Valve Dysfunction of the Cloth-Covered Starr-Edwards Ball Valve
— Analysis of Excised Valve Findings at Reoperation —

Motomi Shiono, MD; Akira Sezai, MD; Mitsumasa Hata, MD;
Mitsuru Iida, MD; Nanao Negishi, MD; Yukiyasu Sezai, MD

Background  Between June 1968 and March 1977, Starr-Edwards cloth-covered ball valves were used for valve replacement on a routine basis.

Methods and Results  Among the 66 operative survivors who underwent an isolated aortic or mitral valve replacement, 20 patients required reoperation 22 times because of valve dysfunction, thromboembolic complication, paravalvular leakage, hemolytic anemia, and/or prosthetic valve endocarditis. Reoperation was performed at a mean of 15.9±9.8 years after initial replacement. Excised valves were examined and reoperation after initial operation was reviewed. Operative mortality was 10.0%. Freedom from reoperation for aortic valve replacement and mitral valve replacement was 56.2% at 34 years and 61.0% at 37 years after initial operation, respectively. Cloth wear or pannus formation were observed in all excised prostheses. Orifice cloth was more markedly worn in mitral valves than in aortic valves, particularly in mitral valves of more than 20 years old. Pannus overgrowth contributed to valve regurgitation in the older valves.

Conclusions  Early diagnosis of valve dysfunction and reoperation are recommended as soon as symptoms appear. (Circ J 2005; 69: 844–849)

Key Words:  Cloth wear; Pannus formation; Reoperation; Starr-Edwards ball valve

Since the first successful valve replacement using the original Starr-Edwards (S-E) caged silastic ball valve, some engineering modifications were made to enhance hemodynamic performance and fixation. The fabric covering was extended to the inflow orifice and then to the cage, and a silastic ball was changed to a stellite ball, which resulted in a group of “cloth-covered S-E ball valves”1,2. Between June 1968 and March 1977, the cloth-covered valve were used for aortic and mitral valve replacement (MVR) on a routine basis. Long-term results with the S-E ball valves have been reported showing satisfactory results with reliable durability and safety; they could represent the standard in mechanical valve replacement until recent prostheses can show a significant improvement in long-term results. However, reoperation after valve replacement with the S-E ball valve is unavoidable, and there have been only a few articles reporting detailed data concerning reoperations for the cloth-covered model of the S-E ball valve. The present study reports valve dysfunction and reoperation for the cloth-covered S-E ball prostheses.

Methods

Patients
The cloth-covered S-E ball valves (aortic model 2300, 2310, 2320, and 2400, and mitral model 6300, 6310, 6320, and 6400) were implanted in the aortic and/or mitral position as the first choice for prosthetic substitution at our institution between June 1968 and March 1977. Oral anticoagulation regimens were administered after surgery and left at our outpatient clinic or local general practitioner’s clinic. Among the 66 operative survivors who underwent an isolated aortic valve replacement (AVR; n=14) or MVR (n=52), 20 patients (11 male and 9 female) required reoperation 22 times because of valve dysfunction, thromboembolic complication, paravalvular leakage, hemolytic anemia, and/or prosthetic valve endocarditis. Reoperation was performed at a mean of 15.9±9.8 years (range, 2.3 to 34.2 years) after initial valve replacement. The S-E valves were re-implanted 8 times in the aortic position (n=7; group A) and 14 times in the mitral position (n=13; group M) at a mean age of 44.7±13.9 years (range, 14 to 66 years). The S-E valves used at the initial operations and indications for reoperation are listed in Table 1.

Excised valves were carefully examined, and morbidity after the initial and subsequent operations was defined.
Valve Dysfunction of Starr-Edwards Ball Valve

according to the guidelines for reporting morbidity and mortality after cardiac valvular operations, as published by Edmunds et al. Cloth wear was presented as follows: (+) slight cloth wear at struts and/or orifice; (++) moderate cloth wear at struts and/or orifice; and (+++) cloth tear at orifice and/or cloth dislodgement at struts. Pannus formation was presented as follows: (+) pannus formation at sewing ring; (++) pannus formation at sewing ring and

Table 1 Number of Implantations and Reimplantations and Causes of Reoperation

<table>
<thead>
<tr>
<th>Valve model</th>
<th>Year of implant</th>
<th>No. of implants</th>
<th>No. of reimplants</th>
<th>Causes of reoperation (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic valves</td>
<td>2300</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>2310</td>
<td>1970–1971</td>
<td>5</td>
<td>1</td>
<td>Prosthetic endocarditis (1)</td>
</tr>
<tr>
<td>2320</td>
<td>1971–1974</td>
<td>6</td>
<td>4</td>
<td>Paravalvular leak (2), thromboembolism (1), hemolysis (1)</td>
</tr>
<tr>
<td>2400</td>
<td>1975–1977</td>
<td>5</td>
<td>2</td>
<td>Thromboembolism (1), valve dysfunction (1)</td>
</tr>
<tr>
<td>Total</td>
<td>16</td>
<td>7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mitral valves</td>
<td>6300</td>
<td>1968–1970</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>6310</td>
<td>1970–1971</td>
<td>19</td>
<td>5</td>
<td>Valve dysfunction (3), thromboembolism (2)</td>
</tr>
<tr>
<td>6320</td>
<td>1971–1974</td>
<td>18</td>
<td>5</td>
<td>Valve dysfunction (3), thromboembolism (2)</td>
</tr>
<tr>
<td>6400</td>
<td>1975–1977</td>
<td>10</td>
<td>2</td>
<td>Valve dysfunction (1), thromboembolism (1)</td>
</tr>
<tr>
<td>Total</td>
<td>58</td>
<td>14</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig 1. Freedom from reoperation curves after Starr-Edwards cloth-covered ball valve implantation in the aortic or mitral position (Numbers in the lower part indicate the percentage at the time).

Fig 2. Freedom from reoperation curves after Starr-Edwards cloth-covered ball valve implantation in the patient population (Numbers below the curve indicate the freedom rate at the time).
struts; and (+++) pannus overgrowth at studs.

Continuous data were presented as mean ± SD; chi-square tests were performed to compare and to check the differences between patient groups A and M for significance. Reoperation-free curves were obtained by using the Kaplan-Meier method and were compared using the log-rank test. Statistical analysis was carried out using StatView software version 5.0 (SAS Institute, Inc, NC, USA).

Results

Reoperations were performed in a total of 20 patients (30.3% of the operative survivors). One group A patient and 1 group M patient underwent reoperation with the S-E cloth-covered model for paravalvular leakage and pannus stenosis respectively. Structural valve dysfunction was found in all 20 patients 21 times excluding 1 group A patient who underwent reoperation for paravalvular leakage. The reasons of reoperation were valve dysfunction (9 patients), thromboembolism (7 patients), paravalvular leakage (2 patients), prosthetic endocarditis (1 patient), hemolytic anemia (1 patient), and pannus stenosis (1 patient) (Table 1).

Operative Mortality at Reoperation

Reoperations were performed in 7 patients (50% of the patient population) with AVR and in 13 patients (25% of the patient population) with MVR. A significant difference in the rate of reoperation between group A and group M was not found. In the aortic position, patient 1 died on the first postoperative day after a second AVR operation with model 2320 because of bleeding and operative mortality after redo AVR was 14.2%. In the mitral position, patient 2 died because of low output syndrome after redo MVR operation with model 6320, and operative mortality after redo MVR was 7.6%. Overall 30-day mortality for both redo AVR and redo MVR was 10.0%.

Freedom From Reoperation

Freedom from reoperation for AVR and MVR was 56.2% at 34 years and 61.0% at 37 years, respectively (Fig 1). The standard error for all Kaplan-Meier percentages was 5%. Freedom from reoperation between 2 groups was not significant, and overall actuarial freedom from reoperation was 89.9% at 10 years, 78.3% at 20 years, 73.3% at 30 years, and 59.5% at 37 years (Fig 2).

Thromboembolic Events

Thromboembolic events including valve thrombosis and/or embolism were observed in 40% of the patients who required reoperation. The incidence rate of thromboembolism was 28.6% (2/7) in group A and 38.5% (5/13) in group M. A significant difference in the incidence rate of thromboembolism was not found between group A and group M.

Concomitant Valve Procedures

Concomitant valve procedures at reoperation are listed in Table 2, and reoperations were required mainly for valve-related complications and/or other aggravated valve lesions. Abnormal prosthetic regurgitation was more frequently observed in the mitral position than in the aortic position. More complicated procedures were required in patients who underwent valve replacement in the mitral position.

Table 2 Valve Age, Findings of the Excised Valves, and Concomitant Valve Procedures

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Redo age (years)</th>
<th>Gender</th>
<th>Valve age (years)</th>
<th>Model</th>
<th>Redo cause</th>
<th>Excised valve</th>
<th>Concomitant Valve Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aortic valves</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>1</td>
<td>43</td>
<td>M</td>
<td>2.3</td>
<td>2320</td>
<td>PVL (+)</td>
<td>(+)</td>
<td>ReAVR (S-E 2320)</td>
</tr>
<tr>
<td>2</td>
<td>35</td>
<td>M</td>
<td>3.7</td>
<td>2320</td>
<td>HA (+)</td>
<td>(+)</td>
<td>ReAVR (Hancock) + TAP</td>
</tr>
<tr>
<td>3</td>
<td>56</td>
<td>M</td>
<td>6.1</td>
<td>2400</td>
<td>TE (+)</td>
<td>(+)</td>
<td>ReAVR (SJM) + TAP</td>
</tr>
<tr>
<td>4</td>
<td>22</td>
<td>M</td>
<td>9.2</td>
<td>2320</td>
<td>PVL (+)</td>
<td>(+)</td>
<td>ReAVR (SJM) + TAP</td>
</tr>
<tr>
<td>5</td>
<td>41</td>
<td>F</td>
<td>15.3</td>
<td>2320</td>
<td>TE (+)</td>
<td>(+)</td>
<td>ReAVR (SJM) + TAP</td>
</tr>
<tr>
<td>6</td>
<td>38</td>
<td>M</td>
<td>18.5</td>
<td>2310</td>
<td>PE (+++)</td>
<td>(+++)</td>
<td>ReAVR (SJM) + TAP</td>
</tr>
<tr>
<td>7</td>
<td>52</td>
<td>M</td>
<td>27.5</td>
<td>2400</td>
<td>VD (+)</td>
<td>(+++)</td>
<td>ReAVR (ATS)</td>
</tr>
<tr>
<td>Mean</td>
<td>41.0±11.0</td>
<td>11.8±9.1</td>
<td></td>
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</tbody>
</table>

Mitral valves

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Redo age (years)</th>
<th>Gender</th>
<th>Valve age (years)</th>
<th>Model</th>
<th>Redo cause</th>
<th>Excised valve</th>
<th>Concomitant Valve Procedures</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 (1)</td>
<td>14</td>
<td>M</td>
<td>3.9</td>
<td>6300</td>
<td>PS (+)</td>
<td>(+)</td>
<td>ReMVR (S-E 6320)</td>
</tr>
<tr>
<td>2</td>
<td>56</td>
<td>F</td>
<td>8.5</td>
<td>6310</td>
<td>TE (+)</td>
<td>(+)</td>
<td>ReMVR (SJM)</td>
</tr>
<tr>
<td>3</td>
<td>32</td>
<td>M</td>
<td>10.1</td>
<td>6300</td>
<td>TE (+)</td>
<td>(+)</td>
<td>ReMVR (SJM)</td>
</tr>
<tr>
<td>4</td>
<td>44</td>
<td>M</td>
<td>10.8</td>
<td>6320</td>
<td>VD (+)</td>
<td>(+)</td>
<td>ReMVR (SJM) + AVR (SJM) + TVR (SJM)</td>
</tr>
<tr>
<td>5</td>
<td>33</td>
<td>F</td>
<td>11.0</td>
<td>6320</td>
<td>VD (+)</td>
<td>(+)</td>
<td>ReMVR (SJM) + AVR (SJM) + TVR (SJM)</td>
</tr>
<tr>
<td>6</td>
<td>59</td>
<td>M</td>
<td>12.3</td>
<td>6400</td>
<td>TE (+)</td>
<td>(+)</td>
<td>ReMVR (SJM) + TVR (SJM)</td>
</tr>
<tr>
<td>1 (2)</td>
<td>28</td>
<td>M</td>
<td>14.7</td>
<td>6320</td>
<td>VD (+)</td>
<td>(+)</td>
<td>ReMVR (SJM) + TVR (SJM)</td>
</tr>
<tr>
<td>7</td>
<td>58</td>
<td>F</td>
<td>16.5</td>
<td>6400</td>
<td>VD (+)</td>
<td>(+)</td>
<td>ReMVR (SJM)</td>
</tr>
<tr>
<td>8</td>
<td>54</td>
<td>M</td>
<td>17.7</td>
<td>6310</td>
<td>VD (+)</td>
<td>(+)</td>
<td>ReMVR (SJM) + TVR (SJM)</td>
</tr>
<tr>
<td>9</td>
<td>44</td>
<td>F</td>
<td>21.8</td>
<td>6320</td>
<td>TE (+)</td>
<td>(+)</td>
<td>ReMVR (SJM) + TVR (SJM)</td>
</tr>
<tr>
<td>10</td>
<td>45</td>
<td>F</td>
<td>26.3</td>
<td>6320</td>
<td>VD (+)</td>
<td>(+)</td>
<td>ReMVR (ATS) + AVR (ATS) + TAP</td>
</tr>
<tr>
<td>11</td>
<td>61</td>
<td>F</td>
<td>31.9</td>
<td>6310</td>
<td>VD (+)</td>
<td>(+)</td>
<td>ReMVR (ATS) + TAP + LA plication</td>
</tr>
<tr>
<td>12</td>
<td>57</td>
<td>F</td>
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<td>6310</td>
<td>TE (+)</td>
<td>(+)</td>
<td>ReMVR (ATS) + TAP</td>
</tr>
<tr>
<td>13</td>
<td>66</td>
<td>F</td>
<td>34.2</td>
<td>6310</td>
<td>VD (+)</td>
<td>(+)</td>
<td>ReMVR (ATS) + TAP + TVR (CEP)</td>
</tr>
<tr>
<td>Mean</td>
<td>46.5±15.0</td>
<td>18.0±9.8</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Excised Valve Findings

Cloth wear/tear or pannus formation were observed in all prostheses, as shown in Table 2. As postoperative time passed, degradation was more markedly extended in the prostheses than expected. The cloth inside the valve struts was worn through and the cage metal exposed, while remnant cloth surrounding the outside was detached from struts and loosened. Orifice cloth was more markedly worn in the mitral valves than in aortic valves, and tear was usually observed in valves that were more than 20 years old (Fig 3). Also, pannus overgrowth over the studs around the orifice area was observed resulting in regurgitation through the valve orifice in the valves (Figs 4, 5). Pannus overgrowth was marked at the struts area close to the orifice because of pannus overgrowth.

Fig 3. Intraoperative view of the 27.5 year-aged aortic valve (model 2400) in patient 1 (Left). Cloth wear was observed around the valve orifice area and pannus overgrowth around the orifice, markedly at the strut area. Excised valve showed severe pannus formation over the studs around the orifice (Right). Dislodgement of the cloth on the struts was slightly observed in this ‘track’ model. The stellite ball could not touch the studs around the orifice because of pannus overgrowth.

Fig 4. Intraoperative view of the 34.2 year-aged mitral valve (model 6310) in patient 13 (Left). Pannus overgrowth was observed behind the struts at the valve orifice, and the cloth was completely worn around the valve orifice area. Excised valve showed severe pannus formation over the studs on the strut orifice (Right). Significant cloth wear and dislodgement were observed inside the struts and orifice presenting bare metal struts and orifice. The stellite ball could not touch the studs around the orifice because of pannus overgrowth.

Fig 5. Intraoperative view of the 32.5 year-aged mitral valve (model 6310) in patient 12 (Left). Pannus overgrowth and thrombus formation were observed behind the struts at the valve orifice, and the cloth was completely worn around the valve orifice area, presenting bare metal orifice. The excised valve showed severe pannus and thrombus formation over the valve orifice, especially at the strut area (Right). The stellite ball could not touch the studs around the orifice because of pannus overgrowth.
where the struts arose. The stellite ball could not touch the
studs around the orifice because of pannus overgrowth.
Pannus inside the orifice contributed to valve dysfunction
through insufficient valve closing. These findings, such as
severe cloth wear/tear and pannus overgrowth in the orifice
area, contributed to thromboembolic complications and
hemodynamic deterioration, especially in patients who
underwent valve replacement more than 20 years ago.

Discussion

Since the first successful valve replacement using the
original S-E caged silastic ball valve, implantations of S-E
valves, which experienced several modifications, exceed
200,000 cases and long-term results with this valve have
been reported showing satisfactory results with reliable
durability and safety.2,4 The cloth-covered model of the S-
E stellite-ball valve was introduced to eliminate the larger
metal surface and ball variance in the original silastic ball
prosthesis, with the intention of reducing thromboembolism.
The fabric extension was extended from the inflow
orifice to the cage (model 2300 and model 6300), and com-
posite seat prosthesis (model 2310 and model 6310), which
featured small metallic studs around the orifice was intro-
duced, resulting in the protection of the orifice cloth on
valve closure. Subsequent models (model 2320 and 6320)
were introduced in which the valve cage tapered toward the
orifice so that the ball was situated on the composite seat
along the centerline of the cage. Then the final ball valves,
called ‘track valves’ (model 2400 and model 6400), were
introduced and had a bare stellite track inside each strut so
that the poppet touched only the metal track and studs,
protecting struts and orifice cloth from ball wear and tear.8
However, the initially observed improvement was a func-
tion of the time frame of implantation and the cloth cover-
ing offered no overall advantage with regard to reduced
thromboembolism. Later, these cloth-covered models were
discontinued in favor of the original bare strut design, and
these models became historical prostheses. However, there
are still surviving patients with these valves who require
strict follow-up.

Complications and morbidity after S-E ball valve re-
placement are thromboembolism, valve thrombosis, anti-
coagulant-related bleeding events, paravalvular leakage,
and/or endocarditis which are the major limitations of any
mechanical prostheses. Ball variance is a rare complication
which occurs in early postoperative years. Tayama et al
presented a case report of a patient who had an aortic S-E
silastic ball valve implanted 28 years previously, demon-
strating no abnormality of the explanted silastic ball, which
shows that the S-E ball valve is durable in some patients.7,8
Cloth wear or tear is regarded as a unique problem of the
cloth-covered S-E ball valve. The incidence of cloth wear
in surviving patients who had a cloth-covered S-E valve
replacement has been reported less than 2.6%/patient-year
within 10 years’ follow-up based on the results of autopsy
and/or reoperation and/or reoperation2,9,10,11 and 6% within 12 to 15 years’
follow-up12 while actual incidence of cloth wear over 15
years has not been reported. Shah et al have indicated the
following findings suggesting cloth wear: (1) transient
cerebral ischemia attacks or infarction of the systemic
organs despite appropriate anticoagulant therapy; (2) arte-
rial embolism more than 4 years after valve replacement;
(3) increased metal click sounds; (4) persistent severe
hemolytic anemia; and (5) abnormalities in the positional
relationship between the ball and the valve location at
valve opening/closing under fluoroscopy, or regurgitation
of contrast medium from the valve orifice? They concluded
that the diagnosis of cloth wear is impossible before re-
operation and it was made by exclusion of other causes of
recurrent transient cerebral ischemic attacks or systemic
emboli and by exclusion of other causes of hemolytic
anemia. Aggressive management of complications of cloth
wear by reoperation is likely to prevent disabling or lethal
consequences. Recently, Vermes et al evaluated the ability
of transesophageal echocardiography (TEE) to detect cloth
wear in 9 asymptomatic patients with a cloth-covered S-E
aortic valve. An echogenic mobile structure attached to the
prosthesis, suggestive of a tear, was detected in 5 patients
(55%), although transthoracic echocardiography failed to
detect any abnormality in all patients. Two patients had
symptoms and underwent reoperation; cloth tear was more
extensive than suspected by TEE. Cloth tear is a frequent
finding that can be detected by TEE in asymptomatic
patients with cloth-covered S-E aortic prostheses. They
recommended performing TEE and reoperation in these
patients as soon as symptoms appeared.13 In a report by
Starr’s group among the 250 patients with model 6310/20
aortic prosthesis, 14 patients required reoperation and 10
(71%) patients were found to have strut cloth wear at reop-
eration; among the 171 patients with model 6310/20 mitral
prosthesis, 9 patients needed reoperation and 2 patients
were confirmed to have orifice cloth tear. In the aortic
position, Lund et al reported a detailed follow-up for 717
patients who underwent AVR with a silastic ball valve, a
cloth-covered valve or a track valve.14 In their study, the 3
valve types did not differ with regard to long-term survival
or freedom from complications, and there were no instances
of structural failure apart from wear of the cloth covering
the cage struts of the cloth-covered valves. Higashita et al
examined a late follow-up in children with the S-E valves,
focusing on the effect of valve prosthesis-patient mismatch
in the growing patient.15 Both studies concluded that the S-
E ball valves were durable through the remaining lifetime
of the patients and the ability to secure near normal age and
sex-specific survival provided valve and patient size mis-
match was avoided.

Vitale et al reviewed the pathologic and echocardio-
graphic findings in 87 patients with mitral valve obstruc-
tion of 3 types of mechanical valves to ascertain the inci-
dence of pannus formation and thrombosis. The frequency
of pannus formation has been much higher than that of
thrombus formation, but thrombosis is of earlier onset than
pannus formation. Thrombosis is because of the deposition
of clots on the prosthesis, and a pannus occurs because of
an inflammatory reaction developing on both valve sur-
faces.16 In our previous study reviewing the reoperation for
cloth-covered S-E valves, there were 12 patients who
required reoperation.17 In the previous study, the mean
interval at reoperation was 11.7 years, and marked cloth
wear was observed in all aortic valves, but only slight wear
in mitral valves. Orifice pannus formation was observed in
some patients. In the present study, the mean interval at
reoperation was 15.9 years and the cloth wear frequently
involved the mitral position; cloth tear was frequently
observed for those with more than 15 years’ follow-up. The
degradation process of the prosthesis would progress more
markedly and frequently in the mitral position than in the
aortic position because the prosthesis has been exposed to a
too cruel condition of the pressure difference. Pannus over-

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growth inside the orifice and over the studs was frequently observed, resulting in valve dysfunction through valve regurgitation rather than stenosis. Abnormal valve regurgitation was more frequently observed in the mitral position than in the aortic position. Nowadays, most of the surviving patients who underwent a S-E ball valve replacement have survived at least 25 years after the operation. Some of them required reoperation for valve-related complications or aggravated secondary valve lesions during the follow-up period.

More complicated procedures were required in patients who underwent valve replacement in the mitral position. Table 2 shows procedures at reoperation. Tricuspid valve operation was frequently required for secondary massive tricuspid regurgitation. Reoperations were performed using exclusively 3 types of prostheses: Hancock bioprosthesis (Medtronic, Inc, Minneapolis, MN, USA), St Jude Medical (SJM) bileaflet prosthesis (St Jude Medical, Inc, St Paul, MN, USA), and Advancing The Standard valve (ATS) medical bileaflet prosthesis (ATS Medical, Inc, Minneapolis, MN, USA), between 1977 and 1978, 1978 and 1993, and 1993 and 2005, respectively. After reoperation, structural dehiscence was observed in 1 patient who had the Hancock bioprosthesis and required reoperation. Two patients who underwent reoperation using the SJM bileaflet prosthesis required reoperation because of valve thrombosis in the tricuspid position. Thereafter, the Carpenter-Edwards Pericardial valve (American Edwards Laboratories, Santa Ana, CA, USA) was used for tricuspid replacement. Linealized rates of thromboembolic events at our institution of the cloth-covered S-E ball valve, SJM bileaflet prosthesis, and ATS bileaflet prosthesis were 1.29%/patient-year, and 0.51%/patient-year, respectively. Thromboembolic events in the cloth-covered S-E ball valve were higher than those in the bileaflet valves. These rates of each valve type were almost similar to the previous reports.

Valve dysfunction because of cloth wear and pannus overgrowth was more extensive than expected based on the reoperations. Clinical manifestations of heart failure, such as increasing dyspnea during exercise, edema of the extremities, disappeared after reoperation, especially in patients who underwent valve replacement more than 20 years ago. These hemodynamically deteriorated conditions could be corrected by reoperation. Aggressive management by reoperation is recommended when the cardiothoracic ratio is markedly increased on chest X-ray, and moderate prosthetic regurgitation is observed with heart failure symptoms, especially in the mitral patients. With the aortic patients, many of the surviving patients are in good condition, however, early diagnosis of these valve-related complications and decision to reoperate after strict management by chest X-ray and echocardiography are recommended as soon as symptoms appear in order to improve the long-term results for surviving patients who underwent the cloth-covered S-E ball valve replacement.

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The authors are grateful to Edwards Lifesciences, Ltd, for providing financial support for this study.

References