PREFERABILITY OF BIOPROSTHESSES FOR
ISOLATED AORTIC VALVE REPLACEMENT
—A Comparative Study between Mechanical
and Bioprosthetic Valves—

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Comparative long-term performance characteristics of mechanical valves and
bioprosthetic valves were analyzed retrospectively among patients who had
undergone isolated aortic valve replacement between 1968 and 1987. One
hundred sixty-seven patients received either mechanical (n = 82) or bioprosthetic (n = 85) valves. The cumulative follow-up was 926 patient-years
(mean 6.1 ± 4.7 years, ranging from 0.5 to 20.2 years, 100% complete follow-
up). Actuarial survival rate, including operative death, at 10 years was
74 ± 7% for mechanical and 77 ± 7% for bioprosthetic valve recipients. The
rates of freedom from thromboembolism, structural valve failure, prosthesis
valve endocarditis, and valve re-replacement at 10 years were 77 ± 7%, 100%,
96 ± 2% and 95 ± 3% for mechanical, and 94 ± 4%, 83 ± 8% (p < 0.05),
88 ± 5% and 75 ± 8% (p < 0.05) for bioprosthetic valve recipients, respectively.
Thromboembolism occurred more frequently in the mechanical valve
recipients (p < 0.01), and structural valve failure in the bioprostheses
recipients (p < 0.05). There was no mortality at the time of valve re-replacement.
Most of the bioprosthesis recipients received no anticoagulation
therapy beyond 3 months postoperatively. Cardiac medication in the late
postoperative period was not required in 31.3% of bioprosthetic, and 3.2%
of mechanical valve recipients (p < 0.01). These results show that bioprosthesis in the aortic position exhibits a superb antithrombogenicity and may
enable a drug-free state, though its limited durability requires reoperation.

The choice between bioprosthetic and
mechanical valves for aortic valve replace-
ment has been controversial. The mechanical
valve is better for durability, but requires perma-
nent anticoagulant therapy for prophylaxis of
thromboembolism. Furthermore, thromboem-
bolism, valve thrombosis, and anticoagulant-
related hemorrhage are major complications in
mechanical valve recipients. The bioprosthetic
valve has limited durability, but it usually requires
no long-term anticoagulant therapy with warfarin
because of its good antithrombogenicity. This
is important with regard to the postoperative
quality of life. The patient implanted with a
bioprosthetic valve will be able to resume an
active life-style in a drug-free condition. There-
fore, from the aspects of durability and anti-
 thrombogenicity, we undertook a comparative
analysis of mechanical and bioprosthetic valves
after isolated aortic valve replacement.

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Fig. 1. Variety of prosthetic valves replaced in the aortic position from 1968 to 1987.
SE: Starr-Edwards ball valve, BS: Björk-Shiley valve, SIM: St. Jude Medical valve,

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<th>TABLE 1 PREOPERATIVE CLINICAL CHARACTERISTICS OF PATIENTS</th>
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<td>Previous aortic valve replacement (n)</td>
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<td>Predominant hemodynamic lesion (n)</td>
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<td>Regurgitation</td>
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<td>Concomitant procedure (n)</td>
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<td>OMC and/or MAP</td>
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<td>Ao. graft replace.</td>
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PATIENTS AND METHODS

One hundred sixty-seven consecutive patients who underwent isolated aortic valve replacement with either a mechanical (n = 82) or a bioprosthetic valve (n = 85) between 1968 and December 1987 at Kyushu University Hospital are the base of this study. The mechanical valves used included 17 Starr-Edwards ball, 27 Björk-Shiley, and 38 St. Jude Medical valves; bioprostheses included 41 Hancock, 3 Carpentier-Edwards porcine, 8 Ionescu-Shiley pericardial, and 33 Carpentier-Edwards pericardial valves. The Starr-Edwards ball valve was used in the early stage of this study from 1968 to 1976. Cardioplectic anoxic arrest was not employed during that period. After 1977, bioprosthetic or mechanical valves were selected arbitrarily according to the individual surgeon's preference. Recently, the St. Jude Medical valve (mechanical), and the Carpentier-Edwards pericardial valve (bioprosthetic), have been predominantly used (Fig. 1). We excluded from this analysis any patients receiving multiple valve replacements, but we included patients undergoing aortic valve replacement and other concomitant operations such as mitral commissurotomy and/or valvuloplasty, graft replacement of ascending aortic aneurysm, aortic annular augmentation, coronary artery bypass grafting, closure of ventricular septal defect, tricuspid annuloplasty, closure of aortic aneurysm orifice, and aortopulmonary central shunt.

The preoperative clinical characteristics of the patients receiving mechanical or bioprosthetic valves are listed in Table I. An analysis of multiple variables including sex ratio, preoperative functional class, cardiothoracic ratio, hemodynamic status, and predominant hemodynamic lesions showed no statistical differences. There were significant differences with respect to age and concomitant procedures. The age at operation was higher for the bioprosthetic (48.9 ± 13.7 years old) than for mechanical valve recipients (43.0 ± 15.5) (p < 0.02). This has become relatively more apparent in the last 3 years; 55.3 ± 10.9 years old for the bioprostheses recipients and 43.0 ± 14.3 for the mechanical valve recipients (p < 0.002). Concomitant procedures took place more frequently in patients receiving mechanical valves (59%) than in those receiving bioprosthesses (29%) (p < 0.01), due to the predominant tendency to select mechanical valves for patients requiring concomitant operations such as aortic graft replacement and coronary artery bypass.

Warfarin anticoagulation was initiated after the removal of the chest tube for all patients and was continued indefinitely in patients receiving mechanical valves. Patients with bioprosthetic
valves received warfarin for up to 3 months after operation, after which it was discontinued. At the time of this follow-up study, 95% of the current survivors with mechanical valves (60/63) and 13% with bioprostheses (8/64) were still receiving warfarin in order to reach thrombotest values of between 15% and 30% (p < 0.01).

Standard definitions of mortality and morbidity after the valve replacements were employed. Any new focal or diffuse neurologic event, permanent or transient, appearing either after the operation or during the follow-up interval was considered to be thromboembolism. Only if another source could be conclusively identified as the cause of the neurologic events, would the episode not be considered valve-related. Visceral or extremity vessel emboli were included in this determination. Valve thrombus or episodes of anticoagulant-related hemorrhage, if fatal or severe enough to necessitate hospitalization, was not identified in this study. Prosthetic valve endocarditis (PVE) was defined as an episode of sepsisemia in the absence of a source other than the prosthesis, which necessitated either prolonged antibiotic therapy or reoperation. Structural valve failure, which was observed only in the bioprosthetic valves of this study, was ascertained at reoperation or autopsy and defined by the presence of a characteristic leaflet calcification or cuspal disruption in the absence of PVE.

The patient follow-up was achieved either by direct contact with patients or their referring physicians, and was completed over a 6-month closing interval ending October 1988. At each follow-up visit the functional class, drug therapy, physical findings, chest X-ray, and electrocardiogram were documented. The follow-up data were available for all patients, resulting in a 100% follow-up rate. All the current patient follow-up data were obtained by one of the authors and entered into a computer data base. The final results were obtained using the STAX program (a software system custom-designed for life tables). A cumulative total of 926 patient-years (pt-yrs) were available for analysis; 489 pt-yrs for mechanical and 437 pt-yrs for bioprosthetic valve recipients. The mean duration of follow-up for all patients was 6.1 ± 4.7 years (range 0.5 to 20.2 years); 7.0 ± 5.4 for mechanical, and 5.2 ± 3.7 for bioprosthetic valve recipients (p < 0.04). Patients undergoing reoperation for re-replacement of aortic prostheses and/or additional cardiac valve replacement were omitted from the

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Fig. 4. Actuarial rate of freedom from structural valve failure (SVF) in bioprosthetic (B) and mechanical (M) valve recipients.

Fig. 5. Actuarial rate of freedom from prosthetic valve endocarditis (PVE) in bioprosthetic (B) and mechanical (M) valve recipients.

Analysis and considered to have withdrawn as either alive or dead, depending upon their status 30 days after reoperation.

An actuarial analysis of the life table method was performed. The actuarial rates were expressed as the percent of patients event-free. The continuous data are represented as the mean ± 1 standard deviation. The actuarial probability estimates are expressed as the mean ± 1 standard error. A Z-test or generalized

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Wilcoxon test was used for comparison of actuarial rates. The incident data were compared by the t-test and the chi-square test. A p value less than 0.05 was considered significant.

RESULTS

Operative mortality: Nine patients (5.4%) died within 30 days of operation; 8 (9.8%) with mechanical valves and 1 (1.2%) with a bioprosthetic valve (p < 0.05). Two patients with Starr-Edwards valves were operated on before the introduction of cardioplegia. Five patients with mechanical valves had concomitant procedures such as mitral commissurotomy and/or valvuloplasty, coronary artery bypass or Bentall procedure. One valve-related death, a non-structural valve dysfunction, that is stuck valve, occurred in a patient receiving a Björk-Shiley valve.

Late mortality: Nineteen patients (12.0%) died in the late postoperative period. The causes of late death were 11 cardiac-related (5 sudden death, and 6 congestive heart failure) and 5 valve-related (4 prosthetic valve endocarditis, 1 cerebral embolism), and 3 noncardiac-related (1 cancer, 1 cerebral bleeding due to hypertension, 1 sepsis from a pacemaker generator infection). The actuarial survival rate including operative mortality at 10 years was 74 ± 7% for mechanical and 77 ± 7% for bioprosthetic valve recipients (Fig. 2).

Thromboembolism: One or more thromboembolic episodes occurred in 9 patients with mechanical valves, and one proved fatal. Four patients with mechanical valves incurred more than 2 such events. Two patients with Starr-Edwards ball valves did not receive warfarin at the onset of event. Two patients with bioprosthetic valves, who had not recieved anticoagulant therapy, experienced a thromboembolic event. One patient with a Carpentier-Edwards porcine valve had atrial fibrillation. Another patient with a Hancock valve was scheduled for reoperation due to a structural valve failure and mitral restenosis. Freedom from thromboembolism at 10 years was 77 ± 7% for mechanical and 94 ± 4% for bioprosthetic valve recipients (Fig. 3). A significant difference between mechanical and bioprosthetic valve recipients was confirmed by a generalized Wilcoxon test (p < 0.01).

Valve failure: Structural valve failure in the absence of PVE was identified in 6 patients with bioprosthetic valves, who underwent reoperation without fatality. The actuarial freedom from structural valve failure at 10 years was 100% for mechanical and 83 ± 8% for bioprosthetic valve recipients (p < 0.05) (Fig. 4). A significant difference between mechanical and bioprosthetic valve recipients was confirmed by the generalized

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Wilcoxon test (p < 0.05). Nonstructural valve dysfunction occurred in 5 patients with mechanical valves (1 stuck Björk-Shiley valve, 4 perivalvular leaks), and in 1 patient with a bioprosthesis (perivalvular leak).

Prosthetic valve endocarditis: PVE occurred in 3 patients with mechanical valves; 2 required reoperation and one received antibiotic therapy, which ended in death. Seven patients with bioprosthetic valves experienced PVE; 4 required reoperation, 1 received antibiotic therapy which ended in death, and 2 the infection was identified by autopsy. Initial valve replacement was performed at an active stage of endocarditis in 2 patients with mechanical and 1 with bioprosthetic valves. Freedom from PVE was 96 ± 2% for mechanical and 88 ± 5% for bioprosthetic valve recipients at 10 years (Fig. 5).

Reoperation: Thirteen patients underwent valve re-replacement with no mortality. Three patients with mechanical valves were reoperated on because of 1 perivalvular leak and 2 PVE. Four PVE and 6 structural valve failures accounted for 10 reoperations in the bioprosthesis recipients. The actuarial freedom rate from reoperation at 10 years was 95 ± 3% for the mechanical valves and 75 ± 8% for the bioprosthetic valves (p < 0.05) (Fig. 6). Significant differences were confirmed at 8 through 12 years by the Z test (p < 0.05). The incidence of reoperation for valve re-replacement increased beyond 8 years postoperatively in the patients with bioprostheses.

Medical treatment in the late postoperative period: Heart medication such as anticoagulants, digitalis, diuretics, calcium antagonists, and antiarrhythmic drugs were not always required in the late postoperative period in patients with bioprosthetic valves. The rate of freedom from heart medication in the current survivors was 3.2% (2/63) for the mechanical, and 31.3% (20/64) for the bioprosthetic valve recipients (p < 0.01).

DISCUSSION

Surgical therapy of acquired aortic valvular disease requires prosthetic valve replacement in almost all cases. In limited cases, aortic valvular repair is attempted. To date, many different types of prosthetic valves have been used clinically, but no one ideal prosthetic valve has yet been developed. Roberts listed the 6 ideal characteristics of a good prosthetic cardiac valve as: (1) good hemodynamic characteristics; (2) nonthrombogenic; (3) does not degenerate; (4) does not significantly alter blood components; (5) can be inserted without undue difficulty; and (6) does not disturb the patient. The mechanical and bioprosthetic valves currently used in the aortic position should be discussed from the view point of these ideal characteristics. Prostheses with valve size larger than 21 mm have an adequate hemodynamic performance. Systemic anticoagulation is always strictly required in all mechanical valve recipients as prophylactic therapy for thromboembolism. Nevertheless, in bioprosthetic valve recipients, it may be sufficient to use such medication for only 3 months after operation. Durability is greater for mechanical valves than for bioprosthetic valves. There is no significant difference in the risk of PVE in patients with either bioprosthetic or mechanical valves. On the other hand, Sweeney et al. showed that patients receiving a bioprosthesis for active endocarditis had a significantly higher reoperation rate and a significantly greater incidence of recurrent endocarditis. With regard to breakdown of the blood, there is a chance of mechanical valve causing intractable hemolysis. Insertion of the mechanical valve may be easier than the bioprosthesis, because of its low profile, but its sound is audible at various grades. In this regard, we had one case of suicide from neurosis caused by a noisy mechanical valve sound.

Recently, mechanical valves have been selected predominantly in response to the restricted durability of bioprosthetic valves. The annual hazard of reoperation for bioprosthetic valves increases with the duration of follow-up, reflecting an increased number of patients with structural failures. It is generally accepted that for the first 5 years bioprosthetic valves are superior, yet over the next 5 year the advantage shifts toward the mechanical valves, and if the structural valve failure pattern with porcine valves continues, then there will be a widening of the advantage in favor of mechanical valves. It is also important to reevaluate the usage of such bioprosthetic valves with regard to the characteristics of prosthetic valves in the quality of life after reentering society. If a way to counter prosthetic valve dysfunction could be safely achieved, then prosthesis durability should not of itself be an important issue. Some reports show a low reoperative risk for prosthetic valve re-replacement. We also reported that
mortality and morbidity of valve re-replacement were the same as the initial valve replacement if the re-replacement was undergone before the patients reached NYHA Class IV. Thirteen cases in this study underwent re-replacement with no operative deaths. Several reports show that, as far as antithrombogenicity is concerned, the bioprosthetic valve is superior to the mechanical valve in the aortic position. Thromboembolic events in this series of patients occurred at a rate of 2.5%/pt-yr in the mechanical valve recipients in spite of anticoagulant therapy, and only 0.5%/pt-yr among bioprosthetic valve recipients, who were receiving no anticoagulation therapy. Since anticoagulant therapy is unnecessary, about 30 percent of bioprosthetic recipients required no cardiac medication in the late postoperative periods. This would indicate in these patients an improvement in the quality of life and a cured state of valvular heart disease within the period of durability of the prostheses.

Bioprostheses were introduced initially as prosthetic valves for the mitral position. With increasing experience, we decided that the advantageous characteristics of the bioprostheses would be observable in the aortic rather than mitral position, because of the lower incidence of thromboembolism they caused by their nature and reduced stress imposed on the prostheses in this position. Some reports show that structural valve failures of the bioprostheses occur less frequently in the aortic than in the mitral position, as well as less frequently in elderly patients than in younger ones. At present, in adult patients we are using the bioprosthetic valve predominantly in the aortic position without any regard to age at the time of operation.

Bioprosthetic valves in the aortic position show good antithrombogenicity without anticoagulant therapy. In mechanical valves thromboembolic events occur more frequently in spite of anticoagulation. Due to the lack of any need for anticoagulation therapy, patients with bioprostheses have the chance of a drug-free lifestyle. The durability of this prosthesis is worse, however, than mechanical valves, necessitating future re-replacement of bioprostheses to be anticipated. However, valve re-replacement for structural valve dysfunction of bioprostheses can be undertaken without any increased risk, compared with that of the initial replacement. It is our conclusion that from the above data that selection of bioprosthetic valves in the aortic position will improve the quality of life among prosthesis valve recipients.

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