Improved early results after heart valve surgery over the last decade

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Abstract

Objectives: This study was undertaken to investigate time trends in early mortality, morbidity and clinical characteristics of patients undergoing heart valve surgery over the last decade. Methods: A regional, prospectively collected, study comprising all patients (2327) undergoing valve surgery in a defined geographical area from January 1990 to December 1999 was conducted. Data were collected from 1746 patients submitted to aortic valve replacement (AVR), 432 to mitral valve replacement (MVR), 78 to double valve replacement (DVR) and 71 to mitral valve repairs. Logistic regression was used to identify risk factors for early mortality. Time trends of early mortality, morbidity and clinical characteristics were analysed. Results: The total early mortality rate was 5.9%; for AVR it was 4.8%, MVR 9%, DVR 14% and mitral valve repair 1.4%. The risk factor profiles for early mortality were similar in all groups of valve interventions, with shock, age over 70 years and advanced NYHA class as the strongest risk factors. There was a decrease in early mortality over the period which remained after correction for risk factors. The proportion of patients over 70 years of age and of patients with diabetes increased, whereas other risk factors were not altered during the study period. Conclusion: It is confirmed that early risks for death after heart valve surgery have decreased. This improvement was consistent after adjustment for risk factors. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Heart valve surgery; Early mortality; Morbidity; Time trends

1. Introduction

Early results after coronary artery bypass grafting have improved continuously over recent years [1,2]. With regard to heart valve surgery, mortality rates reported in modern case series are lower than those found in earlier eras [3–5], but few studies on this issue have been conducted on a population-based level. After heart valve surgery, patients with no or minimal symptoms (New York Heart Association (NYHA) class I–II) prior to surgery show excellent results, both short- and long-term, while patients in a more advanced NYHA class have an apparent excess mortality and morbidity [6–8]. These observations have led to a tendency towards recommendations to perform surgery in an earlier stage of the disease process [6–8]. As a consequence, patients undergoing valve surgery today are generally exposed earlier to the risks of operative mortality and morbidity. Also, other characteristics of patients submitted to valve replacement have changed. Today a larger number of patients are operated on for degenerative valve disease at an increasingly higher age. Thus, with the optimization of the surgical timing and the changes in patient characteristics, quality assurance of heart valve surgery is becoming increasingly important, so that the patient can be ensured a minimal risk. The aim of this study was to investigate the time trends of the early results and of the clinical characteristics of patients undergoing heart valve surgery over the last ten-year period. Operative mortality and morbidity were used as measures of early results.

2. Material and methods

2.1. Patients

From January 1990 to December 1999 inclusive, 2327 consecutive patients underwent primary heart valve surgery, with (n = 971) or without (n = 1356) concomitant coronary artery bypass grafting (CABG) at the Department of Thoracic and Cardiovascular Surgery of the University Hospital, Uppsala, Sweden. Of these patients, 1746 had aortic valve replacements (AVR), 432 had mitral valve replacements (MVR), 78 had double valve replacements (DVR), and 71 patients had mitral valve repair. There were 1427 men (61%: mean age 65.1 years, range 17–90) and 900 women (39%: mean age 69.9 years, range 27–86). Preoperative clinical characteristics are shown in Table 1. The preopera-
tive ejection fraction was below 30% in 6.4% of the population. Forty-six patients (2.0%) underwent emergency surgery (within 24 h of the decision). Preoperative coronary angiography was performed in all patients over 50 years of age, and in all patients with angina or in whom coronary artery disease was suspected on a clinical basis. All operations were carried out with a standard technique for cardiopulmonary bypass (CPB) and in moderate hypothermia (25–32 °C). Cold crystalloid cardioplegic solution (modified St. Thomas) in a single dose or multidose was most frequently applied.

Our current policy is to recommend a bioprosthesis to patients aged 70 years or older. However, the decision concerning the type and trademark of the prosthesis is left...
to the discretion of each surgeon. A mechanical valve was used in 1480 of the patients (St. Jude 690 patients, Björk–Shiley 104, Carbomedic 576, composite graft 51, and other unspecified 59), and a bioprosthesis in 847 patients (Carpentier–Edwards 491 patients, Sorin 215, homograft 3, aortic repair 7, and miscellaneous types 131).

2.2. Data collection and follow-up

All clinical data were collected at a preoperative interview with the patient and stored in a computer.

The following variables were entered into the analyses: demographic variables (age at operation, sex, year of surgery), history of the disease (previous myocardial infarction), symptoms and clinical status (dyspnea, left heart failure, NYHA functional class, preoperative heart rhythm (sinus rhythm, atrial fibrillation, or other)), preoperative haemodynamics (stable, stable with inotropic treatment or shock), priority of surgery (elective, urgent, or emergency), associated conditions (hypertension, diabetes, history of cerebrovascular disease, decreased renal function (dialysis-dependent or not dialysis-dependent (defined as preoperative S-creatinine above 150 μmol/l)) or any other serious diseases, e.g. malignancies), preoperative catherization data (presence of significant coronary artery disease (i.e. with stenosis of 50% or more in at least one coronary artery)), and characteristics of the surgical procedure (aortic cross-clamp time and cardiopulmonary bypass time, concomitant CABG, concomitant MVR, perioperative myocardial injury [defined as a new Q wave on ECG, and/or an elevation of serum cardiac enzymes measured on the first postoperative day. A concentration of serum aspartate aminotransferase (S-ASAT, normal range < 0.6 μkat/l) exceeding 2.5 μkat/l and/or a concentration of creatinine kinase isoenzyme (CK-MB, normal range <3 μkat/l) exceeding 50 μkat/l was considered elevated]).

NYHA classification [9] of congestive heart failure was made on the basis of the clinical status of the patient at the preoperative interview: patients who suffered slight discomfort in their normal activity were allocated to NYHA class IIIA. Patients who managed only the lightest of activity without discomfort were allocated to NYHA IIIB, and those confined to bed because of symptoms were assigned to NYHA IV.

Left ventricular (LV) function was classified as either normal, moderate dysfunction, or severe dysfunction, on the basis of ejection fraction. Ejection fraction values above 0.5 were considered to be represent normal LV-function, values between 0.50 and 0.35 moderate LV dysfunction, and values below 0.30 severe LV dysfunction.

By use of two national registers, namely the Swedish Cause of Death Register and a continuously updated population register, all patients were followed up in January 2000. All patients were assigned a date of death or identified as being alive within 30 days from surgery.

2.3. Outcome event

Early mortality was defined as death from any cause within 30 days from surgery.

2.4. Postoperative complications

Postoperative complications registered were: heart failure (defined as one of the following: death within the first postoperative day due to heart failure, postoperative requirement of two or more inotropic drugs, failure to wean from CPB after prolonged reperfusion (over 45 min), or inadequate circulation later in the postoperative period). Inadequate circulation was defined as: mean arterial pressure (MAP) below 60 mmHg, poor peripheral perfusion as indicated by oliguria (less than 400 ml/24 h), mixed venous oxygen saturation below 60%, or a cardiac index of less than 2 l/min per m²). Bleeding was defined as excessive postoperative bleeding requiring reoperation. Neurological complication was defined as any neurological deficit occurring postoperatively with a corresponding cerebral lesion on computed tomography.

2.5. Statistical methods

Risk factors for a poor outcome were identified by univariate and multivariate analysis, using the logistic regression model [10]. Estimates for all models were obtained with the maximum likelihood method. The explanatory variables were first considered one by one and then in a multivariate analysis, in order to select the set of variables that best predicted the outcome. The odds ratio (OR) computed from the logistic regression analysis was used as a measure of the relative risk [11]. ORs are given with 95% confidence intervals (CI) within parentheses.

Further, stratified logistic regression models were used for the analysis of the interaction between risk factors and type of lesion. Interaction was then tested for by introduction of an interaction term.

Continuous variables were first tested in their original continuous form and then with a set of dummy variables representing ranges, defined by commonly used, or standard cut-off points. This model was preferred since it could not be assumed that the relation between the continuous variables and the logarithmic odds of operative mortality was linear. The odds ratios and their 95% confidence intervals are in general given for the variable in categorized form; this way of presenting the results was considered the most informative. In the multivariate analyses, the variables were used in their optimal form i.e., the form with the best discriminatory power.

All variables found to be significant (P < 0.05) in the univariate analysis were considered in the multivariate analysis. An alternative model based on the preoperatively available variables was defined.

On the basis of the final multivariate model, based on all available risk factors, a risk score for early mortality was
computed for each patient. Patients were categorized according to that risk score into either a high- or a low-risk group. The predicted outcome was compared with the actual observed outcome using different cut-off points. Sensitivity and specificity obtained by the final model using different cut-off points are presented as a receiver operating characteristic (ROC) curve [12] for validation of the risk model. The area under the ROC curve was used to assess how well the models could discriminate between patients who survived and those who died within 30 days from surgery.

The Cochran-Armitage Trend Test was used to test for trends in the incidence of postoperative complications and to determine the distribution of risk factors over time.

All calculations were performed with the SAS 6.12 statistical procedure.

### 3. Results

#### 3.1. Outcome

The total early mortality rate was 5.9% (138/2327) (Table 2). In the AVR group it was 4.8%, in the MVR group 9.0% and in the DVR group 14%. One of the 71 patients in the mitral repair group died within 30 days. Overall, 49% of the total population were older than 70 years, as compared to 67% (93/138) of those who died early (Table 1).

The most common causes of early death (within 30 days) were cardiac-related conditions and multiple organ failure with frequencies of 62 and 12%, respectively (Table 3).

The occurrence of postoperative complications is shown in Table 2. One hundred and one of the 2327 patients (4.3%) suffered a neurological complication. The incidence of postoperative heart failure was 19.5% (455/2327). In the AVR group it was 16%, in MVR 31% and in DVR 40%. Of the 455 patients who suffered postoperative heart failure, 62% (282/455) were older than 70 years.

#### 3.2. Risk factors

Factors related to an increased risk for early mortality are listed in Tables 1 and 4. Age over 70 years increased the early risk, with an OR for early mortality of 2.1. Patients in an advanced NYHA class, especially NYHA class IV, were also at increased risk, with an OR of 2.2. The strongest predictor of early death was preoperative shock, with an OR of 3.5. Operative factors that increased the risk for early mortality were aortic cross-clamp time over 150 min and in the DVR group 14%. One of the 71 patients in the mitral repair group died within 30 days. Overall, 49% of the total population were older than 70 years, as compared to 67% (93/138) of those who died early (Table 1).

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In an alternative model based only on preoperatively available risk factors (operative variables were excluded), the following risk factors gave independent prognostic information: NYHA class (NYHA I–IIIA OR = 1.0, NYHA IIIB OR = 2.1 (1.7–2.5), NYHA IV OR = 5.7 (5.1–6.3)), old age (age < 70 years OR = 1.0, age > 70 years OR = 2.0 (1.7–2.4)), concomitant MVR (OR = 1.5 (1.1–2.0)), year of surgery (OR = 0.9 for every year since 1990), hypertension OR = 1.7 (1.3–2.0), atrial fibrillation (OR = 1.5 (1.2–1.9)) and decreased renal function (OR = 1.9 (1.3–2.6)).

There was a significant interaction effect between preoperative atrial fibrillation and type of valve procedure (P-value for interaction variable = 0.0015). Atrial fibrillation was a significant risk factor for early mortality (OR = 2.6 (1.6–4.1)) in patients who underwent aortic replacement (i.e. the AVR and DVR groups), but had no effect in the MVR group (OR = 0.96 (0.7–2.8)). The incidence of atrial fibrillation was 10% in the AVR group, 44% in the MVR group, 44% in the DVR group and 35% in the mitral valve repair group.

There were no other significant interaction effects between types of valve interventions and risk factors.

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Table 2

<table>
<thead>
<tr>
<th>Postoperative complications</th>
<th>Total (n = 2327) (%)</th>
<th>Aortic (n = 1746) (%)</th>
<th>Mitral (n = 432) (%)</th>
<th>Double (n = 78) (%)</th>
<th>Mitral repair (n = 71) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early mortality</td>
<td>5.9</td>
<td>4.8</td>
<td>9.0</td>
<td>14</td>
<td>1.4</td>
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<tr>
<td>Bleeding</td>
<td>8.2</td>
<td>8.1</td>
<td>9.9</td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>Sternal infection</td>
<td>1.5</td>
<td>1.7</td>
<td>0.7</td>
<td>1.3</td>
<td>2.8</td>
</tr>
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<td>Atrial fibrillation</td>
<td>37</td>
<td>40</td>
<td>32</td>
<td>24</td>
<td>24</td>
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<tr>
<td>Myocardial injury</td>
<td>21</td>
<td>19</td>
<td>24</td>
<td>31</td>
<td>40</td>
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<tr>
<td>Neurological</td>
<td>4.3</td>
<td>4.6</td>
<td>3.0</td>
<td>6.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Heart failure</td>
<td>19</td>
<td>16</td>
<td>31</td>
<td>40</td>
<td>11</td>
</tr>
<tr>
<td>Postoperative aortic balloon pump</td>
<td>33</td>
<td>19</td>
<td>8</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

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Table 3

<table>
<thead>
<tr>
<th>Cause</th>
<th>n</th>
<th>%</th>
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<tbody>
<tr>
<td>Cardiac</td>
<td>85</td>
<td>62</td>
</tr>
<tr>
<td>Multiple organ failure</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>Postoperative hemorrhage</td>
<td>12</td>
<td>8.7</td>
</tr>
<tr>
<td>Neurological</td>
<td>5</td>
<td>3.6</td>
</tr>
<tr>
<td>Infection</td>
<td>4</td>
<td>2.9</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
<td>12</td>
</tr>
</tbody>
</table>
3.3. Time trends

There was a consistent decrease in early mortality over the study period (OR < 0.9 for every year after 1990 (95% CI 0.87–0.94)) (Fig. 1). This decrease remained after adjustment for risk factors (Table 1) and was seen in all valve groups. There were too few patients in the mitral valve repair group to permit separate analyses of time trends.

While there was a decrease in the incidence of perioperative myocardial injury and postoperative heart failure over the study period (P-value for trend < 0.001, Fig. 2, upper), and of patients with diabetic disease (P-value for trend < 0.0442, Fig. 2, lower), but no other significant change in clinical characteristics over time was detected.

3.4. Prognostic models

A risk score for early mortality was calculated for each patient, using the final multivariate model based on all available risk factors. Patients were categorized according to the calculated risk score into either a high-risk or a low-risk group. Eight hundred and thirty patients had a calculated risk for early death of 10% or more. Of these 830 patients, 10% died within 30 days. Thus the sensitivity of the model using this definition of a high-risk group was 73.2%, and the predictive value for early mortality was 12% (101/830). When different cut-off points in the calculated risk score were used to classify low- and high-risk patients, the sensitivity and specificity obtained are illustrated in a ROC curve. The area under the ROC curve was 0.77 for all available risk factors (Fig. 3).

Using the alternative risk model based on preoperatively available risk factors, 344 patients had a calculated risk for early death of 10% or more. Of these 344 patients, 53 died within 30 days. The area under the ROC curve was 0.66 for the model based only on the preoperatively available risk factors (Fig. 4).

### Table 4

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total</th>
<th>Early mortality (n = 138)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n</td>
<td>n</td>
</tr>
<tr>
<td></td>
<td>OR</td>
<td>CI</td>
</tr>
<tr>
<td>Concomitant MVR</td>
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<td></td>
</tr>
<tr>
<td>No</td>
<td>1817</td>
<td>88</td>
</tr>
<tr>
<td>Yes</td>
<td>510</td>
<td>50</td>
</tr>
<tr>
<td>Concomitant CABG</td>
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<tr>
<td>No</td>
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<td>64</td>
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<td>Yes</td>
<td>971</td>
<td>74</td>
</tr>
<tr>
<td>Aortic cross-clamp time (min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 60</td>
<td>314</td>
<td>12</td>
</tr>
<tr>
<td>60–90</td>
<td>1080</td>
<td>51</td>
</tr>
<tr>
<td>120–150</td>
<td>623</td>
<td>28</td>
</tr>
<tr>
<td>&gt; 150</td>
<td>310</td>
<td>47</td>
</tr>
<tr>
<td>Bypass time (min)</td>
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<tr>
<td>&lt; 120</td>
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<td>26</td>
</tr>
<tr>
<td>120–150</td>
<td>668</td>
<td>29</td>
</tr>
<tr>
<td>150–180</td>
<td>338</td>
<td>22</td>
</tr>
<tr>
<td>&gt; 180</td>
<td>405</td>
<td>61</td>
</tr>
<tr>
<td>Perioperative myocardial injury</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>1850</td>
<td>69</td>
</tr>
<tr>
<td>Yes</td>
<td>477</td>
<td>69</td>
</tr>
</tbody>
</table>

a MVR, mitral valve replacement; CABG, coronary artery bypass grafting; OR, odds ratio; CI, 95% confidence interval; n.s., not significant.

b All available risk factors were used.

c Continuous variables were used in the form with the best discriminatory power, i.e. aortic cross-clamp time over 150 min, bypass time over 180 min.

Fig. 1. Time trend in early mortality during the study period 1990–1999. P-value for trend: <0.009.
4. Discussion

This study is based on a substantial number (2327) of consecutive patients who underwent heart valve surgery within a defined population. Moreover, the registration of all data—clinical, surgical and outcome-related—was done prospectively. The study clearly establishes that the early results after valve surgery have improved over the last decade. During this time period there has been a trend towards a change in the indications for surgery from at least two perspectives. On the one hand, patients with more advanced disease were submitted to surgery as a consequence of increasing age of the patient population. On the other hand, some patients with less advanced heart valve disease were accepted because of a tendency to recommend surgery in an earlier stage of the disease process. Thus, there has been a complex change in the patient material over this time period. However, in the present study the only significant finding that might reflect changing indications was an increased proportion of elderly patients. Despite general agreement favoring earlier surgery in heart valve patients, this policy could not be verified. This must be taken into consideration when interpreting these results. Nevertheless, the observed improvement in early results persisted after adjustment for changes in patient characteristics.

We found that the mortality rates in this study were comparable to those reported from other population-based studies. The STS National Database with 86 580 patients [13], and the CSCR study with 14 190 patients [14], report early mortality rates for AVR of 4.0 and 3.3% and for MVR of 6.0 and 6.2%, respectively. Concomitant CABG increased the early risk, giving rates of 6.8 and 7.1% for AVR/CABG and a rate of 13% for MVR/CABG. The early mortality in our study of 4.8% for AVR and 9.0% for MVR, included concomitant CABG in totally 41% of the cases. Thus, the early mortality rates in this study are in good agreement with the rates of the STS and CSCR databases.

In older studies, declining mortality rates among AVR patients were found in the mid 1980s [15]. Not many studies have been conducted in recent times and in population-based patient groups. The only recent population-based study, from Northern New England [16], showed a decrease in risk-adjusted early mortality from 9.3% (1992–1993) to 5.3% (1996–1997) in patients undergoing AVR without concomitant CABG. The corresponding decline in our study was from 5.6% (1990–1991) to 4.9% for AVR.
(1996–1999) including CAGB, and from 5.6 to 2.5% for isolated AVR. In the Northern New England study a decrease in mortality rate for MVR was also found, from 13.6% in 1992–1993 to 8.2% in 1996–1997. This was confirmed in our study, with a decrease in early mortality from 13.4% in 1990–1991 to 5.0% in 1998–1999 in the combined MVR and CAGB population. The corresponding decrease in patients undergoing MVR without concomitant CAGB was from 15.8 to 2.4%.

While the number of patients undergoing mitral valve surgery has remained constant over the last decade, there has been a shift towards an increased proportion of mitral valve repairs. Moreover, the possibility of valvuloplasty has led to a trend towards earlier surgery in some patients with mitral valve disease. Both of these changes may have contributed to the improved early results.

Today, optimal preoperative assessment and management of patients with heart valve disease include more frequent use of echocardiography [17,18]. Echocardiography provides readily available and more objective measures of, for example, the severity of the lesion and left heart function. However, there is a lack of correlation between hemodynamic severity and clinical outcome, and the importance of obtaining a careful history concerning any symptoms must therefore be emphasized. The onset of symptoms can be insidious, and patients may incorrectly ascribe a decrease in exercise tolerance to other causes. Today optimal timing of surgery is based on careful and recurrent echocardiographic examinations and interviews with patients. This may be compared with earlier eras when the decision-making was predominantly clinical, and might have been the main reason for somewhat late surgical correction in patients with already irreversible damage to the heart.

The incidence of postoperative complications tended to decrease over time. In the total population, there was a substantial decrease in the incidence of heart failure from 25 to 12%. In the AVR group there was a decrease from 20 to 12%, and in the MVR group from 42 to 22%. During the same period the overall incidence of perioperative myocardial injury fell from 20 to 13%. These declines might partly be due to the improved preoperative clinical status of the patient undergoing valve surgery today. There has been a refinement of the medical treatment over the last decade, and medications preserving the functional status of the heart, such as ACE inhibitors and/or beta-blockers, are more frequently in use today. Again, the more optimal timing of surgical correction prevents preoperative deterioration of the systolic and diastolic properties of the heart, which might contribute to the reduction of postoperative heart failure.

In the case of both early mortality and morbidity, the improvement trend must also be attributed to general improvements in the surgical technique, myocardial protection, anesthesia and postoperative care.

In our study, the risk factor profile was comparable to that observed in other studies, with old age and an advanced NYHA class as the most important risk factors. However, preoperative atrial fibrillation is not a generally accepted risk factor for early death in patients undergoing AVR or DVR, but it is a known risk factor for long-term mortality [19]. It may be speculated whether atrial fibrillation in patients undergoing AVR and DVR reflects the presence of more compromised myocardial dysfunction as compared to atrial fibrillation in patients with isolated mitral valve disease.

We have taken into account the majority of the now commonly identified and available risk factors. However, we did not include data about chronic obstructive pulmonary disease and peripheral vascular disease. These variables have been shown to be risk factors for early mortality in risk score models such as the STS mortality score and the EuroSCORE [13,20]. In the present study, comprising only primary heart valve procedures, the included risk factors could discriminate patients at high risk fairly well. Seventy-three percent of the patients who died had a calculated risk of 10% or more. However, a risk model based on data not available prior to surgery has limited usefulness in preoperative risk assessment. In our study, the alternative risk model, based on preoperatively available risk factors, yielded somewhat inferior risk prediction (only 38% of the patients who died had been allocated to the high-risk group) as compared to the risk model based on all available risk factors (including operative risk factors). This finding emphasizes the importance of an optimal surgical technique. It is obvious that a more complicated procedure also results in longer aortic cross-clamp and bypass times. Nevertheless, the aortic cross clamp time and bypass time can at least partly be considered surrogate measures of the quality of the surgical procedure. Given the same preoperative risk factors, the outcome in a single patient will be highly dependent on the surgical quality.

The long-term outcome after heart valve surgery is improved if the operative procedure is carried out in an earlier stage of the disease process [6–8,21–23]. To be able to recommend surgery to asymptomatic or virtually asymptomatic patients, a low operative risk is important. Our study shows that the risks of morbidity and mortality associated with the surgical procedure have been reduced and today are low for most groups of patients undergoing heart valve surgery. However, the decision to submit a patient to surgery must be based on many considerations and cannot be made solely on the grounds of the estimated operative risks.

References


