Surgical Treatment of Congenital Aortic Stenosis

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Experience with 169 patients less than 25 years old and operated on at the Mayo Clinic for congenital aortic stenosis is reviewed. Aortic valvotomy is primarily a palliative procedure, allowing adequate relief of the transaortic valve gradient in only 56 percent of patients and leaving a severe gradient in 20 percent. A low operative mortality justifies its use in patients having valid cardiac disability and left ventricular “strain” on the electrocardiogram or even in asymptomatic younger patients in whom the gradient is 75 mm Hg or greater. Infants who have cardiac failure should also be operated on, the risk apparently not being significantly greater in this age group (no deaths in seven operations). The results of valvotomy in older patients (over 16 years of age) were poorest, and operation on asymptomatic patients in this age group seems unwarranted. The objective of aortic valvotomy should be to achieve as great an opening as possible by incision of fused commissures but avoiding incision of raphae because of the risk of producing aortic insufficiency. Supravalvular aortic stenosis and localized fibromuscular subaortic stenosis can be relieved more adequately and permanently by operation than can valvular aortic stenosis, and operation is therefore indicated even in asymptomatic patients if the gradient is about 50 mm Hg or greater.

Congenital valvular aortic stenosis can seldom be cured by operation, if by “cure” is meant a return to normal function. At the least, valvular deformity persists which may result in progressive thickening and then calcification of the cusps and, more significantly, the stenosis itself often cannot be relieved completely. Particular attention must therefore be given to the degree of improvement which can be anticipated as a result of operation and to the surgical techniques which are most likely to achieve an optimal result. From these considerations it may be possible to define which patients should be advised to undergo operation and when the operation should be performed.

With these objectives, the early and late results of all operations performed at the Mayo Clinic for congenital aortic stenosis were reviewed.

Preoperative Findings

The records of all 169 patients operated on at the Mayo Clinic between January 1, 1956, and July 1, 1966, for congenital aortic stenosis were reviewed. (We authors acknowledge the inclusion of patients operated on by Drs. J. W. Kirklin, F. H. Ellis, Jr., and R. B. Wallace.) Only those patients less than 25 years old were included under this diagnosis because of the difficulty in distinguishing a congenital from an acquired condition in older patients. Sixty of these 169 patients have been reviewed in previous publications. There were 112 boys and 57 girls with an average age of 11.1 years.

The anatomic distribution of the stenoses is shown in Figure 1. The male:female ratio was approximately 1:1 except for the valvular stenosis group, in which it was 2.7:1. The cases of supravalvular aortic stenosis have recently been reported by Rastelli and associates and will not be considered in this discussion. Six of the 11 patients with diffuse subvalvular aortic stenosis had been operated on prior to 1964 and were included in the review by Frye and co-workers; the surgical treatment of this condition has been discussed by Kirklin and Ellis. This communication will draw on the findings of these reports but will analyze particularly the 142 remaining cases in which the stenosis was predominantly valvular (112) or localized subvalvular (30).

Anatomic Considerations

Figure 2 shows the types of deformity and their incidence among the 112 cases of valvar stenosis. A tricuspid valve with a central stenotic orifice and fusion of all three commissures (Fig 2 A) occurred in 20 (18 percent) cases. In five cases (4 percent) there was a unicuspid valve having its orifice located posteriorly in the usual position for the commissure between left and noncoronary cusps (Fig 2 B), but no other commissures were present. A bicuspid valve was found in 87 (78 percent) cases; in
all but one of these, a vestigial raphe bisected the fused cusp, marking the site where a commissure should have formed. In the one exception, the fused cusp showed two raphae, giving the appearance of a four-cusp valve (Fig 2 C). In 53 cases (61 percent of the 87) the raphe was between the two coronary cusps, the commissure between the right and noncoronary cusps being fused and the orifice located between the left and noncoronary cusps (Fig 2 D). In 31 cases (36 percent of the 87) the raphe was between the right and noncoronary cusps, the fused commissure was between the two coronary cusps, and the orifice was between the left and noncoronary cusps (Fig 2 E). In only two cases of bicuspid valve was the commissure between the left and noncoronary cusps abnormal, being the site of a raphe in one (Fig 2 F) and fused in the other (Fig 2 G). Mild to moderate valvular calcification was encountered in 11 of the 112 patients with valvular stenosis; the youngest of the 11 was a 12-year-old boy. The calcification was not severe enough to cause significant immobility of the valve at the time of primary operation in any patient. However, in one patient who underwent another operation eight years later (at the age of 31 years) for recurrent stenosis, the valve was heavily calcified and immobile.

Additional cardiovascular anomalies were noted in 31 (22 percent) of the 142 patients with valvular or localized subvalvular lesions. Patent ductus arteriosus and coarctation of the aorta were the most common lesions, occurring as an isolated additional finding in 11 and 8 patients, respectively (Table 1). The incidence of an associated cardiovascular lesion in patients with localized subvalvular stenosis (27 percent) was not significantly different from that in patients with valvular stenosis (20 percent).

Eight of the 142 patients showed a combination of obstructive lesions of the left ventricular outflow tract (most of the possible combinations were represented). These cases are classified in this report according to our best judgment of the dominant lesion.

**Clinical Findings**

Forty-five percent of the patients (64 cases) had no symptoms preoperatively (Table 2). Dyspnea was the most common symptom. Chest pain and syncope were encountered less frequently, and right-sided congestive heart failure was rare, occurring only in three infants and responding to digitalis therapy in all three.

A harsh ejection type systolic murmur at the second right intercostal space was heard in all patients. In the majority it was graded as 3 or louder (on the basis of 1 to 6) and was associated with a thrill transmitted to the carotid arteries. In addition to the systolic murmur, a faint, early diastolic murmur was heard in 50 patients (38 [34 percent] of the valvular group and 12 [40 percent] of the subvalvular group). A protosystolic click was noted in 73 (65 percent) of the patients with valvular stenosis but in none of those with localized subvalvular stenosis.

**Roentgenographic Evaluation**

The cardiothoracic index ranged from 0.38 to 0.70, the average being 0.48. The left ventricle was considered to be enlarged in 116 cases (82 percent). Poststenotic dilatation of the ascending aorta was observed in 44 (39 percent) of the 112 cases of valvular stenosis and in 2 (7 percent) of the 30 cases of localized subvalvular stenosis.

**Electrocardiographic and Vectorcardiographic Evaluation**

Preoperative electrocardiograms were available in 118 cases (90 of valvular and 28 of localized subvalvular

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**Table 1—Associated Cardiovascular Anomalies in Patients with Congenital Aortic Stenosis**

<table>
<thead>
<tr>
<th>Anomaly</th>
<th>Valvular (112 Patients)</th>
<th>Localized Subvalvular (30 Patients)</th>
<th>Total (142 Patients)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Patent ductus arteriosus</td>
<td>9</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Coarctation of aorta</td>
<td>7</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Coarctation and patent ductus</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Persistent left superior vena cava</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Aortic insufficiency, severe</td>
<td>2</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Mitral insufficiency, severe</td>
<td>0</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Mitral insufficiency and patent ductus</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Valvular and subvalvular pulmonary stenosis and left superior vena cava</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Atrial septal defect</td>
<td>1</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Ventricular septal defect</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>23</td>
<td>8</td>
<td>31</td>
</tr>
</tbody>
</table>

*Noted in 142 patients with congenital valvular (112) or localized subvalvular (30) aortic stenosis under the age of 25 years.*
Table 2—Symptoms in 142 Cases of Congenital Aortic Stenosis

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Valvular (112 cases)</th>
<th>Localized Subvalvular (30 cases)</th>
<th>Total (142 cases)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No.</td>
<td>%</td>
<td>No.</td>
</tr>
<tr>
<td>None</td>
<td>51</td>
<td>46</td>
<td>13</td>
</tr>
<tr>
<td>Dyspnea</td>
<td>51</td>
<td>46</td>
<td>15</td>
</tr>
<tr>
<td>Angina</td>
<td>30</td>
<td>27</td>
<td>11</td>
</tr>
<tr>
<td>Syncope</td>
<td>27</td>
<td>24</td>
<td>12</td>
</tr>
<tr>
<td>Right ventricular failure</td>
<td>3</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

A diagnosis of left ventricular hypertrophy was based on criteria reported by Namin, plus vectorial analysis of the scalar electrocardiogram in the frontal and horizontal planes with particular reference to the relationship of the QRS to the T vector. A discordant T vector with the QRS-T angle greater than 90 degrees was interpreted as indicating severe left ventricular hypertrophy ("strain"). The electrocardiograms of these patients were analyzed.

Table 3—Electrocardiographic Findings According to Age in Patients with Congenital Aortic Stenosis

<table>
<thead>
<tr>
<th>Interpretation of ECC</th>
<th>Age (yr)</th>
<th>No.</th>
<th>Normal</th>
<th>L.V.H.</th>
<th>L.V. &quot;strain&quot;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;1</td>
<td>6</td>
<td>0</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>1-16</td>
<td>96</td>
<td>10</td>
<td>33</td>
<td>53</td>
</tr>
<tr>
<td></td>
<td>&gt;16</td>
<td>16</td>
<td>0</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>118</td>
<td>10</td>
<td>35</td>
<td>73</td>
</tr>
</tbody>
</table>

*LVH = left ventricular hypertrophy.

without prior knowledge of the pressure gradient or type of stenosis; only the age of the patient was known.

The distribution of patients according to age and electrocardiographic findings is shown in Table 3. The incidence of "strain" patterns was high in infants and in those more than 16 years of age. Comparison of the peak systolic left ventricular-to-aortic pressure gradients, measured either at catheterization or at operation, with the electrocardiograms at various ages indicates a significantly higher incidence of "strain" patterns associated with lower pressure gradients in infants (less than 1 year old) and adults than in patients in childhood and early adolescence.

Hemodynamic Findings

Cardiac catheterization was performed preoperatively at our institution in 33 cases in order to assess the gradient and the area of the stenotic orifice. Forty-nine other patients had undergone catheterization at other hospitals before referral. In the remaining patients, the decision to operate was based on the clinical manifestations and electrocardiographic findings. The peak systolic gradient across the stenosis ranged between 53 and 161 mm Hg in the patients catheterized here (37 with valvular and six with localized subvalvular stenosis). In patients in whom it could be calculated, the area of stenosis? ranged between 0.35 and 0.78 cm²/M² with a mean of 0.54 cm²/M².

Gradients were measured at operation before perfusion in the majority of patients. Among those with valvular stenosis, gradients were 25 mm Hg or less (mild) in 2 percent, 26 to 50 mm Hg (moderate) in 26 percent, and greater than 50 mm Hg (severe) in 72 percent. All patients in the subvalvular group showed severe gradients, except for four (13 percent) in whom the gradients were moderate.

Effect of Operation

Operative Technique

Extracorporeal circulation was used in all the operations except one, in 1956, in which moderate hypothermia and inflow occlusion were used. The perfusate was cooled moderately (30 C) in all perfusions except the first 41, and myocardial ischemia was allowed to persist during aortic cross clamping in all except 16 operations in which coronary artery perfusion was used. The total perfusion time averaged 39 minutes, and the aorta was cross clamped an average of about half of this perfusion time; these averages were similar in the two groups (valvular stenosis and localized subvalvular stenosis).

The fused commissures were sharply incised in 107 of the 112 cases of valvular stenosis; a single cusp was replaced with Teflon prosthesis in three cases, and the entire valve was replaced with a homograft aortic valve in one case.

Table 4—Deaths in Early Postoperative Period

<table>
<thead>
<tr>
<th>Lesion</th>
<th>Age, (yr)</th>
<th>Date of Oper.</th>
<th>Time of Death Postop.</th>
<th>Major Cause</th>
<th>Contributing Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valvular</td>
<td>3</td>
<td>2/26/57</td>
<td>10 hr</td>
<td>Unknown</td>
<td>Rapid decline after initial favorable course; no explanation at autopsy</td>
</tr>
<tr>
<td>Valvular</td>
<td>6</td>
<td>7/17/57</td>
<td>During</td>
<td>Technical</td>
<td>Patent ductus found; no techniques then available to treat this during open-heart surgery</td>
</tr>
<tr>
<td>Localized Subvalvular</td>
<td>9</td>
<td>11/9/61</td>
<td>17 days</td>
<td>Bacterial endocarditis</td>
<td>Cirrhosis; previous splenectomy; staphylococcal infection of aortotomy; died after re-exploration</td>
</tr>
<tr>
<td>Valvular</td>
<td>16</td>
<td>8/20/65</td>
<td>4 days</td>
<td>Unknown</td>
<td>Rapid decline for the 8 hours preceding death; terminal exploration showed moderate amount of serosanguineous pericardial fluid; no autopsy</td>
</tr>
<tr>
<td>Valvular &amp; localized subvalvular*</td>
<td>10</td>
<td>2/2/66</td>
<td>During</td>
<td>Technical; complicated</td>
<td>Severe gradient remained after subvalvular stenosis excised; re-instituted for 130 min, coronary perfusion inadequate, homograft valve inserted; LV failure</td>
</tr>
</tbody>
</table>

*This patient previously had supravalvular aortic stenosis.
and with a caged-ball-valve prosthesis in one case. All 30 localized subaortic stenoses were resected by a transaortic approach.

Operative Mortality

Five patients (3.5 percent) died within one month after operation (Table 4). Two deaths were never adequately explained, two were due to technical factors and occurred during the operation, and one resulted from infection of the aortic suture line.

Late Mortality

Ten patients (7 percent) died more than one month after operation (Table 5). Two died of unrelated causes, two of bacterial endocarditis within two months after operation, five because of residual aortic stenosis or insufficiency, and one because of cardiac causes not clearly the result of residual valvular disease.

Clinical Findings

Follow-up information, based on replies to letters of inquiry or examination at this clinic, was available for all but eight patients (6 percent) as of February 1967. The follow-up period ranged from six months to 11 years.

Of the 134 patients with completed follow-up, 108 (81 percent) had remained or became asymptomatic. The remaining 11 living patients were symptomatic because of persisting aortic stenosis in eight or insufficiency in three. An aortic systolic murmur of variable intensity remained audible in every patient.

Aortic insufficiency was not produced in any patient with localized subvalvular stenosis, although mitral insufficiency occurred in one and required repair subsequently. Aortic diastolic murmurs became audible in only 12 patients with valvular stenosis in whom none was heard preoperatively. Remarkably, an additional 15 patients who had faint diastolic murmurs preoperatively had none postoperatively. The aortic insufficiency encountered postoperatively was mild in all except four patients (moderate in three and severe in one). Three of these four patients died during the follow-up period.

Roentgenographic Evaluation

Thoracic roentgenograms made one or more years postoperatively were available for 61 patients, and the majority (59 percent) continued to show variable degrees of left ventricular enlargement.

Electrocardiographic and Vectorcardiographic Evaluation

In 85 patients, electrocardiograms made one or more years postoperatively were available for comparison with those made prior to operation. Seven of these patients had had normal electrocardiograms preoperatively and they all remained normal. In 24 there had been evidence of left ventricular hypertrophy preoperatively; of these, eight (33 percent) became normal and four (17 percent) progressed to the development of left ventricular "strain." Of 54 which showed left ventricular "strain" preoperatively, 24 (44 percent) lost this pattern postoperatively, but only seven (13 percent) became normal. In seven of the 28 patients with localized subvalvular stenosis, there was a shift of the mean QRS axis in the frontal plane from the 0 to 90 degree quadrant preoperatively to the 270 to 360 degree quadrant postoperatively, suggesting mechanical interference with some of the fibers of the left bundle branch.

Hemodynamic Evaluation

During the operation, pressures were measured in the left ventricle and aorta (or one of its branches) before and after repair. Cardiac output was not yet being measured at operation during the time covered by this report.
but subsequently has been shown almost routinely to be higher just after bypass than preceding it. After repair, a systolic pressure gradient across the previously stenotic area was absent or mild in 59 (56 percent) of the 105 patients with a valvular lesion and in 24 (83 percent) of the 29 patients with a localized subvalvular lesion so studied. Twenty-five (24 percent) of the patients with valvular stenosis and three (10 percent) of those with localized subvalvular stenosis had a moderate residual gradient. Twenty-one patients (20 percent) of the patients with valvular stenosis and two (7 percent) of those with localized subvalvular stenosis had severe residual gradients; in six of these 23, no significant reduction of the gradient was accomplished by the operation.

Eighteen patients have undergone cardiac catheterization one to six years after operation (15 had valvular stenosis and three had subvalvular stenosis). These form a highly selected series; many were catheterized because of persistence of abnormality such as the presence of symptoms or an abnormal electrocardiogram. Eight of these patients, all with valvular stenosis, had been catheterized before operation, and the valve index had increased in each at the postoperative study, the average increase being from 0.52 cm²/M² preoperatively to 1.40 cm²/M² postoperatively. The average valve index in the 18 patients was 1.51 cm²/M². The gradient at the time of late postoperative catheterization was within 20 mm Hg of the postrepair gradient at operation in all but two of the 18 patients; in one it had decreased by 48 mm Hg at the later study, and in one it had increased by 107 mm Hg.

**Summary of Evaluations**

Comparison of the various parameters for assessing the preoperative and the postoperative status of the patients (Table 6) shows a significant improvement after operation in nearly all categories. However, the results overlap to such an extent that any attempt to define good and poor results in specific patients becomes too arbitrary. The hemodynamic data must be considered to be the most accurate means of assessment, even though in this series there were few late postoperative cardiac catheterizations and cardiac output determinations were not performed during operation at the time of measurement of the residual gradient after repair.

**Influence of Age on Result**

In this series seven patients were 12 months of age or younger and three of these were 3 months of age or younger. All of the infants showed evidence of left ventricular failure preoperatively, which responded somewhat to medical management. Each had valvular stenosis. There were no early or late deaths in this group, and all remain improved up to five years postoperatively.

Twenty-one patients underwent operation between the ages of 17 and 25 years; 16 had valvular and five had localized subvalvular stenosis. The latter five have all had a good result. Among the 16 patients with valvular stenosis there were no operative deaths but two late deaths (Table 5), both of which occurred after a second operation performed because of a poor result of the first operation. Of the surviving 14 patients, one was lost to follow-up, one will soon need reoperation for residual stenosis, and the remainder continue to be improved.

From the standpoint of both hemodynamic and electrocardiographic parameters, the patients more than 16 years of age obtained poorer results. The gradient after repair

### Table 6—Summary of Preoperative and Postoperative Data from Patients with Congenital Aortic Stenosis

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preop.</th>
<th>Postop.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No cardiac symptoms or disability</td>
<td>45%</td>
<td>81%*</td>
</tr>
<tr>
<td>Systolic murmur</td>
<td>All</td>
<td>All</td>
</tr>
<tr>
<td>Significant aortic insufficiency</td>
<td>0%</td>
<td>3%</td>
</tr>
<tr>
<td>LV enlargement on roentgenogram</td>
<td>82%</td>
<td>59%</td>
</tr>
<tr>
<td>Electrocardiogram:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>8%</td>
<td>26%</td>
</tr>
<tr>
<td>LV hypertrophy</td>
<td>30%</td>
<td>34%</td>
</tr>
<tr>
<td>LV &quot;strain&quot;</td>
<td>62%</td>
<td>40%</td>
</tr>
<tr>
<td>Death due to cardiac disease</td>
<td>0-18%</td>
<td>9%†</td>
</tr>
</tbody>
</table>

Hemodynamics

- Valve area at cardiac catheterization §: 0.52 cm² to 1.40 cm²
- Systolic pressure gradient at operation:
  - Postop. <25 mm Hg 2% 0% 56% 83%
  - 25-50 mm Hg 26% 13% 24% 10%
  - >50 mm Hg 72% 87% 20% 7%

*Percent of entire group, not just survivors.
†Incidence of preoperative death reported in the literature.
§Postoperative incidence is the sum of operative deaths (5) and postoperative deaths due to cardiac causes (8).
§†Eight patients with preoperative and postoperative catheterizations.

The results of this surgical experience with patients having congenital aortic stenosis are similar in many respects to those in preceding reports. From Table 6 we can conclude that operation improves the hemodynamic status of the group as a whole, although it falls considerably short of providing complete cure. Individual variation in the results is striking, with some patients being improved much more than others.

The fixed, nonvalvular stenoses (localized subvalvular or supravalvular) are more amenable to operation because, once relieved by operation, later progression of stenosis is not anticipated, whereas in valvular stenosis, progressive stenosis due to calcification during adulthood is probably inevitable. Therefore, for the nonvalvular fixed stenoses, the indications for operation should be more liberal, with a view toward achieving maximal relief of the gradient early after diagnosis in the older patients with valvular stenosis was greater than 50 mm Hg in 38 percent (compared to 20 percent for all patients with valvular stenosis). Among the 78 patients whose preoperative electrocardiogram was abnormal and for whom a postoperative electrocardiogram was available, an analysis by age group (Table 7) shows a greater incidence (P < 0.05 by χ² test) of improvement in infants (less than 1 year old) and in those 1 to 16 years old than in the patients more than 16 years old. Further analysis of those 1 to 16 years old indicated no significant differences between those 1 to 6 years, 7 to 11 years, and 12 to 16 years in regard to postoperative electrocardiographic changes.

**DISCUSSION**

The results of this surgical experience with patients having congenital aortic stenosis are similar in many respects to those in preceding reports. From Table 6 we can conclude that operation improves the hemodynamic status of the group as a whole, although it falls considerably short of providing complete cure. Individual variation in the results is striking, with some patients being improved much more than others.

The fixed, nonvalvular stenoses (localized subvalvular or supravalvular) are more amenable to operation because, once relieved by operation, later progression of stenosis is not anticipated, whereas in valvular stenosis, progressive stenosis due to calcification during adulthood is probably inevitable. Therefore, for the nonvalvular fixed stenoses, the indications for operation should be more liberal, with a view toward achieving maximal relief of the gradient early after diagnosis in

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all instances in which it is at least of moderate severity (systolic gradient > 50 mm Hg), even if symptoms are not present. The technique for repair of supravalvular stenosis has been described previously. It has become increasingly apparent that resection of the zone of localized fibromuscular subaortic stenosis must be as radical and extensive as possible within the anatomic limitations of this region (Fig 3). The mitral valve must be protected. Resection of septal tissues beneath the commissure between right and noncoronary aortic cusps must be avoided to prevent injury to the bundle of His; hence, the resection must be confined to that portion of the septum to the left of this region and along the left lateral wall of the outflow tract, with extension deeply into myocardium.

Because aortic valvotomy usually falls considerably short of achieving complete and permanent cure, it is best to consider it a palliative procedure. Being palliative, its objective is more to relieve a serious handicap or threat to life than to prevent some possible future complication or deterioration.

The chief indications for aortic valvotomy are the presence of cardiac symptoms due to aortic stenosis or the threat of death which may occur suddenly, the latter being more difficult to evaluate. In this connection, it is generally agreed that the great majority of patients with congenital aortic stenosis who suddenly die had symptoms before death or showed the electrocardiographic alterations of left ventricular "strain." Clearly, then, patients with congenital aortic stenosis who have true cardiac disability or left ventricular "strain" on the electrocardiogram or both are candidates for operation.

Problems in deciding about the necessity of aortic valvotomy arise with those patients who have objective evidence of significant aortic stenosis but who remain asymptomatic. Table 6 shows that this situation is not uncommon in this series: considerably fewer patients had cardiac symptoms (55 percent) than had roentgenographic (82 percent), electrocardiographic (92 percent), or hemodynamic (at least 72 percent) indications of significant aortic stenosis. The most specific of these objective means of evaluation is cardiac catheterization which should include measurement of the gradient between the left ventricle and aorta, cardiac output, and usually left ventriculogram. Thus, cardiac catheterization is indicated in a high percentage of patients with aortic stenosis who are being considered for operation. The results of this study are interpreted by us to support continuation of the policy of advising operation for the asymptomatic child with congenital valvular aortic stenosis when cardiac catheterization demonstrates a peak systolic gradient of 75 mm Hg or greater.

The results of our experience with aortic valvotomy in infants and those of others clearly indicate the advisability of operating on any infant who has shown cardiac failure due to aortic stenosis. Of 22 patients with congenital aortic stenosis and onset of symptoms between birth and 12 months of age studied by Hastreiter and associates, 16 died by the age of 15 months, and five of the six surviving patients had been operated on (two of those who died had also undergone operation). Medical treatment should be instituted in these infants as a preoperative measure but probably should not be relied on alone if an episode of failure has occurred.

The poorest results after aortic valvotomy in our experience were in patients 17 years of age or older. At least two explanations might be possible: (1) Less could be accomplished by incising a fused commissure or commissures because of the increas-
ing fibrosis or even calcification of cusps at this age, and (2) the left ventricular myocardium had become altered by chronic hypertrophy and fibrosis and thus could not recover, as a result of a given amount of improvement in valvular orifice, to the extent that a younger myocardium could. Both factors probably play a role, but the former seems the more plausible and demonstrable because, in our experience, an intraoperative postrepair gradient greater than 50 mm Hg was encountered in 38 percent of these patients, nearly twice that of the entire group. It appears that the indications for operation should be stricter in this older group than for younger patients, more closely approximating the indications for operation in adults with calcific aortic stenosis and thus excluding patients who are asymptomatic. With longer follow-up studies and the improved substitute valves now available, valvular replacement is becoming more frequently used at the initial operation for patients in this age group.

With the acceptance of aortic valvotomy as a palliative procedure in the treatment of congenital aortic stenosis, it is easier to place the objective of operation in a more acceptable perspective. This objective should be to obtain as optimal an opening in the valve as is possible without compromising its competence. In practice, this means that (1) the fused commissure(s) must be carefully and precisely incised at the very center to within about 2 mm of the aortic wall but not into the aortic annulus itself, and (2) poorly developed raphae which are not true commissures should not be incised. The distinction between a commissure and a raphe depends on the height of the annular attachment of the commissure and the consequent depth of the adjacent valvular cusps, or conversely, the low level of attachment of the raphe toward the base of the sinus of Valsalva and the consequent shallowness of the adjacent cusps.

References

Reprint requests: Dr. McGoone, Mayo Clinic, Rochester, Minnesota 55901.

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