Hemodynamic Function of the Kay-Shiley Prosthetic Cardiac Valve
Observations after Mitral or Tricuspid Valve Replacement*

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Eighteen patients were catheterized before and nine months (average) after mitral and/or tricuspid valve replacement with the Kay-Shiley prosthesis. In 14 patients with Kay-Shiley mitral prostheses, average cardiac index rose from 2.2 L/min/M² preoperatively to 2.8 postoperation, average left atrial mean pressure fell from 26 to 18 mm Hg, and the average left atrioventricular mean diastolic gradient decreased from 15 to 8 mm Hg. In eight patients with Kay-Shiley tricuspid prostheses, average cardiac index rose from 1.74 to 2.54 L/min/M², average right atrial mean pressure fell from 13 to 10 mmHg, and the average mean diastolic gradient across the tricuspid prostheses was 4 mmHg. The in vivo effective orifice areas of the Kay-Shiley mitral and tricuspid prostheses averaged 75 percent of the in vitro orifice areas. Kay-Shiley mitral prostheses were used only when the left ventricle was too small to accommodate a Starr-Edwards prosthesis; consequently, the Kay-Shiley prostheses employed were small, accounting in part for significant prosthetic stenosis observed in some patients.

The hemodynamic function of Starr-Edwards prosthetic valves has been studied extensively, but the circulatory dynamics following valve replacement with other prostheses, such as the Kay-Shiley disc valve, have been less well characterized. Between January, 1966, and October, 1970, Kay-Shiley prostheses were used at the National Heart and Lung Institute to replace mitral and/or tricuspid valves in 48 patients. In addition to preoperative cardiac catheterization, 18 of the patients were also studied by catheterization six to 23 months (average, nine) after operation. The hemodynamic function of the Kay-Shiley prostheses in these 18 patients is the subject of this report.

METHODS

Right heart catheterization was performed either through an antecubital cutdown or from the femoral vein using the Seldinger technique. Left atrial pressure was measured directly by transseptal catheterization or indirectly by pulmonary arterial wedge pressure. The left ventricle was entered by retrograde arterial catheterization preoperatively, and by percutaneous left ventricular puncture postoperatively. In patients with tricuspid prostheses, right ventricular pressure was measured by percutaneous puncture. The mean pressure gradient between left atrium and left ventricle, or between right atrium and right ventricle, was obtained by planimetric integration of the area between the simultaneously recorded phasic pressure tracings during diastole. Cardiac output was determined by the indicator (indocyanine green) dilution technique. The effective orifice areas of the prostheses were calculated using the Gorlin formula. All significant tests were two-sided.

RESULTS

The type of operative procedure performed and the mortality figures for the entire group of 48 patients are summarized in Table 1. In the study group of 18 patients, 16 were in atrial fibrillation preoperatively, and two were in sinus rhythm.
aortic prostheses. Pertinent postoperative hematologic findings are summarized in Table 2. In these 14 patients, the average cardiac index rose slightly from 2.2 L/min/M² preoperatively to 2.8 L/min/M² postoperatively (P < .07). Left atrial mean pressure at rest averaged 26 mmHg preoperatively and fell to 18 mmHg after operation (P < .01). Average left ventricular end-diastolic pressure remained unchanged (11 mmHg). The average left atrial-left ventricular mean diastolic pressure gradient fell from 15 mmHg preoperatively to eight mmHg postoperatively (P < .01). Seven patients with Kay-Shiley mitral prostheses had postoperative left ventricular cineangiograms. One patient (No. 4) had moderate mitral regurgitation, and a second (No. 12) had trace regurgitation. In the other five patients the valve was completely competent.

All eight patients with Kay-Shiley tricuspid prostheses also had mitral prostheses (four Kay-Shiley, four Starr-Edwards), and one of them also had a Starr-Edwards aortic prosthesis. The hemodynamic data obtained in these eight patients are also included in Table 2. The average cardiac index rose from 1.7 L/min/M² preoperatively to 2.5 L/min/M² postoperatively (P = < .02). Average right atrial mean pressure decreased insignificantly from 13 mmHg preoperatively to 10 mmHg postoperatively, and in no patient was the postoperative right atrial mean pressure less than eight mmHg. The average right ventricular pressure fell insignificantly from 68/12 mmHg before to 51/8 mmHg after operation. None of the patients with tricuspid prostheses had postoperative right ventricular cineangiograms.

The in vivo effective orifice areas of the Kay-Shiley prostheses in the mitral position ranged from 1.3 to 2.1 cm²—59 percent to 95 percent (average, 2.0 cm²). The in vivo effective orifice area of the tricuspid prosthesis ranged from 1.5 to 2.7 cm²—70 percent to 85 percent (average, 2.2 cm²).

Postoperatively these two and three additional patients were in sinus rhythm; the other 13 patients remained in atrial fibrillation.

Of the 14 patients with Kay-Shiley mitral prostheses, four also had Kay-Shiley prostheses in the tricuspid position, and two had Starr-Edwards aortic prostheses. Pertinent postoperative hemodynamic findings are summarized in Table 2. In these 14 patients, the average cardiac index rose slightly from 2.2 L/min/M² preoperatively to 2.8 L/min/M² postoperatively (P < .07). Left atrial mean pressure at rest averaged 26 mmHg preoperatively and fell to 18 mmHg after operation (P < .01). Average left ventricular end-diastolic pressure remained unchanged (11 mmHg). The average left atrial-left ventricular mean diastolic pressure gradient fell from 15 mmHg preoperatively to eight mmHg postoperatively (P < .01). Seven patients with Kay-Shiley mitral prostheses had postoperative left ventricular cineangiograms. One patient (No. 4) had moderate mitral regurgitation, and a second (No. 12) had trace regurgitation. In the other five patients the valve was completely competent.

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77 percent) of the in vitro orifice areas provided by the manufacturer (Table 3). The in vivo effective orifice areas of the tricuspid prostheses ranged from 1.3 to 2.9 cm²—41 percent of 90 percent (average, 71 percent) of the in vitro orifice areas (Table 3). In general, in vivo effective orifice areas were larger with the larger size prostheses.

DISCUSSION

At the National Heart and Lung Institute, Kay-Shiley prostheses have been used for mitral valve replacement only in patients in whom at operation the left ventricle was judged to be too small to accommodate a Starr-Edwards prosthesis. Thirteen of the 14 patients with the Kay-Shiley mitral prosthesis had pure or predominant mitral stenosis; the 14th (No. 10) had acute severe mitral regurgitation without left ventricular dilatation. Consequently, the Kay-Shiley valves employed have been small. The size used most frequently was no. 4; sizes ranged from nos. 1 to 7 in the entire group and from nos. 3 to 6 in the 18 patients studied postoperatively. Thus, the left atrial pressures were higher, the mitral valvular gradients were larger, and the effective mitral orifice areas smaller in these patients than in those patients whose mitral valves were replaced with sizes 2 M, 3 M, and 4 M Starr-Edwards prostheses, models 6120 or 6310.5

The left atrial pressures, valve gradients, and orifice areas in the present patients were similar, however, to those observed in patients with 2 M and 3 M Starr-Edwards model 6300 prostheses; this is not surprising, since these Starr-Edwards valves have in vitro orifice areas nearly identical to those of nos. 4 and 5 Kay-Shiley valves (Table 3).

In this clinic disc valves are always utilized for tricuspid valve replacement because the disc prostheses do not project into the ventricular cavity as far and are better accommodated in the right ventricle than are ball valves.11 Most often tricuspid valve replacement was required because of tricuspid regurgitation (six of the eight), and, accordingly, most of the Kay-Shiley prostheses used in the tricuspid position were larger (two were size 5 and 6 were size seven) than those employed in the mitral area. Consequently, the tricuspid prostheses, in general, had smaller diastolic pressure gradients and larger effective orifice areas than the mitral prostheses. However, pressure normally is quite low in the right atrium, and even these larger valves were sufficiently obstructive to maintain right atrial mean pressure considerably above the upper limit of normal (5 mmHg in this laboratory) in every patient.

In both the mitral and tricuspid positions, Kay-Shiley prostheses had calculated effective orifice areas that were smaller than the in vitro orifice areas. We also have observed this in patients with Starr-Edwards prostheses, and the most likely explanation is the use of a constant in the Gorlin formula that is inappropriate for these prostheses.

During the past four years at the National Heart and Lung Institute, hospital mortality in patients undergoing mitral valve replacement with Starr-Edwards prostheses has been 14 percent, whereas hospital mortality among patients in whom Kay-Shiley prostheses were utilized has been 29 percent (Table 1). Although this difference could be attributed to intrinsic differences in the prostheses, other explanations seem more likely. First, in 31 of the 48 patients some operative procedure in addition to mitral valve replacement was necessary (Table 1). Second, it has been the experience in this as well as other clinics that the incidence of early and late postoperative complications is increased when mitral valve replacement is necessary in patients in whom the left ventricular cavity is small or normal in size.12 As previously mentioned, 13 of the 14 patients in the present study had pure or predominant mitral stenosis, and none of the 14 had dilatation of the left ventricle. A small or normal sized left ventricle frequently will not permit insertion of a Starr-Edwards prosthesis and will permit only a Kay-Shiley prosthesis of smaller size. When a small prosthesis must be used, significant residual mitral stenosis may result.3

Thus, for the reasons stated above a critical comparison of Kay-Shiley and Starr-Edwards valves cannot be made on the basis of the data in this study. It appears likely that the higher operative mortality in patients in whom Kay-Shiley valves were inserted is related to patient selection rather than to the type of prosthesis employed, and in patients with left ventricles too small to accommodate ball valve prostheses, disc prostheses are still used at the National Heart and Lung Institute.

REFERENCES

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Table 3—Comparative in Vitro Orifice Areas

<table>
<thead>
<tr>
<th>Size</th>
<th>Kay-Shiley</th>
<th>Starr-Edwards</th>
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<td></td>
<td>6000/6120</td>
<td>6300</td>
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<tr>
<td>1</td>
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</tr>
<tr>
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10 Gorlin R, Gorlin SG: Hydraulic formula for calculation of the area of the stenotic mitral valve, other cardiac valves, and central circulatory shunts. Am Heart J 41:1-29, 1951

A Compliment to Cervantes on Don Quixote

Among the unforgettable characters of fiction there is none more real or more appealing than the knight of the Mournful Countenance. If we should try to account for his hold on our affections, we would probably think not so much of his hilarious misadventures as of his noble and courageous spirit. The world must ultimately respect men who pay allegiance to something higher than satisfaction of their own needs and pleasures, who willingly suffer ridicule and privation to serve their ideals. We may or may not look with approval on Don Quixote's ideal of chivalry, but we must admire the fortitude with which he strives to live by it.

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