Long-Term Clinical Course and Symptomatic Status of Patients after Operation for Hypertrophic Subaortic Stenosis

BARRY J. MARON, M.D., WALTER H. MERRILL, M.D., PAUL A. FREIER, B.A., KENNETH M. KENT, M.D., PH.D., STEPHEN E. EPSTEIN, M.D., and ANDREW G. MORROW, M.D.

SUMMARY Long-term results of operation for IHSS were reviewed in 124 patients operated upon between 1960 and 1975. Most patients improved symptomatically and manifested marked reduction in LV outflow gradient at rest postoperatively. However, ten (8%) patients died of causes related to operation, 14 (12%) had persistent or recurrent severe functional limitation, and 11 (9%) died up to 13 years postoperatively due to hypertrophic cardiomyopathy. Overall annual mortality rate was 3.5% and was 1.8% for late deaths alone.

OPERATION FOR idiopathic hypertrophic subaortic stenosis (IHSS) and obstruction to left ventricular outflow ameliorates cardiac symptoms and relieves the outflow gradient in most patients.1-13 Although previous reports from this institution have described the early alterations in functional and hemodynamic state which follow operation,1-3 9 few long-term follow-up data are available.13-18 To evaluate the long-term consequences of operation for IHSS we have reviewed a consecutive series of 124 operated patients who have been followed for one to 17 years.

Selection of Patients

Between January 1960 and February 1978, 208 patients with IHSS were operated upon at the National Heart, Lung, and Blood Institute (NHLBI). The case records of the 124 patients who underwent operation between January 1960 and December 1975 were reviewed. Four patients were excluded from the study group (fig. 1): 1) one surviving patient who had aortic valve replacement at age 52 years for severe aortic regurgitation and congestive heart failure (secondary to bacterial endocarditis), and underwent septal myotomy-myectomy at the same time; 2) one patient who died in an automobile accident; 3) one patient who committed suicide; and 4) one patient who died of acute fulminating pancreatitis.

At the time of operation the remaining 120 patients ranged in age from eight to 75 years (median 44); 68 were men and 52 were women. The clinical condition of each of the 120 patients was determined as of January 1, 1977. The period of postoperative follow-up of the survivors was one to 17 years with a mean follow-up of 5.2 years. Of the 120 study patients, 111 underwent septal myotomy-myectomy by the techniques described previously1-47 and the remaining nine patients had only septal myotomy.11 Three patients had had previous operations at other institutions without symptomatic improvement or reduction of the left ventricular outflow gradient.

Of 11 late postoperative deaths, six were sudden and five were due to chronic heart failure. Atrial fibrillation was significantly more common in patients who died late postoperatively than in survivors. Nine of the 11 late deaths had associated medical problems that may have contributed to their outcome. In conclusion, long-lasting clinical improvement occurred in most patients who survived operation for IHSS. However, 12% of patients deteriorated clinically over the 5.2 year average follow-up, and there is continued, small annual mortality.

From the Cardiology Branch and Clinic of Surgery, National Heart, Lung, and Blood Institute, National Institutes of Health, Bethesda, Maryland.

Address for reprints: Barry J Maron, M.D., Cardiology Branch, National Heart, Lung, and Blood Institute, Bldg. 10, Room 7B-15, National Institutes of Health, Bethesda, Maryland 20014.

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hemodynamic burden would prevent subsequent sudden death. 4) An 18-year-old boy from a small village in Greece was in functional class II but had severe outflow obstruction. Echocardiographic studies were not routinely performed at our institution prior to 1972. Therefore, since most patients in this study had either no or incomplete echocardiographic evaluation, available echocardiographic data will not be presented.

Results

Analysis of Operatively Related Deaths

Ten of the 120 patients died of the consequences of operation. The circumstances of these operatively related deaths are summarized in table 1. Although patient S.H. (#31) died two months and C.K. (#59) 21 months after operation, they were considered to be operative deaths. S.H. incurred complete heart block at operation. At the time of pacemaker implantation, one month postoperatively, he had a cardiac arrest and subsequent cerebral damage secondary to hypoxia (which appeared to be related to an anesthetic accident) and died one month later. C.K. died of sepsisemia (related to immunosuppressive therapy) after renal transplantation that was performed 21 months following septal myotomy-myectomy. His chronic renal failure was due to bilateral renal artery occlusion and subsequent renal infarction that occurred four days after his cardiac operation. In addition, patient R.F. (#79) died during the course of a second septal myotomy-myectomy performed at NHLBI at age 22 years. This patient had had little improvement in symptomatic state and unsatisfactory relief of his left ventricular outflow obstruction after an initial operation performed three years earlier. The clinical and hemodynamic findings present preoperatively in the ten patients who died early after opera-

tion did not differ from those in patients who survived operation.

Analysis of Late Postoperative Deaths

Of the 110 study patients who survived operation, 14 died late after operation of causes that could not be related to the operative procedure per se, and the remaining 96 have survived to date. The circumstances surrounding the deaths of three of these 14 patients strongly suggested that their deaths could not be attributed to cardiomyopathy: 1) a 47-year-old woman (P.S., #54) who died of complications of a cerebrovascular accident initially incurred three years previously during cardiac catheterization; 2) a 71-year-old woman (M.B., #63) who died of a massive myocardial infarction and also had significant coronary atherosclerosis at necropsy (60% narrowing of the left anterior descending coronary artery and 50% narrowing of the right coronary artery); and 3) a 44-year-old man (J.G., #26) whose death was considered due primarily to the effects of chronic alcoholism and a dilated cardiomyopathy. This patient died five years after septal myotomy-myectomy with evidence of progressive right heart failure. At necropsy there was hepatic cirrhosis and ascites; the ventricular cavities were markedly dilated and the ventricular walls were only mildly (and symmetrically) thickened.

The remaining 11 patients died of causes that appeared related to cardiomyopathy seven months to 13 years after the operation (median six years) (table 2). At death, these patients ranged in age from 23 to 64 years (median 52 years); three were over 55 years of age. Eight patients were men and three were women. At the time of death two patients were in functional class I, three were in class II, and six were in class III or IV; preoperatively all had been in functional class III or IV. Nine of the 11 patients had postoperative hemodynamic studies. In each of these patients either a trivial or no outflow gradient was present under basal conditions; with provocative maneuvers, four patients had outflow gradients but only in one patient was the gradient greater than 30 mm Hg. Postoperative LVEDP was > 15 mm Hg in only three of the nine patients.

Six of the 11 patients died suddenly and unexpectedly, presumably due to arrhythmia. At the time of death each of these six patients was sedentary (including one who was asleep). The remaining five patients died after chronic illnesses characterized by progressive, severe congestive heart failure. The 11 patients who died late and the 96 long-term survivors did not differ with respect to age at operation, age at the last clinical assessment, sex or preoperative functional class.

The survival curve for 117 study patients (including 96 survivors, ten operatively related deaths and 11 late deaths presumably due to hypertrophic cardiomyopathy) is shown in figure 2. The overall annual mortality rate was 3.5%; when only late deaths due to cardiomyopathy were considered, the annual mortality rate was 1.8%. The outcomes of all patients in the study group are summarized graphically in figure 1.

Identification of Potential Contributing Factors for Late Death

Of the 11 patients who died late after operation, nine had potentially deleterious associated cardiovascular or general medical problems that had been identified preoperatively,
TABLE 1. Circumstances of Operatively Related Deaths in Ten Patients with IHSS

<table>
<thead>
<tr>
<th>Patient*</th>
<th>Age at death (yr/sex)</th>
<th>Time post-op (days)</th>
<th>Associated cardiovascular and medical problems</th>
<th>Circumstances</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.K. (#8)</td>
<td>53 M</td>
<td>6</td>
<td>None</td>
<td>Sudden death; persistent postop AF. Postop CHB and CVA; cardiac arrest suddenly during pacemaker implantation.</td>
</tr>
<tr>
<td>S.H. (#31)</td>
<td>27 M</td>
<td>60</td>
<td>None</td>
<td>Low cardiac output; failure to come off cardiopulmonary bypass.</td>
</tr>
<tr>
<td>E.L. (#32)</td>
<td>42 M</td>
<td>0†</td>
<td>CAD</td>
<td>MV replacement also performed; low cardiac output, arrhythmias; extensive myocardial necrosis at necropsy.</td>
</tr>
<tr>
<td>H.H. (#39)</td>
<td>18 M</td>
<td>2</td>
<td>None</td>
<td>Laceration of LV, hemorrhage, shock.</td>
</tr>
<tr>
<td>O.H. (#46)</td>
<td>62 F</td>
<td>0.1</td>
<td>Obesity, CAD, hypertension</td>
<td>Plication of an LV aneurysm also performed; low cardiac output, renal failure; possibly due to renal infarct caused by emboli or thrombi.</td>
</tr>
<tr>
<td>B.J. (#49)</td>
<td>19 F</td>
<td>9</td>
<td>None</td>
<td>Bilateral occlusion renal arteries 4 days postop with chronic renal failure; died of sepsis after renal transplantation.</td>
</tr>
<tr>
<td>C.K. (#59)</td>
<td>42 M</td>
<td>21 mo.</td>
<td>Chronic AF, hypertension</td>
<td>Aortic tear; uncontrollable hemorrhage.</td>
</tr>
<tr>
<td>R.F. (#79)</td>
<td>22 M</td>
<td>0†</td>
<td>Paroxysmal AF; intractable supraventricular tachyarrhythmias</td>
<td>Low cardiac output, hypotension, bradycardia; probably due to rupture of papillary muscle at operation.¶</td>
</tr>
<tr>
<td>E.P. (#104)</td>
<td>61 F</td>
<td>1</td>
<td>Obesity, CAD, hypertension</td>
<td>Sudden death; ventricular tachycardia and fibrillation.</td>
</tr>
<tr>
<td>M.K. (#113)</td>
<td>26 M</td>
<td>3</td>
<td>None</td>
<td></td>
</tr>
</tbody>
</table>

*Patient numbers refer to their order in operative series.
†Intraoperative death at second septal myotomy-myectomy performed three years after initial operation.
¶A previous septal myotomy-myectomy had been performed at another institution one year previously.

Abbreviations: AF = atrial fibrillation; CAD = coronary artery disease; CHB = complete heart block; CVA = cerebrovascular accident; LV = left ventricle; mo. = months; MV = mitral valve; postop = postoperative.

postoperatively, or both (table 2). These abnormalities included clinically significant chronic obstructive pulmonary disease (chronic bronchitis) in three patients, obesity (body weight ≥ 25% over the recommended weight for sex and height\(^{19}\)) in three patients, systemic hypertension (average blood pressure of ≥ 160/95 mm Hg in the hospital, and/or a history of hypertension requiring medical therapy) in two patients, particularly severe, chronic congestive heart failure associated with frank pulmonary edema in three patients, significant coronary artery disease in two patients, ventricular fibrillation in one patient, and chronic alcoholism in one patient. The presence of one or more of these potentially complicating cardiovascular or general medical problems was significantly more common in patients who died late postoperatively (9 of 11 or 82%) than in the surviving patients (41 of 96 or 43%; \(P < 0.05\)). Furthermore, the presence of paroxysmal atrial fibrillation alone (minimum of two episodes) appeared to be a significant contributing factor to poor clinical outcome and eventual death (by virtue of contributing to poor cardiac function, or as an antecedent to a cerebrovascular accident). In four patients the arrhythmia occurred both preoperatively and postoperatively, and in another patient it occurred only postoperatively. The prevalence of preoperative and/or postoperative atrial fibrillation in the patients who died late (5 of 11 or 45%) was significantly greater than in those patients who have survived (14 of 96, or 15%; \(P < 0.05\)). Of the 13 patients with preoperative atrial fibrillation, 12 had this arrhythmia persist postoperatively. Hence operation did not abolish atrial fibrillation in patients with IHSS.

In two patients who died late postoperatively a ventricular septal defect had been created at the time of septal myotomy-myectomy. In one of these patients (C.I., #93), who had associated coronary artery disease, the ventricular septal defect was large (pulmonary-to-systemic flow ratio of 2.0) and complete heart block was also produced. This patient died suddenly and unexpectedly two years later despite the presence of a functioning pacemaker. In the other patient (L.P., #35) the ventricular septal defect was also large (pulmonary-to-systemic flow ratio of 2.5), but complete heart block was not produced. The ventricular septal defect was repaired by operation four years after septal myotomy-myectomy, but the patient continued to have severe symptomatic limitation until his death one year later. It should be pointed out, however, that two other patients in the study group had hemodynamically significant ventricular septal defect (pulmonary-to-systemic flow ratios of 1.5 and 1.7) produced by operation, including one with complete heart block. These two patients have survived 11 and eight years postoperatively, although both are severely symptomatic. Five other patients with permanent complete heart block (operatively produced in three, spontaneous with late postoperative onset in two) have also survived.

Symptomatology

The latest preoperative and the most recent postoperative symptomatic state of the 96 survivors and the 11 patients who died late of cardiomyopathy are summarized in terms of New York Heart Association functional classes (fig. 3). The three patients who died late of causes other than cardiomyopathy did not differ from other surviving or nonsurviving patients with regard to preoperative and/or postoperative clinical or hemodynamic findings and will be excluded from the analysis. Of the 95 patients who were symptomatic preoperatively and have survived to the present, 81 have perceived, without the need for cardioactive medications, an improvement in their symptomatic state after operation sufficient to be assigned to at least one lower functional class. Three other patients who progressed from class IV to
### Table 2. Circumstances of Death and Clinical Characteristics of 11 Patients Who Died Late after Operation of Causes Related to IHSS

<table>
<thead>
<tr>
<th>Patient</th>
<th>Age at death (yr)/sex</th>
<th>Time post-op (yr)</th>
<th>NYHA Class</th>
<th>LVOT gradient (mm Hg)</th>
<th>LVEDP (postop)</th>
</tr>
</thead>
<tbody>
<tr>
<td>C.F. (#1)</td>
<td>23 M</td>
<td>13</td>
<td>III</td>
<td>Preop Basal 175</td>
<td>15</td>
</tr>
<tr>
<td>W.D. (#15)</td>
<td>53 M</td>
<td>9</td>
<td>III</td>
<td>Preop Basal 75</td>
<td>12</td>
</tr>
<tr>
<td>L.R. (#21)</td>
<td>53 F</td>
<td>8</td>
<td>III</td>
<td>Preop Basal 120</td>
<td>10</td>
</tr>
<tr>
<td>B.W. (#22)</td>
<td>60 F</td>
<td>7 mo.</td>
<td>IV</td>
<td>Preop Basal 90</td>
<td>7</td>
</tr>
<tr>
<td>P.F. (#24)</td>
<td>52 M</td>
<td>8</td>
<td>III</td>
<td>Preop Basal 40</td>
<td>7</td>
</tr>
<tr>
<td>R.S. (#25)</td>
<td>40 M</td>
<td>9</td>
<td>III</td>
<td>Preop Basal 55</td>
<td>32</td>
</tr>
<tr>
<td>J.F. (#34)</td>
<td>42 M</td>
<td>3</td>
<td>III</td>
<td>Preop Basal 20</td>
<td>9</td>
</tr>
<tr>
<td>L.P. (#35)</td>
<td>64 M</td>
<td>6</td>
<td>III</td>
<td>Preop Basal 70</td>
<td>20</td>
</tr>
<tr>
<td>C.I. (#93)</td>
<td>58 M</td>
<td>2</td>
<td>III</td>
<td>Preop Basal 40</td>
<td>8</td>
</tr>
<tr>
<td>R.S. (#102)</td>
<td>50 M</td>
<td>2</td>
<td>III</td>
<td>Preop Basal 80</td>
<td>17</td>
</tr>
<tr>
<td>S.L. (#112)</td>
<td>46 F</td>
<td>1</td>
<td>III</td>
<td>Preop Basal 70</td>
<td>—</td>
</tr>
</tbody>
</table>

* >75% luminal narrowing of left anterior descending and left circumflex arteries at necropsy.

†Successfully resuscitated from documented episode of ventricular fibrillation 18 months prior to operation.

‡50-70% luminal narrowing of left anterior descending artery and 70-90% narrowing of right coronary artery by coronary arteriography 3 months prior to operation (implantation of two aortocoronary bypass grafts and septal myotomy-myectomy); at operation patient incurred traumatic ventricular septal defect (pulmonary to systemic flow ratio = 2.0 with pulmonary arterial pressure of 45/15 mm Hg), which was not repaired, and complete heart block.

§At the time of septal myotomy-myectomy the patient incurred a traumatic ventricular septal defect (pulmonary to systemic flow ratio = 2.4 with pulmonary arterial pressure of 55/10 mm Hg) which was repaired four years later.

Abbreviations: AR = aortic regurgitation; CAD = coronary artery disease; CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; CVA = cerebrovascular accident; LVOT = left ventricular outflow tract; PAF = paroxysmal atrial fibrillation; PND = paroxysmal nocturnal dyspnea.

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**Figure 2.** Percent survival after operation for 117 patients with IHSS plotted as a function of time in the study. Included in the analysis as an operative death is one patient who died at the time of his second septal myotomy-myectomy performed three years after an initial operation.

**Figure 3.** Preoperative and postoperative functional class and clinical outcome in 107 patients surviving operation. Three patients who died of cardiovascular causes unrelated to IHSS have been excluded. NYHA = New York Heart Association.
tion, and remained asymptomatic for periods of seven months to 16 years (median two years) before symptoms recurred. Six of the other seven patients showed improvement in symptomatic state to class II immediately following operation. Hence, 13 of the 14 surviving patients who were not significantly improved when evaluated late postoperatively did experience transient but significant improvement (to at least one lower functional class) early after operation. Likewise, 10 of the 11 patients who died late postoperatively of cardiomyopathy also experienced symptomatic improvement early after operation (including five patients who improved transiently to functional class I).

Eight of the 14 surviving patients who were not improved late postoperatively had one or more potentially complicating cardiovascular or general medical problems. Such complicating factors were significantly more common in the combined population of patients who either did not show long-lasting symptomatic improvement after operation or died (17 of 25, 68%), compared to the patients who survived and were improved (33 of 82, 40%, \(P < 0.05\)).

Surviving patients and those who died late of cardiomyopathy did not differ with respect to the particular symptom complex present preoperatively. Of the 95 surviving patients who had been symptomatic preoperatively, 75 (79%) reported symptoms of congestion (dyspnea with exertion, fatigue, orthopnea, or paroxysmal nocturnal dyspnea) as well as chest pain of apparent cardiac origin; syncope had occurred in 36 of these 75 patients. Sixteen (17%) of the 95 patients reported only congestive symptoms without chest pain. Of the remaining four patients, three had chest pain and syncope and one had chest pain only. Of the 11 patients who died late of cardiomyopathy nine had both congestive symptoms and chest pain preoperatively, and the remaining two patients had congestive symptoms only; seven of the 11 patients who died late of cardiomyopathy postoperative catheterization was performed in 103 of these 107 patients. The initial postoperative study was usually performed six to nine months after operation, and in 25 patients subsequent hemodynamic assessments were also made one to 15 years after operation.

In 99 of the 103 postoperative hemodynamic studies, the systolic pressure gradient between the left ventricle and a systemic artery was measured both under basal conditions and with provocation (i.e., with Valsalva maneuver, isoproterenol infusion, or amyl nitrite administration); in the remaining four patients this assessment was made only under basal conditions. In patients who have had more than one postoperative catheterization, only data from the most recent study are presented.

The peak systolic pressure gradients between the left ventricle and a systemic artery recorded preoperatively under basal conditions ranged from zero to 210 mm Hg, and in 79 of the 107 patients the outflow gradient was ≥ 50 mm Hg (average 73 mm Hg). The 28 patients with gradients < 50 mm Hg under basal conditions had gradients ≥ 50 mm Hg produced by provocative maneuvers (i.e., provocable obstruction). Patients with provocable obstruction did not differ from patients with obstruction under basal conditions with regard to postoperative survival; 10% of patients with gradients ≥ 50 mm Hg under basal conditions and 11% of patients with only provokable obstruction died. In addition, 85% of survivors with gradients ≥ 50 mm Hg under basal conditions improved symptomatically postoperatively, compared to 88% of survivors with provocable gradients.

Peak systolic pressure gradients between the left ventricle and a systemic artery recorded postoperatively under basal conditions ranged from zero to 55 mm Hg; the postoperative gradient was less than the preoperative gradient in all but one patient (in whom the gradient increased by 20 mm Hg). No outflow gradient was present under basal conditions in 85 of the 103 patients; in 12 of the other 18 patients the gradients were 5–20 mm Hg. Outflow gradients were elicited with provocative maneuvers postoperatively in 54 patients. These gradients ranged from 5 to 120 mm Hg.

### Hemodynamic Data

Preoperative cardiac catheterization was performed in each of the 96 surviving patients and also in the 11 patients

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<table>
<thead>
<tr>
<th>Associated cardiovascular and medical problems</th>
<th>Postoperative clinical course</th>
<th>Circumstances of death</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>Asymptomatic; CVA × 2; Mild CHF</td>
<td>Sudden; died in sleep</td>
</tr>
<tr>
<td>PAF</td>
<td>Chronic CHF (with pulmonary edema × 2)</td>
<td>Sudden during sedentary activity</td>
</tr>
<tr>
<td>Obesity, PAF (post only)</td>
<td>Chronic CHF (with pulmonary edema × 1)</td>
<td>Marked increase in CHF one week prior to death</td>
</tr>
<tr>
<td>Obesity, diabetes, PAF, COPD</td>
<td>Chronic CHF (with pulmonary edema); CVA × 2</td>
<td>Severe CHF; probable CVA</td>
</tr>
<tr>
<td>CAD*, obesity, COPD, hypertension</td>
<td>Asymptomatic</td>
<td>Severe CHF</td>
</tr>
<tr>
<td>CAD†, hypertension, moderate AR</td>
<td>Dysspnea, orthopnea, fatigue</td>
<td>Severe CHF</td>
</tr>
<tr>
<td>Chronic alcoholism, PAF, cardiac arrest</td>
<td>Occasional chest pain; mild dyspnea</td>
<td>Severe CHF</td>
</tr>
<tr>
<td></td>
<td>Successfully resuscitated from episode of ventricular tachycardia and fibrillation proceeded by bouts of atrial fibrillation 12 days after operation; chronic CHF</td>
<td>Severe CHF</td>
</tr>
</tbody>
</table>

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The peak systolic pressure gradients between the left ventricle and a systemic artery recorded preoperatively under basal conditions ranged from zero to 210 mm Hg, and in 79 of the 107 patients the outflow gradient was ≥ 50 mm Hg (average 73 mm Hg). The 28 patients with gradients < 50 mm Hg under basal conditions had gradients ≥ 50 mm Hg produced by provocative maneuvers (i.e., provocable obstruction). Patients with provocable obstruction did not differ from patients with obstruction under basal conditions with regard to postoperative survival; 10% of patients with gradients ≥ 50 mm Hg under basal conditions and 11% of patients with only provokable obstruction died. In addition, 85% of survivors with gradients ≥ 50 mm Hg under basal conditions improved symptomatically postoperatively, compared to 88% of survivors with provocable gradients.

Peak systolic pressure gradients between the left ventricle and a systemic artery recorded postoperatively under basal conditions ranged from zero to 55 mm Hg; the postoperative gradient was less than the preoperative gradient in all but one patient (in whom the gradient increased by 20 mm Hg). No outflow gradient was present under basal conditions in 85 of the 103 patients; in 12 of the other 18 patients the gradients were 5–20 mm Hg. Outflow gradients were elicited with provocative maneuvers postoperatively in 54 patients. These gradients ranged from 5 to 120 mm Hg.
and were ≥ 50 mm Hg in 21 patients, including 15 patients with no or trivial gradients (≤ 20 mm Hg) under basal conditions. In none of the 25 patients with serial postoperative catheterizations was there evidence that the left ventricular outflow gradient had recurred at any time after operation.

No significant difference was evident between the 96 survivors and the 11 patients who died late with regard to the magnitude of the preoperative left ventricular outflow gradient under basal conditions (72 ± 5 mm Hg [SE] vs 76 ± 13 mm Hg) (fig. 4), the change between the preoperative and postoperative outflow gradient under basal conditions in patients with preoperative gradients ≥ 50 mm Hg (89 ± 3 mm Hg vs 93 ± 19 mm Hg) (fig. 4), or the maximal postoperative gradient under basal conditions or with provocation (23 ± 3 mm Hg vs 11 ± 7 mm Hg) (fig. 5).

Only one of the 23 patients with small preoperative outflow gradients under basal conditions (< 25 mm Hg) died late postoperatively (although three other patients did not show long-lasting symptomatic improvement).

None of the 25 patients who either died late postoperatively or failed to show long-lasting symptomatic improvement (and underwent their most recent hemodynamic evaluation two to 15 years after operation) had > 5 mm Hg gradient under basal conditions postoperatively.

Left ventricular end-diastolic pressure (LVEDP) measured preoperatively in 107 patients ranged from 5 to 45 mm Hg (mean 18 mm Hg) (fig. 6). Postoperative LVEDP was measured in 103 of the 107 patients and ranged from 4 to 38 mm Hg (mean 17 mm Hg). Of the 73 patients in whom LVEDP was abnormally elevated preoperatively (> 12 mm Hg) and was also measured postoperatively, 48 showed diminished LVEDP postoperatively; in only 18 patients did LVEDP become normal postoperatively. Of the 30 patients with normal preoperative LVEDP, 22 became abnormally elevated postoperatively and eight remained normal. Hence, LVEDP measured postoperatively was abnormally elevated in 77 (75%) of 103 patients. There was no significant difference between the survivors and the late deaths with regard to the magnitude of the preoperative LVEDP (19 ± 1 mm Hg vs 16 ± 2 mm Hg) or the postoperative LVEDP (17 ± 1 mm Hg vs 14 ± 3 mm Hg), or the change between preoperative and postoperative LVEDP (fig. 6). Furthermore, there was no difference between survivors and patients dying late with regard to preoperative or postoperative mean left atrial or pulmonary arterial wedge pressures.

To determine whether persistent functional limitation following operation could be related to a poor hemo-
dynamic result, postoperative functional class was compared with hemodynamic variables measured after operation in the 96 survivors. There was no correlation between the postoperative functional class and the hemodynamic result in this group of patients; of the 14 patients in whom marked symptomatic persistence after operation, nine had no or trivial postoperative left ventricular outflow obstruction under basal conditions and with provocation (≤ 25 mm Hg) and six had normal or only slightly elevated LVEDP (< 15 mm Hg).

**Electrocardiographic Findings**

Electrocardiographic data are summarized in table 3. Preoperatively, 29 (27%) of the 107 surviving patients and patients dying late showed evidence of conduction abnormalities on the electrocardiogram. Postoperatively, conduction abnormalities were present in 99 (96%) of 103 patients in whom an electrocardiogram without pacemaker artifact was available; 47 (45%) of the 103 patients showed typical left bundle branch block. No differences were evident between those 96 survivors and the 11 patients who died late due to hypertrophic cardiomyopathy with regard to the prevalence or the type of pre or postoperative electrocardiographic conduction abnormality. Furthermore, postoperative electrocardiographic abnormalities did not differ between those patients who died suddenly and those who died of chronic congestive heart failure; preoperatively, ten of these 11 patients showed no conduction abnormality.

**Discussion**

In previous publications from this Institute, the relatively short-term results of operation in patients with IHSS have

<table>
<thead>
<tr>
<th>Type of ECG conduction abnormality</th>
<th>No. patients preop†</th>
<th>Survivors</th>
<th>No. patients postop‡</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>78 (73%)</td>
<td>3†† (3%)</td>
<td>1††† (10%)</td>
<td>4 (4%)</td>
</tr>
<tr>
<td>Typical LBBB</td>
<td>2 (2%)</td>
<td>44 (47%)</td>
<td>3 (30%)</td>
<td>47 (45%)</td>
</tr>
<tr>
<td>IVCD of LBBB type§</td>
<td>5‡‡ (7%)</td>
<td>29 (31%)</td>
<td>2 (20%)</td>
<td>31 (30%)</td>
</tr>
<tr>
<td>LAHB¶</td>
<td>12‡‡‡ (11%)</td>
<td>10 (11%)</td>
<td>1 (10%)</td>
<td>11 (11%)</td>
</tr>
<tr>
<td>LAD§</td>
<td>7 (7%)</td>
<td>7 (8%)</td>
<td>3 (30%)</td>
<td>10 (10%)</td>
</tr>
<tr>
<td>CHB with functioning pacemaker postop**</td>
<td>—</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td>107</td>
<td>96</td>
<td>11</td>
<td>107</td>
</tr>
</tbody>
</table>

‡Precedes assessment of ECG conduction abnormality.
††Each of the three patients had normal QRS duration of <0.12 sec and normal mean QRS axis. Hence, a conduction abnormality could not be definitively identified. However, in two of the three patients the postoperative QRS duration was increased by 0.03 sec over the preoperative value which was, at least, presumptive evidence for the presence of conduction system damage.

§ Represents analysis of the last electrocardiogram obtained before hospital discharge.

¶§ Mean QRS axis > -30° but absence of Q1 and R11 and normal QRS duration.

†††Previous septal myotomy-myectomy performed elsewhere in one patient.

**Abbreviations:** CHB = complete heart block; IVCD = intraventricular conduction defect; LAD = left axis deviation (> -30°); LAHB = left anterior hemiblock; LBBB = left bundle branch block.
been reported. The present investigation provides an analysis of the longer-term results of this operation in all patients operated upon since 1960, when the first such procedure was performed, through 1975. Thus, patients have been followed from one to 17 years, with an average follow-up of 5.2 years.

A patient was operated upon, with rare exception, only if symptoms severely impaired the quality of life and were not sufficiently improved by the administration of propranolol. In agreement with previous reports, while operative mortality was 8%, all but two (i.e., 2%) of the survivors experienced substantial alleviation of their cardiac symptoms early after operation. In addition, all but two patients manifested marked reduction or abolition of the left ventricular outflow gradient measured under basal conditions.

The present study reveals, as previously thought, that the operation does not totally prevent progression of symptoms and that it does not always prevent fatal events. For example, 13 patients who experienced symptomatic improvement early after operation deteriorated subsequently and are now in functional class III or IV. In addition, patients continued to die following operation from causes presumably related to their underlying cardiac disease. These deaths have either been sudden and probably due to ventricular arrhythmia, or have occurred in the setting of chronic and progressive congestive heart failure. Such observations indicate that in all patients with IHSS the cardiomyopathic process is the factor which determines the patient’s ultimate course. It is, of course impossible to determine from these data whether the patients who eventually died would have died earlier had operation not been carried out.

It is important to emphasize that virtually all severely symptomatic patients seen at the NHLBI with hypertrophic cardiomyopathy and obstruction to left ventricular outflow, who were not benefited by propranolol therapy, were operated upon. Some patients with associated medical and cardiovascular problems that may have contributed adversely to their subsequent clinical course were operated upon, even though they could not realistically have been expected to derive long-lasting symptomatic benefit from operation. Our data show that the patients who died late postoperatively or were severely symptomatic at long-term postoperative evaluation had significantly more associated medical or cardiovascular problems (pulmonary disease, obesity, hypertension, coronary artery disease, history of ventricular fibrillation, atrial fibrillation, chronic alcoholism, or severe congestive heart failure associated with pulmonary edema) than those patients who survived and were improved postoperatively.

Although late cardiac deaths still occurred, the annual rate of such events was relatively small (1.8%). An annual mortality rate of about 3% has been reported for patients with obstructive hypertrophic cardiomyopathy who were not operated upon. The implication of this comparison is that operation for IHSS does not increase, and may decrease, long-term mortality. However, such a comparison of nonoperated and operated patients is of dubious validity since patients who undergo operation constitute a different subgroup than do the nonoperated patients. Hence, it is impossible to determine definitively whether operation alters the longevity of patients with IHSS; such information can only be obtained from a prospective randomized study.

Although the principal indication for operation at our institution is the presence of severe symptoms refractory to propranolol therapy, it would be desirable to identify factors preoperatively that might predict the duration and quality of postoperative survival. Such information would be useful in weighing the option of earlier operation in certain patients. Unfortunately, our analysis of preoperative functional status, hemodynamic findings, and conduction abnormalities on electrocardiogram did not prove to be useful in predicting which patients were at risk of late postoperative death, or which patients would not experience functional improvement.

The presence of atrial fibrillation, however, seemed to be a particularly poor prognostic sign. Five of the 11 patients who died from cardiac causes late postoperatively experienced multiple episodes of atrial fibrillation. Whether such a rhythm disturbance reflects irreversible left ventricular dysfunction that ultimately causes death, or is itself an etiologically important primary cause of death, remains to
be determined. However, it should be pointed out that the presence of atrial fibrillation is not invariably responsible for poor long-term prognosis, since this rhythm was present in 15% of the long-term survivors. Moreover, almost three-fourths of these latter patients showed some improvement symptomatically following operation. Thus, although the prevalence of atrial fibrillation in patients experiencing late death was significantly higher than in survivors, atrial fibrillation per se cannot serve as the sole indication for operation in the absence of severe symptoms.

In conclusion, approximately 30% of the patients in this series either did not survive operation, died late of factors presumably related to their underlying cardiomyopathy, or did not manifest continued long-term symptomatic improvement (fig. 7). About 70% experienced substantial long-term symptomatic benefit. Furthermore, many of the patients who ultimately died or in whom severe symptoms recurred did experience gratifying initial symptomatic relief that often persisted for years after operation. As a result of these observations we believe that septal myotomy-myectomy is indicated for patients with obstructive hypertrophic cardiomyopathy who are severely symptomatic and whose symptoms do not respond satisfactorily to nonoperative treatment.

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References

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