolic volume ($V_{ED}$), the volume ejected by the left ventricle ($V_{ED} - V_{ES}$) varied between 50 and 64 per cent. Values for stroke volume (SV) varied between 8 and 59 ml. per square meter per beat. Regurgitant volumes ($V_{R}$) ranged between 25 and 204 ml. per square meter per beat (fig. 4).

**Angiocardiographic Appearances**

In each case, contrast medium injected into the left ventricle was seen to regurgitate into the left atrium. Regurgitation occurred before aortic opacification in case 1, when only the root of the aorta had opacified in cases 2 and 4, and when the aortic arch was opacified in cases 3, 5, 6, and 7. In case 2, the left atrium was enormously enlarged (fig. 5a) but no regurgitation of contrast medium into pulmonary veins was seen, a finding present in cases 1, 4, and 7 (fig. 6). An abnormal ridge of muscle was seen posteriorly in the left ventricle in case 7 (fig. 5b). Cases 3 and 6 both exhibited dilatation of the sinuses of Valsalva and aortic root (fig. 5c and d).

**Discussion**

**Clinical Observations**

Since the hemodynamics of isolated congenital mitral insufficiency are similar to those of mitral insufficiency from any other cause, the physical signs and roentgenologic and electrocardiographic findings are identical (table 1). Enlargement of the left atrium may reach aneurysmal proportions; this was a feature of the first case of congenital mitral insufficiency reported in the literature and of case 2 reported here.

A congenital basis for the lesion may be established at operation or at necropsy. Failing this, and in the absence of associated congenital heart lesions, such an etiology may be assumed when the murmur is heard very early in life prior to the age when acquired valvular lesions are expected. In six of the seven cases reported here, the murmur was detected at 2 years of age or less and none of the patients had a history of carditis.

There was operative evidence as to the anatomic nature of the lesion in cases 1 and 2.

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**Figure 5**

Angiograms. a (case 2). Systole, showing gross enlargement of left atrium. b (case 7). Systole showing abnormal ridge of muscle posteriorly in the left ventricle. c (case 3). Diastole, showing dilatation of aortic root. d (case 6). Systole, showing dilatation of aortic root.

In case 1, the anterior leaflet of the mitral valve was deficient in many portions, with numerous folds extending to the free margin. The minor leaflet was small and not freely mobile. Commissural tissue was deficient. The tricuspid valve was also grossly insufficient, with an essentially similar appearance. Both valves were excised and replaced by Starr-Edwards ball-valve prostheses. On discontinuing cardiopulmonary bypass, there was a progressive rise in right ventricular pressure and the patient failed to survive. It was thought that death was due to the severe pulmonary vascular disease that had been found during preoperative studies. Necropsy demonstrated thickening and hyalinization of muscular pulmonary arteries with obstructive intimal proliferation and scattered foci of acute arteritis representing unusually severe pulmonary vascular disease. There was no histo-
logic evidence of previous carditis. We have been unable to find a similar case reported in the literature.

In case 2, the patient was found to have a cleft in the anterior leaflet of the mitral valve and no atrial or ventricular septal defect. This type of lesion probably results from faulty embryogenesis of the endocardial cushions and may be a variant of common atrioventricular canal. Three similar cases have been reported.3, 14, 15

Mitral insufficiency occurs in the Marfan syndrome.16 Heart disease associated with this syndrome can be classified as degenerative, since the diastasis, but not the defect, is present at birth.16 Mitral murmurs in the Marfan syndrome have been heard at birth,17 however, and the valvular involvement may, in such instances, be truly congenital. Two of the patients described here (cases 3 and 6) had body features suggestive of the Marfan syndrome and both were demonstrated to have dilatation of the ascending aorta at angiocardiography, a finding common in this syndrome. The electrocardiogram in case 6 resembled, in certain respects, that described in some cases of the Marfan syndrome.18

Volume Calculations

The accuracy of determinations of volume of left heart chambers by biplane angiocardiography is well established. Errors arise when there is an abnormal rhythm during filming or when atrial opacification is inadequate for measurement purposes. Injection of contrast medium into the pulmonary artery reduces these complications. In the present study, contrast medium was injected into the left ventricle but an additional injection was made into the pulmonary artery in case 7. Both sets of films were measured with respect to left heart volumes and showed good agreement. Other potential errors in the determination have been recognized19, 20 and tend to result in an overestimate of ventricular volume. Dodge and co-workers21 used contrast-filled postmortem hearts and models to investigate five methods based on the ellipsoid5 for calculating left ventricular volume angiocardiographically. For the best model, the calculated volumes exceeded the measured volumes by approximately 10 per cent and a regression equation was derived to eliminate the overestimate.

Perhaps the strongest evidence for the accuracy of volume measurements in vivo lies in the agreement between estimates of stroke volume by angiocardiography on the one hand and by the Fick22 and the dye methods23 on the other. In the group of 26 subjects with no valvular insufficiency studied in this laboratory, however, the regression equation, \[ Y = 7.30 + 0.991 X, \]

indicates an overestimate of 12 per cent (table 2), which is similar in direction and magnitude to that found by others.23

Quantitation of Regurgitant Volume

The presence of mitral insufficiency is established when injection of contrast medium into the left ventricle is followed by significant regurgitation in the absence of abnormality of cardiac rhythm. Quantitation of such regurgitation has been attempted by estimating the intensity of left atrial opacification24, 25 or by comparing the time relationship of left atrial and aortic opacification.26 On the basis of such methods, cases 1 and 2 would be classified as having severe, case 4 as moderate, and cases 3, 5, 6, and 7 as mild, mitral insufficiency. Recently Sandler and associates,27 using the technic reported here, found regurgitant flows of up to 14.2 L per minute in 19 adult patients with aortic and mitral valve disease; the regurgitant flow in the cases reported herein ranges from 2.0 to 29 L per minute per square meter. In the most severe case (case 1), 96 per cent, and in the least severe case (case 7), 33 per cent of the total left ventricular ejection volume regurgitated into the left atrium. Such estimates of regurgitation \( (V_R) \) are affected by the accuracy of indicator-dilution determinations of forward flow \( (SV) \). Theoretically, valvular insufficiency should not affect calculation of \( SV \), providing systematically recirculated indicator is not included in the computation. However, data available28 suggest that indicator-dilution curves performed with injection into the left ventricle may underestimate \( SV \) in the presence of mitral in-
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sufficiency. Regurgitant flows calculated in these patients are still surprisingly large and represent a high output state of the left ventricle. Yet, in cases 3 to 7, the lesion was considered, on clinical grounds, to be mild and not to require operation despite regurgitant flows of 30 to 60 per cent—a situation in marked contrast to patients with ventricular and atrial septal defects in whom left-to-right shunts of this magnitude would indicate consideration for surgical repair of such defects.

**Relationship of Regurgitation to Ventricular Volume**

In the absence of a marked increase in heart rate and in the presence of a regurgitant flow, a normal cardiac output can be maintained by (1) an increase in the proportion of end-diastolic volume ejected as total stroke volume or (2) an increase in end-diastolic volume, the proportion ejected by the ventricle remaining approximately the same. Our results show that it is the latter mechanism which is operating. Thus, while there were considerable increases in end-diastolic volume, the total left ventricular ejection volume \( V_{ED} \) averaged 59 per cent of end-diastolic volume \( V_{ED0} \), which is, in fact, a somewhat smaller proportion than that found by us (67 per cent) in 18 subjects with normal left ventricles who were studied under identical conditions. Similar values for per cent ejection can be derived from data reported in adults, by Dodge and associates,\(^23\, 24\) and in children without insufficiency, by Bunnell and co-workers,\(^29\) in regard to the proportion of end-diastolic volume ejected. Similar results have been obtained in normal dogs.\(^31\) Thus, the children described herein were able to maintain a reasonable forward flow as a result of a substantial increase in end-diastolic volume (figs. 3 and 4). The increases in end-diastolic, end-systolic, and regurgitant volumes serve effectively to categorize the severity of insufficiency.

**Left Atrial Volumes**

In the present series, both absolute atrial volumes and changes in atrial volume were, like the ventricular volumes, significantly increased above the normal range (fig. 4). In conjunction with the abnormal ventricular volumes, these changes in atrial volume reinforce the diagnosis of mitral insufficiency and categorize its severity. In normal subjects or in patients with mitral stenosis, the magnitude of the change in atrial volume is less than the stroke volume. In mitral insufficiency, the change in atrial volume, although greater, still may not equal the total volume of blood ejected by the left ventricle (regurgitant plus forward flow).\(^5\) Since the atrium is never a closed chamber, part of the regurgitant flow can be accommodated in pulmonary veins and, in cases 1 and 7, in which the change in atrial volume was less than ventricular stroke volume, contrast medium was seen to pass from the left ventricle into the pulmonary veins (fig. 6). Minimal regurgitation into pul-

Figure 6

Case 1. Angiocardiogram during systole, showing regurgitation into pulmonary veins.
monary veins was also seen in case 4, in which atrial volume change was nearly equal to left ventricular stroke volume.

Diagnostic Implications

Assessment of regurgitant volume on the basis of left atrial pressure pulses, whether direct or indirect (pulmonary arterial wedge pressure), is notoriously susceptible to error. Of the measurements available, the Ry/v ratio is commonly regarded as the least reliable. However, in cases 4 to 7, left atrial pressure was not increased sufficiently to make such calculations meaningful, despite significant regurgitation.

Indices of regurgitation derived from indicator-dilution curves are also subject to error. Gross distortion of the curve occurs when the left atrial volume is large; conversely, a small left atrium may produce little distortion of the curve despite a relatively large regurgitant flow. Distortion of the indicator-dilution curve was pronounced in cases 1 and 2, in which there was considerable left atrial enlargement. In the remaining cases there was no significant distortion of the indicator-dilution curves recorded at a peripheral arterial sampling site (C_l/C_R ratio < 0.65), despite significant regurgitation. The present cases demonstrate that, while abnormality in either the wedge-pressure pulse or the indicator-dilution curve may offer evidence for the presence of significant mitral regurgitation, there are cases with hemodynamically significant regurgitation in which neither the pressure pulse nor the indicator-dilution curve may show abnormality of diagnostic significance. Quantitative estimates of regurgitant volume based on either of these methods, therefore, are unlikely to give uniformly consistent results.

The technic described in this paper permits direct evaluation of regurgitation and appears to be a satisfactory method for recognition and approximate quantitation of mitral insufficiency. Moreover, a new dimension—volume and volume change—is added to the description of the hemodynamics of congenital mitral insufficiency.

Summary

Clinical, hemodynamic, and angiographic findings are described in seven cases of congenital mitral insufficiency. The volumes and changes in volume of the left atrium and left ventricle were calculated from the angiocardiograms and were found to be increased above the range of normal. Left ventricular stroke volumes thus obtained were compared with forward flows calculated from indicator-dilution curves in order to quantitate regurgitant flow. Regurgitant flows varied between 19 and 94 per cent of the total left ventricular ejection volume, and forward flow was maintained as a result of a considerable increase in left ventricular volume. The left ventricular ejection volume was 50 to 64 per cent of the end-diastolic volume.

References

9. Miller, C. A. H., and Swan, H. J. C.: Normal left heart volumes determined angiocardio-
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graphically in subjects of differing body size. Unpublished data.


28. Rahmtoola, S. H.: Personal communication to the authors.


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