Postoperative Follow-Up of Patients with Ventricular Septal Defect

By Hugh D. Allen, M.D., Ray C. Anderson, M.D., George R. Noren, M.D., and James H. Moller, M.D.

SUMMARY

This study deals with 341 patients who underwent operative correction of ventricular septal defect at the University of Minnesota Hospitals from 1954 to 1960. Seventy-one patients (21%) died during operation or in the immediate postoperative period; another 30 patients (9%) died following discharge from the hospital and as late as 14 years after operation. One hundred-forty patients had postoperative cardiac catheterizations, 28 of whom were catheterized more than five years after operation. Postoperative hemodynamic data were compared with available preoperative data and show no significant change in total pulmonary resistance. Although the majority of our survivors are asymptomatic, we believe that periodic postoperative clinical and laboratory evaluation is important to the continued well-being of the patient.

Additional Indexing Words:

- Hemiblock
- Pulmonary vascular disease
- Complete heart block
- Endocarditis
- Postoperative hemodynamics

VENTRICULAR SEPTAL DEFECT has been the subject of innumerable articles relating to clinical and laboratory features, natural history and palliative or corrective operations. Fewer articles have described the long-term follow-up of patients after closure of their defect, and these have been limited in subject, sample numbers or time span.

We have reviewed the records of 341 patients who underwent operative correction of their ventricular septal defect at the University of Minnesota Hospitals prior to 1961. To determine the long-term results of corrective operation, we have followed these patients for periods up to 17 years after operation. Some data presented here have been included in previous reports from this hospital, but this report is the first comprehensive discussion of our experience from 1954 to 1961.

Materials and Methods

Hospital records for the 341 patients were reviewed. Tabulations were made of the age at operation, immediate and delayed postoperative mortality and morbidity, preoperative and postoperative hemodynamic data, and autopsy and lung biopsy findings. Attempts were made to determine the clinical status of the surviving patients, either by direct contact with the patient or by correspondence with relatives, personal physicians or other hospitals.

Postoperative cardiac catheterizations were performed in 140 of the survivors. The patients were studied in a resting state and without premedication. Cardiac pressures were obtained routinely and oxygen values were measured by the Van Slyke method. Cardiac output was calculated using either a measured oxygen consumption or, when not available, by assuming a value of 172 cc O₂/min/m². Since many of the catheterizations were performed at a time when left atrial or wedge pressures were not routinely measured in our laboratory, our resistance values represent total pulmonary resistance, not pulmonary arterial resistance.

A Control Data Corporation Series 3300 computer was used for the storage and analysis of hemodynamic data.

Results

The status of the 341 patients is summarized in figure 1. Seventy-one patients died during the operation or in the immediate postoperative period; another 30 died in the follow-up period. Of the 240 survivors, 150 have been followed more than ten years, 70 less than ten years, and 20 have been lost to follow-up. The total number of patient follow-up years was 2,267.

Late Deaths

Thirty patients died after hospital discharge (fig. 2). Death occurred most frequently following syncopal episodes secondary to operatively induced heart block (7 patients), or during reoperation for residual ventricular septal defect (4 patients) or tricuspid regurgitation (3 patients). Three patients with operatively induced heart block had been treated with
hemodynamic evidence of persistent or increasing pulmonary vascular disease, even though the defect was closed (table 1). Although only a small shunt was present preoperatively in patient 2, the systolic pulmonary arterial pressure rose from 35 mm Hg to 80 mm Hg postoperatively. Preoperative studies of the fourth patient had shown a systolic pulmonary arterial pressure of 100 mm Hg and a 50% left-to-right shunt at the ventricular level. Lung tissue, obtained at operation, was compared to sections of tissue obtained at autopsy examination. Each patient showed at least grade III (Heath-Edwards) changes at the time of operation and progression of vascular disease following correction.

The death of two other patients was attributed to a sudden dysrhythmia. A widened QRS complex (0.18 sec) was present postoperatively in one patient, and the other patient showed left axis deviation (left anterior hemiblock) and complete right bundle branch block (fig. 3). The latter patient died unexpectedly 14 years after operation, presumably from a Stokes-Adams episode, and his case is reported by Moss.33

Bacterial endocarditis caused death in three patients. One patient died from staphylococcal sepsis four months after complete closure of her ventricular septal defect. At autopsy, vegetations were present on the patch and on the tricuspid valve. We consider this infection to be a postoperative complication. The two other patients, each with a residual ventricular septal defect, died from bacteriologically proven bacterial endocarditis. Two other patients died from congestive cardiac failure secondary to tricuspid regurgitation. Two patients died in accidents and the three remaining patients died from unknown causes.

Hemodynamic Studies

Cardiac catheterization was performed on 140 of the 270 patients surviving the immediate postoperative period. These studies were done as part of the routine follow-up and catheterization was not limited to those patients with suspected residual abnormalities.

Residual shunt: A residual left-to-right shunt was found in 40 of the 140 patients (29%). Incidence was not related to the age of the patient at the time of operation. The residual shunt was greater than 50% and less than 75% in only five of the 40 patients. The magnitude of the shunt postoperatively was the same or less than the preoperative value in all 40 patients.

Pulmonary arterial pressure: Values for postoperative systolic pulmonary arterial pressure were available for 131 patients. The level of pressure was measured at less than 30 mm Hg in 63 patients.
(48%), between 30 and 50 mm Hg in 48 (37%), between 50 and 75 mm Hg in 11 (8%) and greater than 75 mm Hg in 9 (7%).

Postoperative levels of systolic pulmonary arterial pressure were compared with preoperative values in 124 patients (fig. 4). In 121 patients the pressure was the same or less. The three others showed a postoperative increase of 25 mm Hg or greater. The presence of a residual shunt did not adversely affect the decrease in pressure following operation.

Total pulmonary resistance: Postoperative data on total pulmonary resistance were available for 102 patients. Resistance was less than 4 mm Hg/L/min/m² in 55 patients (54%), between 4 and 6 mm Hg/L/min/m² in 18 (17%), between 6 and 8 mm Hg/L/min/m² in 13 (13%), and greater than 8 mm Hg/L/min/m² in 16 (16%).

Adequate data for determination of both pre- and postoperative total pulmonary resistance were available for 74 patients, including 24 with residual shunts. The mean value of total pulmonary resistance did not change significantly following operation (fig. 5). The resistance dropped more than three units following operation in nine patients and increased more than three units in 12 patients. The resistance remained the same in the other 53 patients.

Late postoperative catheterization: Cardiac catheterization was performed preoperatively and again at least five years following operation in 28 patients. Suspected residual pulmonary arterial hypertension was one reason for carrying out repeated studies. A residual shunt greater than 33% was not present in any of the 28 patients.

Seventeen patients had a postoperative systolic pulmonary arterial pressure under 35 mm Hg; the other 11 had pressure values between 40 and 100 mm Hg. None of the 28 patients showed a postoperative pressure higher than the preoperative value.

Total pulmonary resistance was less than 4 mm Hg/L/min/m² in 14 patients and in the other 14 ranged to 18 mm Hg/L/min/m². In six patients, the resistance rose at least 3 mm Hg/L/min/m² from the preoperative value.

### Table 1

**Late Deaths from Pulmonary Vascular Disease**

<table>
<thead>
<tr>
<th>Patient</th>
<th>L→R shunt (%)</th>
<th>Pulmonary arterial pressure (mm Hg)</th>
<th>L→R shunt (%)</th>
<th>Pulmonary arterial pressure (mm Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>34</td>
<td>125/55 85</td>
<td>0</td>
<td>131/82 97</td>
</tr>
<tr>
<td>2</td>
<td>39</td>
<td>35/8 15</td>
<td>0</td>
<td>80/40 50</td>
</tr>
<tr>
<td>3</td>
<td>38</td>
<td>80/35 60</td>
<td>0</td>
<td>80/30 52</td>
</tr>
</tbody>
</table>

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### Figure 3

Electrocardiogram of patient whose late death was attributed to arrhythmia. Complete right bundle branch pattern and left axis deviation (left anterior hemiblock) are present.

### Figure 4

Comparison of preoperative and postoperative levels of pulmonary arterial systolic pressure in 124 patients. Closed circle indicates patients with no residual shunt. Open circle indicates patients with residual shunt.

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Fifteen patients had two catheterizations following operation; the interval between the studies was at least four years. The systolic pulmonary arterial pressure remained constant in 10 patients. In the other three patients (fig. 6a), the pressure increased 13 and 19 mm Hg. Preoperative studies of these three patients had revealed a left-to-right shunt greater than 60% and a systolic pulmonary arterial pressure ranging from 78 to 120 mm Hg. Total pulmonary resistance was studied in 11 of the 15 patients. Serial studies showed that in three patients total pulmonary resistance rose more than 3 mm Hg/L/min/m²; these patients were asymptomatic. In the remaining eight patients, resistance was unchanged (fig. 6b). The Student's t-test showed no significant change in either systolic pulmonary arterial pressure or total pulmonary resistance in any of the 15 serially studied patients.

Late Postoperative Complications

Thirty-five patients developed complete atrioventricular block immediately following operation. The block was transient in 21 patients; each of these subsequently developed a normal sinus rhythm and the block did not reappear. Fourteen patients showed persistent block; eight of these patients died, including three in whom pacemakers had been implanted.

There have been no known cases of postoperative bacterial endocarditis other than those discussed earlier.

Clinical Status

Cardiac symptoms (usually a limitation in exercise tolerance) were present in 10 of 199 patients reporting on this point. Five symptomatic patients underwent postoperative cardiac catheterization. In one patient the pulmonary arterial pressure was 50 mm Hg, in two other patients the pressure was between 30 and 50 mm Hg, and in the other two patients it was less than 30 mm Hg. Cardiac catheterizations had not been performed in the other five symptomatic patients. Twelve asymptomatic patients with postoperative studies had pulmonary arterial systolic pressure over 50 mm Hg, including two patients with residual left-to-right shunts of over 50%.

Sixteen patients reported participation in organized competitive sports; none had significant residual defects. Twenty-seven patients applied for life insurance and eight were refused, including six with no residual cardiac abnormality. Four patients who obtained insurance had no residual defects and were allowed standard premium rates. Increased premium

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**Figure 5**
Comparison of preoperative and postoperative level of total pulmonary resistance in 74 patients. Symbols as in figure 4.

**Figure 6**
Serial postoperative cardiac catheterization data. a) Level of pulmonary arterial systolic pressure. b) Level of total pulmonary resistance. Serial observations of an individual patient connected. Symbols as in figure 4.
rates were demanded of the other 15 patients, including 12 with no evident residual cardiac abnormality. Two patients with no known residual defects were drafted into the military service; one failed his induction physical examination and the other was discharged 29 days after induction because of chest pain. One patient with no residual defect volunteered for military service and served uneventfully.

Discussion

A high number of late deaths (30) occurred in our patients, representing almost 10% of the initial group undergoing operation and 11% of those surviving the early postoperative period. Deaths occurring in patients undergoing operation for ventricular septal defect or those occurring from complete heart block are not unexpected and have been described by others.\textsuperscript{1, 5, 10} Five of our patients died from tricuspid insufficiency secondary to transection of the papillary muscle of Lancisi. The number of deaths related to these three causes have been reduced due to improved operative techniques.

Our study revealed deaths occurring from two problems that deserve special mention: 1) coexistent complete right bundle branch block and left axis deviation and 2) bacterial endocarditis.

Complete right bundle branch block was recognized early as an almost regular sequel to ventriculotomy and closure of ventricular septal defect, but the significance of its association with surgically induced left axis deviation was not appreciated until recent years.\textsuperscript{34-38} As currently interpreted, this combination represents an interruption of the right bundle of His and the anterior fasciculus of the left bundle. Subsequent interruption of the posterior fasciculus by fibrosis or infarction results in complete heart block and its attendant hazards. One of our patients showed these postoperative electrocardiographic changes and died 14 years postoperatively from development of complete block. Death in another of our patients was attributed to arrhythmia. His electrocardiogram showed an extremely broad QRS complex, but not the typical picture of bifascicular block. The postoperative occurrence of complete right bundle branch block and left posterior hemiblock may also represent a hazard. This occurrence, which can be a complication of myocardial infarction,\textsuperscript{38} has not been described or evaluated for patients undergoing repair of a ventricular septal defect. None of our patients with transient heart block following operation have redeveloped heart block, although this complication has been described by others.\textsuperscript{39}

Death was associated with bacterial endocarditis in three of our patients. A residual ventricular septal defect was present in two patients. In the third, death involved staphylococcal sepsis with vegetation on the tricuspid valve and patch and occurred within four months of operation. In this patient we feel bacterial endocarditis should be classed as a surgically associated infection. We know of no reported case of bacterial endocarditis, with or without death, in patients with successfully closed ventricular septal defects after four months of uneventful postoperative convalescence. Until 1971, we did not recommend prophylactic penicillin for patients with normal postoperative findings. The American Heart Association Committee on Rheumatic Fever has recommended that antibiotic prophylaxis be followed for these patients\textsuperscript{40} and we agree with this recommendation.

Twenty-nine percent of our patients showed a residual left-to-right shunt, a figure close to that reported by others.\textsuperscript{1, 9, 15, 20-24} In most of our patients with residual shunts, the size of the shunt was significantly reduced and further operations were not recommended. There was no significant over-all decrease in total pulmonary resistance following operation, but individual patients (particularly some under three years of age) did show a decrease. The changes in our patients were not as striking as the decreases reported by Cartmill and associates,\textsuperscript{1} Blount and Woodwarck,\textsuperscript{17} and Hallidie-Smith and associates.\textsuperscript{20}

Total pulmonary resistance tended to be higher pre- and postoperatively in those patients older than three years of age at the time of operation. This finding corresponds with the general concept of increasing pulmonary vascular resistance with age, when significant left-to-right shunts are present; it could also be related to patient selection. Similarly, occasional drops in resistance values for individual younger patients in our study conforms to the idea of less reversibility in arteriolar changes in older patients.

Since there were no significant changes in total pulmonary resistance, postoperative pulmonary arterial pressures tended to reflect changes in volume of shunt. The late serial postoperative catheterization in 15 of our patients showed no significant change in total pulmonary resistance, although some patients operated on after five years of age showed further increases in spite of closure of the shunt. The increase suggests progression of pulmonary vascular disease and has been reported by others.\textsuperscript{21, 22}

The nature of our study precluded an adequate definition of the postoperative physical and social profile of the patients. The majority of patients denied cardiac symptoms, whether residual abnormalities were present or not. Moreover, some patients reporting symptoms had no evidence of a residual cardiac abnormality. Other patients reported difficulties in obtaining jobs because of employer reluctance to hire individuals who have had heart surgery.
Operative correction for ventricular septal defect did not significantly affect changes in the level of total pulmonary resistance in our patients. Postoperative cardiac catheterization should be performed in all patients with suspected residual cardiac abnormality, generally a year following surgery, but earlier if serious symptoms or signs of failure persist. Careful attention should be paid to patients with abnormal electrocardiograms, particularly those with evidence of bifascicular block. Antibiotic prophylaxis against bacterial endocarditis should be recommended for all in accordance with the recommendations of the American Heart Association. Periodic clinical evaluation of patients at five year intervals is advisable, as subtle but significant complications always seem to become manifest as experience and understanding increases.

Acknowledgment

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