Valve Replacement in Rheumatic Heart Disease*

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In a consecutive series of 50 patients undergoing single and multiple cardiac valve replacement operations for rheumatic heart disease at the Peter Bent Brigham Hospital, there were only two in-hospital deaths and four late deaths. Rehabilitation was good to excellent in 82 percent of patients, with follow-up studies from 6 to 18 months. Advances in surgical management contributing to lowering operative risks include use of total hemodilution, hypothermic ischemic cardioplegia, simple, gentle and accurate valve fixation of hemodynamically proved valves, avoidance of air embolism, and strict adherence to a few simple principles in postoperative care.

Replacement of intracardiac valves has become safer and more efficacious since its inception. Safety, manifested by lower rates of mortality and morbidity, has improved most markedly as a result of better prostheses, better surgical technique, and simpler yet more sophisticated cardiopulmonary bypass. Efficacy has improved due to development of prosthetic and tissue valves allowing restoration of nearly normal mechanical function and better management of the thromboembolic potential of prostheses.

To assess the current risk and early results of valve replacement in patients suffering from symptomatic late sequelae of rheumatic heart disease, we have reviewed a consecutive series of 50 patients who underwent mitral valve replacement alone, or in combination with, other valve replacement from July, 1970, through December, 1971.

The in-hospital mortality of 4 percent is lower than generally reported for patients needing mitral or multiple valve replacement, although the preoperative hemodynamic status of the patient, age, number of antecedent cardiac operations, and other factors are similar. Details of surgical management which contribute to a low operative risk for valve replacement are described.

Clinical Material

The records of 50 consecutive patients undergoing valve replacements for rheumatic heart disease at the Peter Bent Brigham Hospital from July 1, 1970, through Dec. 30, 1971, were reviewed. Follow-up studies were complete in all patients for 6 to 18 months, averaging 13 months.

All patients were evaluated before operation, with complete history and physical examination, hematologic and blood chemistry studies and electrocardiography. Phonocardiography was performed in 40 patients, and 46 patients underwent cardiac catheterization. The clinical classification suggested by Harken and Ellis was used (Fig 1) to describe the severity of disability before and after surgery. Cardiac rhythm before and after surgery, severity of congestive heart failure, embolization before and after surgery, previous cardiac operations, presence of significant extracardiac disease, and extent of rehabilitation after valve replacement were evaluated in all patients.

All atrioventricular valves were replaced with prostheses, except for one patient in whom a stent-mounted homograft was used. The atrioventricular prosthesis utilized was the Harken caged disc (type 4) valve, with a single sewing ring (Surgitool. Artificial Organs Division, Travenol Laboratories, Inc., Morton Grove, III). This valve, with its relatively bulky Silastic disc and four slender metal struts, has been shown to have excellent hemodynamic characteristics and a low tendency toward thromboembolism. In patients with aortic, as well as mitral, valve replacement, Starr-Edwards model 1200...
diuretic therapy was present in 35 patients (70 percent) and tricuspid valve replacement had a prior pulmonary mitral valve replacement. One patient treated with mitral systemic emboli and four of five pulmonary emboli had obtained in 42 patients (84 percent). Atrial fibrillation was tion. Severe heart failure involving a need for chronic heart failure as manifested by dyspnea, pulmonary or peripheral edema was present in all patients before opera-

75% of the 38-71 years, with an average of 53 years. There were 19 men and 31 women. A

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75% of the 50 patients ranged from 38 to 71 years, with an average of 53 years. There were 19 men and 31 women. A positive history of rheumatic fever, joint pains, or chorea was obtained in 42 patients (84 percent). Atrial fibrillation was present in 42 patients (84 percent) before surgery. Conges-
tive heart failure as manifested by dyspnea, pulmonary or peripheral edema was present in all patients before operation. Severe heart failure involving a need for chronic diuretic therapy was present in 35 patients (70 percent) before operation.

75% peripheral arterial embolization had occurred in five patients (10 percent), and five patients had experienced at least one episode of pulmonary embolization before surgery. All systemic emboli and four of five pulmonary emboli had occurred in patients who subsequently underwent isolated mitral valve replacement. One patient treated with mitral and tricuspid valve replacement had a prior pulmonary embolus.

Significant associated disease unrelated to rheumatic fever occurred in 20 patients (40 percent). Most frequent unrelated diseases were: coronary artery disease (16 percent), diabetes mellitus (14 percent), chronic obstructive lung disease (10 percent), and hypertension (4 percent).

There were 16 patients (32 percent) who had undergone previous cardiac surgery as shown in Table 1. Mitral valvulo-

75% at flow rates dependent upon gravity drainage from the venous system. The bubble oxygenator at flow rates dependent upon

75% of the patient's left to expose the mitral valve. The valve is excised together with the chordae tendineae and tips of the papillary muscles. A 5 to 8 mm cuff

** Table 1—Previous Cardiac Operations in Patients Selected for Surgery

<table>
<thead>
<tr>
<th>Valve Replaced</th>
<th>Total No. of Cases</th>
<th>Closed Valvuloplasty</th>
<th>Valve Replaced</th>
<th>Total</th>
<th>%</th>
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<tbody>
<tr>
<td>Mitral</td>
<td>33</td>
<td>10</td>
<td>1</td>
<td>11</td>
<td>33</td>
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<td>Mitral and aortic</td>
<td>12</td>
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<td>3</td>
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<tr>
<td>Mitral and tricuspid</td>
<td>4</td>
<td>2</td>
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<td>2</td>
<td>50</td>
</tr>
<tr>
<td>Mitral, aortic and tricuspid</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
<td>14</td>
<td>2</td>
<td>16</td>
<td>32</td>
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** Table 2—Hemodynamic Status Before Operation

<table>
<thead>
<tr>
<th>Valve Replaced</th>
<th>LA* or PC**&gt;15 mm Hg</th>
<th>PA+ [Mean] mm Hg</th>
<th>Cardiac Index&lt;2L/ Min/M²</th>
<th>LVEDP++ mm Hg</th>
<th>PVR III*</th>
<th>Total</th>
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<tbody>
<tr>
<td>Mitral (31)</td>
<td>29</td>
<td>27</td>
<td>7</td>
<td>4</td>
<td>15</td>
<td>12</td>
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<tr>
<td>Mitral and aortic (12)</td>
<td>8</td>
<td>8</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Mitral and tricuspid (3)</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Mitral, aortic and tricuspid (1)</td>
<td>—</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Total (46)</td>
<td>40</td>
<td>38</td>
<td>10</td>
<td>8</td>
<td>24</td>
<td></td>
</tr>
</tbody>
</table>

*Left atrial
**Pulmonary capillary wedge pressure
†Pulmonary artery
‡Left ventricular end-diastolic pressure
§Pulmonary vascular resistance

**Surgical Technique

*Mitral Valve Replacement

A median sternotomy incision is now uniformly used for mitral valve replacement. Venous cannulae are placed through pursestring sutures in the right atrium into the superior and inferior cavae. No caval tapes are used. The arterial inflow catheter is a simple tube (Bardic no. 18 or no. 20) inserted through a pursestring suture into the ascending aorta, as described by Daily et al.³ Cardiopulmonary bypass is maintained using a Travenol 6LF bubble oxygenator at flow rates dependent upon gravity drainage from the venous system. The average flow in adults is 3 to 4 L/min (1.8-2.4 L/min/M²). Patients are cooled to 28-30°C, the heart is electrically fibrillated, and the aorta is cross-clamped. Local cardiac cooling is obtained by continuous infusion of cold (4°C) lactated Ringer's solution into the pericardial wall through a sterile nasogastric tube during the ischemic interval. The left atrium is opened through an incision on the right side, between the interatrial groove and the entrance of the right pulmonary veins. The atrial incision is only about 6 cm in length. A small retractor is inserted, and the heart is rotated toward the patient's left to expose the mitral valve. The valve is excised together with the chordae tendineae and tips of the papillary muscles. A 5 to 8 mm cuff

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of both the anterior and posterior mitral leaflets is preserved. It is considered essential to divide the secondary chordae tendineae to completely mobilize the valve rim allowing retraction of the edges into the surgeon’s view. The ischemic heart, cooled by bathing in 4°C lactated Ringer’s solution, is quite soft and pliable. The surgeon is thus able to suture the prosthetic sewing ring to the mitral “annulus” with precision and gentleness. The relatively dry field provided by aortic cross-clamping is essential to precision. A suitable size prosthetic or tissue valve is then affixed to the “annulus,” using either simple interrupted sutures or horizontal mattress sutures of prosthetic material. The valve is made incompetent by placing a catheter through the right coronary artery is occluded by a vascular forceps. A needle vent is placed to evacuate air from the aortic root. The patient is then rewarmed to 37°C and the heart is defibrillated. When all air has been expressed from the beating heart via the aortic vent and by aspiration of the ventricular apex and left atrium, bypass is discontinued in a gradual fashion, with transfusion from the pump suitable to allow maintenance of an arterial blood pressure mean of 70 to 80 mm Hg. Both left and right atrial pressures are monitored to assess the need for infusion of catecholamines or additional transfusion. A temporary pacing wire is implanted into the right ventricular outflow tract in all patients. The wire is removed approximately 48 hours prior to discharge from the hospital.

Aortic Valve Replacement

A median sternotomy incision is used. After establishment of cardiopulmonary bypass, the aortic base is opened in a curvilinear fashion, with the inferior arm of the incision extending into the noncoronary sinus of Valsalva. If coronary perfusion is used, both the right and left coronary arteries are perfused from independent pumps at a mean pressure of approximately 90 mm Hg. The usual flow obtained is 100 to 150 ml/min in the left coronary and 75 to 125 ml/min in the right. When the heart is locally cooled by continuous infusion of cold Ringer’s solution into the pericardium, no coronary perfusion is necessary. The aortic valve is excised totally, including all residual calcium. Particular care is taken to achieve a firm fixation of the valve, using simple interrupted or horizontal mattress sutures. The aortotomy is closed with running suture and all air is expressed from the heart prior to discontinuance of bypass.

Valve Replacement in Rheumatic Heart Disease

Multiple Valve Replacement

When both the aortic and mitral valves are to be replaced, the aortic valve is resected first, and coronary perfusion or cooling of the heart is instituted. The left atrium is opened as described above for mitral valve replacement, and the mitral valve replaced in the usual fashion. The aortotomy is closed tightly. The aortic valve is then replaced and the heart resuscitated. All air is removed as described above for aortic valve replacement. The duration of aortic cross-clamping when coronary artery perfusion is used averages about 90 minutes and about 75 minutes when no coronary perfusion is used.

Tricuspid valve replacement is performed when necessary after mitral or aortic replacement and during the period of rewarming. The chordae tendineae of the tricuspid valve and a small amount of leaflet tissue are excised. The entire septal leaflet is preserved and sutures in this area are taken in the base of the leaflet rather than in the “annulus” to avoid damage to the atrioventricular conduction tissue, which lies adjacent to the attachment of the septal leaflet.

Drainage of the Pericardium

The pericardium is drained by two plastic large bore tubes connected to suction of 20 cm water intensity. One tube is placed in the deepest recess of the pericardium posterior to the left ventricle and the other lies in the anterior mediastinum beneath the sternal closure site. No arrhythmia has resulted from the posterior tube. Avoidance of drainage into the pleural cavities greatly decreases postoperative discomfort, and thereby aids in achieving adequate ventilation. Tamponade is avoided by rigorous attention to maintenance of tube patency during the first several hours after operation. This is readily done by the nurses.

Closure of the Sternum

 Tight approximation of the sternal halves by simple wire loops is essential to smooth recovery. No motion between the sternal edges is tolerable, since pain and apprehension are produced, which may significantly affect the patient’s capability for clearing his airway by coughing.

Postoperative Care

Postoperative care is remarkably uncomplicated when the operation has been carefully and gently conducted and when all significant mechanical abnormalities have been corrected. A few general principles are essential, however, in all cases.
Blood volume replacement and the use of vasoactive drugs is governed by arterial blood pressure and consideration of left and right atrial pressures as described elsewhere.  

Assisted ventilation is discontinued only when significant bleeding has stopped, the patient is totally alert and cooperative, and when the tidal volume exceeds 400 ml, with a peak inspiratory capability (against obstruction) of 15 to 20 cm of water. Cachectic and weakened patients may frequently require ventilatory assistance for 36 hours or longer. Previous strokes may compromise both diaphragmatic and intercostal motion and cough coordination. Particular care is needed in these instances. Pulmonary physiotherapists assist the patient to cough and perform exercises in deep breathing for several days after extubation. Nasotracheal suction is very rarely indicated.

Serious arrhythmias are avoided by maintenance of serum potassium levels between 4.5 and 5.5 mEq/L and by minimal use of digitalis preparations.

Drainage tubes are removed 18 to 24 hours after surgery and patients are ambulatory without delay.

All patients have been treated with sodium warfarin after prosthetic valve replacement to maintain the prothrombin time at approximately twice the control value measured in seconds. No other anticoagulant is used. Sodium warfarin therapy is started on the second day after surgery in small doses (2.5 to 7.5 mg) to gradually prolong the prothrombin time to nearly twice normal.

RESULTS

Mortality

There were only two in-hospital deaths in this consecutive series of 50 patients undergoing valve replacement for rheumatic heart disease (Table 3). One patient died of cerebral embolism following mitral valve replacement, and one patient died from hyperkalemia ten days after mitral and tricuspid valve replacement.

Late Mortality and Extent of Rehabilitation

All patients have been interviewed and examined at intervals of three to six months after surgery.

There have been three late deaths after mitral valve replacement. One late death was due to chronic lung disease and hypoxia at three months following mitral and tricuspid valve replacement.

Rehabilitation was considered "excellent" when the patient had returned to full-time employment or was living an unrestricted life at home, "good" when activity or employment was minimally restricted, "fair" when employment was severely restricted and activity moderately restricted, and "poor" when activity was severely restricted at home. Extent of rehabilitation of patients in this series 3 to 18 months after surgery is shown in Table 4. In only one instance was there regression after achievement of satisfactory rehabilitation. This patient sustained a cerebral embolus with resultant hemiplegia six months after mitral valve replacement, after having been virtually asymptomatic. No patient experienced significant paravalvular leak or hemolysis.

Late Complications

No clinically evident pulmonary emboli occurred after operation. There were four patients in whom systemic arterial emboli were observed after surgery (8 percent). In two patients evidence of cerebral dysfunction was evident immediately after operation and was presumably due to intraoperative embolization of air or calcific debris. One of these patients died five days after operation without regaining consciousness. At autopsy, there was massive cerebral softening, with no evidence of organic vascular obstruction. The other patient experienced total blindness, which resolved within a few weeks without residual disability. There were two patients who experienced a late episode of cerebral embolization (two months and six months after surgery).

In one patient there has been significant residual aphasia and hemiparesis. Multiple episodes of embolization after valve replacement have not occurred. All postoperative emboli occurred in patients with isolated mitral valve replacement. Both patients who experienced late embolization had satisfactory prolongation of prothrombin time at occurrence of the accident.

Atrial fibrillation was present in 42 patients (84 percent) before surgery and 34 (68 percent) three months after surgery. Cardioversion and quinidine, 0.3 gm four times each day, was utilized to convert atrial fibrillation only in those patients with fibrillation present for less than one year before operation. Transient atrial fibrillation and other ephemeral arrhythmias were observed at some point in the course of many patients, but in only one instance.
was there any significant morbidity. This patient required seven days longer in-hospital convalescence because of slow atrial fibrillation following mitral and tricuspid valve replacement. Our experience with arrhythmias after valve replacement operations has been previously reported in detail elsewhere.5

**Discussion**

The series of cases herein reported is illustrative of the change which has taken place in valve replacement surgery for patients with rheumatic heart disease. The results summarized in Table 4 show what has been accomplished in achieving low operative mortality in single and multiple valve replacement. The reasons for the lower surgical mortality for valve replacement in recent years are many. Generally, however, progress may be related to advances in one of the three most important facets of valve replacement surgery, namely, safety in cardiopulmonary bypass, improvement in prosthetic valve design, and evolution of techniques for valvular implantation.

The current practice of many, if not most, centers for the performance of cardiac surgical operations involves the use of disposable bubble oxygenators. These oxygenators lend themselves readily to the use of hemodilution and provide excellent control of gas exchange, allow elimination of large requirements for homologous blood, damage blood minimally for up to three or four hours, and greatly increase ease and simplicity of operation.

Change in design of mitral valve prostheses, particularly, has been useful in eliminating the postoperative mortality and morbidity ascribable to congestive heart failure. The introduction of discoid prostheses and, more recently, homograft or heterograft valves has greatly diminished the need for concern about atroioventricular gradients with normal cardiac indices. The "small ventricle syndrome" encountered when a ball valve prosthesis was introduced into a tiny ventricular cavity (as sometimes present in mitral stenosis) with resultant atroioventricular obstruction, septal erosion and arrhythmias, is seldom, if ever, encountered with low profile valves. The Harken atroioventricular valve used in this series of operations has been demonstrated to provide normal mechanical function.6 It has been our experience that severe congestive heart failure ("low output syndrome") after mitral valve replacement surgery is now exceedingly rare. In the present series, the only two deaths were related to problems in surgical and postoperative technique and not the severity of the underlying illness. The severity of preoperative disability of patients in this series, as illustrated in Table 1, is consistent with that reported by other surgeons.7-9

Late mortality correlates more directly with severity of preoperative illness. Of the four late deaths in this series, three were due to complications directly related to end-stage rheumatic heart disease. One death was a result of bacterial endocarditis arising 16 months after surgery as a complication of purulent conjunctivitis.

Changes in the technique of valvular implantation and preoperative management of cardiac surgical patients have also reduced the risk of valve replacement. The practice of vigorous diuresis prior to surgery has been abandoned in favor of bringing patients to operation with minimal disturbance in fluid and electrolyte balance. All medications, when possible, are withheld for approximately 24 hours prior to surgery. An occasional patient may require additional short-acting digitalis immediately prior to surgery for control of atrial fibrillation, and a few patients require diuretics on the day before operation. The avoidance of hypokalemia is important. It has been our experience that digitalis toxicity is far more dangerous in the operative and immediate postoperative period than any other metabolic abnormality. The maintenance of serum potassium levels between 4.5 and 5.5 mEq/L tends to obviate this potential problem.

The use of intravenously administered morphine and relaxants as the principal analgesic medications during operation is, in our opinion, a significant advance. The cardiac output and blood pressure are minimally disturbed, and the tendency toward changes in rhythm and heart rate is less than we previously observed with other types of anesthetic management.

The technique for affixing prosthetic valves is a matter of indifference, presuming certain general principles are closely followed. The fixation must be absolutely solid, accomplished with gentleness and minimal traction upon sutures, and should be as simple and expeditious as possible. The use of pledgets, complex suturing systems, and the like, seems to prolong operating time, with no significant additional benefit. The practice of maintaining a beating heart during valve replacement surgery has

**Table 4—Rehabilitation After Valve Replacement**

<table>
<thead>
<tr>
<th>Valve</th>
<th>Mitral</th>
<th>Aortic</th>
<th>Mitral</th>
<th>Aortic</th>
<th>Mitral, Aortic</th>
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<tr>
<td>Excellent</td>
<td>21</td>
<td>9</td>
<td>1</td>
<td>1</td>
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</tr>
<tr>
<td>Good</td>
<td>6</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
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<td>Fair</td>
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<tr>
<td>Poor</td>
<td>1</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Late deaths</td>
<td>3</td>
<td>1</td>
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been abandoned by us, since the danger of air embolism is greater, the turgid heart makes perfect exposure much more difficult, and coronary sinus return obscures the operative field or necessitates suction removal, with additional blood trauma. Retraction necessary for adequate visualization of structures within the turgid beating heart makes larger incisions necessary and predisposes to the formation of unhandy tears in both the atrium and aorta. Precise attention to anatomic details, particularly the mitral "annulus," allows the avoidance of technical pitfalls which may produce severe and even fatal postoperative complications for the unwary. Preservation of the base of the posterior mitral leaflet, particularly, is of importance, since the limbs of the "annulus" may be absent over as much as a third of the chord of the posterior leaflet.

The hemodynamic data shown in Table 3 for the 46 patients who underwent preoperative catheterization at the Peter Bent Brigham Hospital illustrate the severity of the hemodynamic deficit in these patients. Persons with pulmonary hypertension, elevated pulmonary vascular resistance, lowered cardiac indices, and elevated left ventricular diastolic pressure, may undergo single or multiple valve replacement quite safely in most instances.

There has been no relationship in our experience between the number of previous operations and the surgical risk for valve replacement surgery. Of course, many patients who have had multiple previous operations are more debilitated at each subsequent operation, and this will eventually be borne out in the surgical statistics. However, there is no specific reason why surgery should be more hazardous because of a previous operation. Exposure of the heart, although technically somewhat more difficult, has now been performed so frequently in patients who have had previous cardiac operations that the methods for freeing the heart of surrounding adhesions have become quite standard and safe. Previously recognized hazards of air embolism in patients after previous cardiac surgical operations are now well controlled by totally mobilizing the heart and taking care to provide vents in the aortic base, left atrium, and left ventricular apex.

Analysis of results in this series of patients reinforces our aggressive approach toward congestive heart failure due to valvular malfunction in patients with rheumatic heart disease regardless of age, previous operations, or severity of hemodynamic aberrations.

REFERENCES