Evaluation of the Quality of Cardiovascular Surgery Care Using Risk Stratification Analysis According to the EuroSCORE Additive Model

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Risk stratification according to the EuroSCORE additive model of 803 consecutive patients undergoing heart and thoracic aorta surgery using cardiopulmonary bypass from August 1994 to December 2000 was performed. The population was divided into 5 clinically relevant risk categories: 0–2% risk, 3–5% risk, 6–8% risk, 9–11% risk, and 12+% risk. Observed and predicted mortalities were compared within 3 groups of patients divided by year of operation (early: August 1994 to September 1996, n=260; middle: October 1996 to September 1998, n=259; late: October 1998 to December 2000, n=284). Overall hospital mortality was 4.5%; predicted mortality was 5.3% in the early, 5.1% in the middle, and 5.4% in the late period; observed mortality was 6.5%, 3.9%, and 3.2%, respectively ($p=0.0024$ in early vs late). In the early period, observed mortality was lower than predicted mortality in the 0–2% and 3–5% risk categories, but higher in the other categories. Moreover, observed mortality increased markedly with the increase in predicted mortality. In the late period, observed mortality was lower than predicted mortality in all 5 risk categories. The EuroSCORE is clinically relevant index for constructing a risk stratification scoring system for Japanese cardiovascular patients as well and shows that the quality of surgical care has improved gradually over the years. (*Circ J* 2002; 66: 145–148)

Key Words: Cardiovascular surgery; EuroSCORE; Observed mortality; Predicted mortality; Risk stratification

For an evaluation of the results of cardiovascular surgery, crude operative mortality rate (ie, the number of deaths divided by the number of operations) is generally employed, although these raw outcome data do not reflect the preoperative condition of the individual patient. Therefore, to resolve that problem, risk stratification analysis was developed^{1–3} for 2 major uses: one is estimating the risk of surgical mortality faced by an individual patient, as an aid to patients and physicians contemplating cardiovascular surgery, and the other is as a tool for measuring the quality of surgical care. Recently, the European System for Cardiac Operative Risk Evaluation (EuroSCORE) additive model was introduced, and it has global scores with simple and objective definitions provided at the data collection stage.² We used the EuroSCORE algorithm to assess the biennial trend towards a reduction in operative mortality rate in order to assess the quality of cardiac and thoracic aortic surgical care in our institution.

Methods

Between August 1994 and December 2000, 803 consecutive patients had surgery for cardiac and thoracic aortic disease: 486 men (61%) and 317 women (39%), aged from 13 to 90 years old (mean, 63 ± 12 years). All patients selected had to have undergone cardiovascular surgery with cardio-

pulmonary bypass, so those who had off-pump coronary artery bypass grafting (CABG) were excluded. The patient population was divided into 3 time periods: early (August 1994 through September 1996, n=260), middle (October 1996 through September 1998, n=259), and late (October 1998 through December 2000, n=284). The distribution of the surgery performed is shown in Table 1, and the data for the EuroSCORE risk factors, which was entered into a database, is shown in Table 2. Expected or predicted mortality was calculated for individual patients using the EuroSCORE additive model, arranged sequentially in order of predicted score. The study population was divided into 5 clinically relevant risk categories: 0–2% risk, 3–5% risk, 6–8% risk, 9–11% risk, and 12+% risk. Mortality was defined as death from any cause within 30 days of operation or within the same hospital admission, and expected mortality was compared with observed or actual mortality for each risk category.

The continuous data were expressed as the mean $\pm$ one standard deviation, and categorical variables were expressed as percentages. Statistical analysis was conducted using StatView 5.0 (SAS Institute Inc, Cary, NC, USA). Comparison of 2 groups was performed for categorical variables with the chi-square test with 2×2 contingency tables or Fisher's exact test as appropriate. The receiver operating characteristic (ROC) curves were plotted to assess the discrimination abilities (accuracy) of the EuroSCORE.⁴ The area under the ROC curve was calculated as an index for how well the model could discriminate between patients who lived and those who died. The discriminative power of the model is thought excellent if the area under the ROC curve is >0.8 , very good if $\geq 0.8 > 0.75$, and good if $\geq 0.75 > 0.70$.⁵ Variables were judged significant at $p<0.05$.

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Table 1 Distribution of the Surgical Procedures

Procedure	No. of patients			Total	Mortality total
	'94.8-'96.9	'96.10-'98.9	'98.10-'00.12		
CABG only	94 (36%)	90 (35%)	117 (41%)	301 (38%)	12 (4.0%)
CABG + Valve	10 (3.8%)	11 (4.2%)	7 (2.5%)	28 (3.5%)	3 (11%)
Valve only	85 (33%)	89 (34%)	82 (29%)	256 (32%)	4 (1.6%)
TAA only	36 (14%)	41 (16%)	44 (15%)	121 (15%)	14 (12%)
TAA + Others	4 (1.5%)	3 (1.2%)	7 (2.5%)	14 (1.7%)	2 (14%)
MI complication	2 (0.8%)	4 (1.5%)	0 (0%)	6 (0.7%)	1 (17%)
Others	29 (11%)	21 (8.1%)	27 (9.5%)	77 (9.6%)	0 (0%)
Total	260 (100%)	259 (100%)	284 (100%)	803 (100%)	36 (4.5%)

CABG, coronary artery bypass grafting; TAA, thoracic aortic aneurysm; MI, myocardial infarction.

Table 2 Results of Univariate Analysis Regarding the Risk Factors of the EuroSCORE

Risk factor	With risk factor		Without risk factor		p value
	Total pts	Mortality (%)	Total pts	Mortality (%)	
Age					
60-64	137	2.2	237	4.6	0.85
65-69	174	4.0			
70-74	148	4.1			
75-79	78	7.7			
80-84	25	12			
85-89	3	0			
≥90	1	0			
Female gender	315	3.2	488	5.3	0.17
Chronic pulmonary disease	8	0	795	4.5	>0.9999
Extracardiac arteriopathy	66	4.5	737	4.5	>0.9999
Neurological dysfunction	16	13	787	4.3	0.16
Previous cardiac surgery	53	7.5	750	4.3	0.29
Serum creatinine >2 mg/dl	32	13	771	4.2	0.050
Active endocarditis	15	6.7	788	4.4	0.50
Critical preoperative state	59	25	744	2.8	<0.0001
Unstable angina	71	13	732	3.7	0.003
LVEF					
30-50%	102	6.9	686	3.6	0.013
<30%	15	27			
Recent myocardial infarct	63	16	740	3.5	0.0002
Pulmonary hypertension	19	21	784	4.1	0.008
Emergency	110	16	693	2.6	<0.0001
Other than isolated CABG	406	3.0	397	6.0	0.040
Surgery on thoracic aorta	134	12	669	3.0	<0.0001
Postinfarct septal rupture	3	33	800	4.4	0.13

LVEF, left ventricular ejection fraction; CABG, coronary artery bypass grafting.

Results

Overall hospital mortality was 4.5% (36 of 803 patients); the mortality rate for each surgical procedure is shown in Table 1 and Table 2 shows the impact of the EuroSCORE risk factors on hospital mortality based on univariate analysis. Eight of the 17 variables influenced mortality significantly; namely serum creatinine >2 mg/dl, critical preoperative state (ventricular tachycardia or fibrillation or aborted sudden death, preoperative cardiac massage, preoperative ventilation before arrival in the anaesthetic room, preoperative inotropic support, intraaortic balloon counterpulsation or preoperative acute renal failure), unstable angina (rest angina requiring intravenous nitrates until arrival in the anaesthetic room), left ventricular dysfunction (left ventricular ejection fraction <50%), recent myocardial infarct (<90 days), pulmonary hypertension (systolic pulmonary artery pressure >60 mmHg), emergency (carried out on referral before the beginning of the next working day), and surgery on the thoracic aorta. Any procedure other than isolated

CABG (major cardiac procedure other than or in addition to CABG) was associated with decreased risk.

Fig 1 shows patient distribution by risk classification: the percentage of patients with a EuroSCORE value of 6% or higher was 39% in the early, 35% in the middle, and 43% in the late period, an increase in the late period without significance ($p=0.079$ in middle vs late). Observed mortality gradually decreased with the years (Fig 2). In the early period, observed mortality was lower than predicted mortality in the 0-2% and 3-5% risk categories but higher in the other categories (Fig 3). Moreover, observed mortality increased markedly with an increase in predicted mortality. In the late period, observed mortality was lower than predicted mortality in all risk categories (Fig 4): predicted overall mortality was 5.3% in the early, 5.1% in the middle, and 5.4% in the late period and observed overall mortality was 6.5%, 3.9%, and 3.2%, respectively ($p=0.0024$ in early vs late). The area under the ROC curve was 0.82 overall, 0.83 in the early and middle periods, and 0.81 in the late period (Fig 5).

Fig 1. Patient distribution according to risk stratification in each period.

Fig 2. Observed mortality according to risk stratification analysis in each period.

Fig 3. Comparison between predicted mortality and observed mortality in the early period.

Fig 4. Comparison between predicted mortality and observed mortality in the late period.

Discussion

Being able to compare surgical outcome at different times and at different institutions is the major advantage of risk stratification because evaluation of the surgical mortality rates of hospitals and surgeons can only be fair and realistic when the observed mortality rates are compared with predicted mortality rates with preoperative risk factors taken into account.⁶ Risk stratification has become an important tool in assessing the quality of surgical care for the increasing age, disease severity, and comorbidity of patients undergoing heart and thoracic aorta surgery. Quality monitoring is a mainstay of good surgical practice and since August 1994 when the hospital opened, we have used the Parsonnet additive model³ because of its classic and easy application,⁷ but have found it difficult to predict the surgical mortality of thoracic aortic surgery with this algorithm.⁸ In 1999, Nashef et al introduced EuroSCORE, in which the risk factor of surgery on thoracic aorta was associated with an increased mortality at a score of 3.² Moreover, it had global scores and simple and objective definitions at the data collection stage. EuroSCORE consists of 3 groups of weighted risk factors (additive % predicted mortality). Patient-related factors are age >60 (1 point per 5 years or part thereof), female gender (1), chronic pulmonary disease (1), extracardiac arteriopathy (2), neurological dysfunction (2), previous cardiac surgery (3), serum creatinine >2 mg/dl (2), active endocarditis (3) and critical preoperative state (3). Cardiac factors are

Fig 5. The receiver operating characteristic (ROC) curve in all patients.

unstable angina on intravenous nitrates (2), reduced left ventricular ejection fraction (30–50%: 1, <30%: 3), recent (<90 days) myocardial infarction (2) and pulmonary systolic pressure >60 mmHg (2). Operation-related factors are emergency (2), other than isolated CABG (2), thoracic aorta surgery (3) and surgery for postinfarct septal rupture (4) (Table 2).² The predicted mortality rate of individual patients is the sum of these appropriate scores.

The risk stratification analysis allows a comparison of the case mix, most readily represented by the mean expected

Table 3 Comparison of the Surgical Results

	EuroSCORE			Total
	0-2	3-5	6+	
<i>Nashef et al</i> ²				
Patients	4,529	5,977	4,293	14,799
Percentage (%)	31	40	29	100
Mortality (%)	0.8	3.0	11	4.7
<i>Pitkanen et al [R]</i> ¹⁰				
Patients	714	548	269	1,531
Percentage (%)	47	36	18	100
Mortality (%)	0.6	1.3	7.8	2.1
<i>Pitkanen et al [P]</i> ¹⁰				
Patients	326	309	186	821
Percentage (%)	40	38	23	100
Mortality (%)	0.3	0.6	3.2	1.1
<i>Present study</i>				
Patients	146	342	315	803
Percentage (%)	18	43	39	100
Mortality (%)	0	1.5	9.8	4.5

R, retrospective validation database; P, prospective validation database.

risk or by the percentage of patients whose risk exceeds poor (a EuroSCORE value of 6% or higher)⁹. In the present patient population, the mean expected mortality rate was 5.3% in the early, 5.1% in the middle, and 5.4% in the late period, and the percentage of patients with a predicted risk 6% or higher was 39%, 35% and 43%, respectively. From these results, the preoperative and operative risk was slightly higher in patients during the late period without significance. The overall observed mortality decreased markedly from 6.5% in the early period to 3.2% in the late period ($p=0.0024$), with the surgical result for patients with a 6% or higher risk particularly improved (Fig 2). However, it should be mentioned that each risk category of 6% or higher had a small patient number. From this risk stratification analysis, we believe that the quality of cardiovascular surgery had gradually improved over the course of years. The primary factors for this improvement are under consideration, but may be the conversion of cardioplegia from crystalloid to blood, progress in patient care during the critical preoperative state and training of staff and doctors in theater and the intensive care unit.

Comparable external data is necessary to put individual institutional findings in perspective. The EuroSCORE is suited for this because the data can be collected easily using standardized definitions. Our observed mortality was parallel to the EuroSCORE application data reported by Nashef et al (Table 3)². Pitkanen et al reported good operative results, particularly in the patient population with 6% or higher risk¹⁰. The percentage of the present patients whose predicted risk exceeded 6% was significantly higher than in other reports ($p<0.0001$), which means that higher risk patients undergo surgery more frequently in our institution than in other institutions.

In the United States another risk stratification method for cardiac surgery, the Society of Thoracic Surgeons National Database (STS database) has gradually gained authority^{1,11,12}. Individual institutions can enter their patient population data into computer software, obtain the predicted mortality rate of each patient and compare their risk-adjusted surgical results with the national standard derived from the North American patient population. However, the computer software for the STS database is expensive whereas EuroSCORE is a free, simple, objective and up-to-date system for assessing cardiac and thoracic aortic surgery².

In conclusion, using to the EuroSCORE additive model we can fairly calculate the predicted risk of surgical mortality faced by an individual patient and evaluate the actual mortality rates of hospitals with risk stratification scoring analysis of the case mix undergoing cardiovascular surgery. The EuroSCORE is a clinically relevant index not only for European but also for Japanese cardiovascular patients. The quality of surgical care in our institution has gradually improved over the years.

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