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Validation of European System for Cardiac Operative Risk Evaluation (EuroSCORE) in North American cardiac surgery ☆

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Abstract

Objective: To assess the performance of the European System for Cardiac Operative Risk Evaluation (EuroSCORE) when applied in a North American cardiac surgical population. **Methods**: The simple additive EuroSCORE model was applied to predict operative mortality (in-hospital or 30-day) in 401 684 patients undergoing coronary or valve surgery in 1998 and 1999 as well as in 188 913 patients undergoing surgery in 1995 in the Society of Thoracic Surgeons (STS) database. **Results**: The proportion of isolated coronary artery bypass grafting (CABG) was greater in STS patients (84%) than in Europe (65%). STS patients were also older (mean age 65.3 versus 62.5), and had more diabetes (30 versus 17%) and prior cardiac surgery (11 versus 7%). Other comorbidity was also significantly more prevalent in STS patients. EuroSCORE predicted overall mortality was virtually identical to the observed mortality (1998/1999: predicted 3.994%, observed 3.992%; 1995: observed and predicted 4.156%). Predicted mortality also closely matched observed mortality across the risk groups. Discrimination was good to very good for the population overall and for isolated CABG in both time periods, with the area under the receiver operating characteristic curve between 0.75 and 0.78. **Conclusion**: Despite substantial demographic differences between Europe and North America, EuroSCORE performs very well in the STS database, and can be recommended as a simple, additive risk stratification system on both sides of the Atlantic.

Keywords: European System for Cardiac Operative Risk Evaluation; Society of Thoracic Surgeons; Database; Risk stratification

1. Introductions

The European System for Cardiac Operative Risk Evaluation (EuroSCORE) was developed between 1995 and 1999 to provide a simple, additive risk model in European adult cardiac surgery [1,2] and has gained wide acceptance in Europe and elsewhere. In North America, the Society of Thoracic Surgeons (STS) has developed a national database which was first established in 1989 for the primary purpose of outcome assessment following cardiac surgery in adults [3] as well as to provide a potential clinical research tool for the future [4]. The STS database is now without doubt the largest of its kind in the medical world. The purpose of this study was to evaluate the performance of EuroSCORE in North American cardiac surgery by testing it on the STS database.

2. Methods

The development of the EuroSCORE risk model has been described in full previously [1,2]. Briefly, comprehensive data were obtained for over 19 000 consecutive patients undergoing open heart surgery in 128 centres in eight European countries. The database thus generated was subjected to multiple regression analysis to determine which risk factors were associated with operative mortality. Weights were allocated to each risk factor on the basis of the odds ratios and a risk model was constructed in which the percentage predicted mortality for a patient could be calcu-

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Table 1
Exact definitions of risk factors in Europe (EuroSCORE) and America (STS)

Risk factor	EuroSCORE definition	STS definition match
Age	Per 5 years or part thereof over 60 years	Per 5 years or part thereof over 60 years
Sex	Female	Female
Chronic pulmonary disease	Long-term use of bronchodilators or steroids for lung disease	Patient required pharmacologic therapy for the treatment of chronic pulmonary compromise, or patient has a FEV1 <75% of predicted value
Extracardiac arteriopathy	Any one or more of the following: claudication, carotic occlusion or >50% stenosis, previous or planned intervention on the abdominal aorta, limb arteries or carotids	Patient has peripheral vascular disease as indicated by claudication either with exertion or rest; amputation for arterial insufficiency; aorto-iliac occlusive disease reconstruction; peripheral vascular bypass surgery, angioplasty or stent; documented AAA, AAA repair, or stent; positive non-invasive testing documented – or – Patient has cerebrovascular disease, documented by any one of the following: Unresponsive coma >24 h; CVA (symptoms >72 h after onset); RIND (recovery within 72 h); TIA (recovery within 24 h); or non-invasive carotid test with >75% occlusion
Neurological dysfunction disease	Severely affecting ambulation or day-to-day functioning	A central neurologic deficit persisting more than 24 h
Previous cardiac surgery	Requiring opening of the pericardium	Prior cardiac surgical operation(s) with or without the use of cardiopulmonary bypass
Serum creatinine	> 200 mmol/l preoperatively	> 200 mmol/l preoperatively
Active endocarditis	Patient still under antibiotic treatment for endocarditis at the time of surgery	Patient currently under antibiotic treatment for endocarditis at the time of surgery
Critical preoperative state	Any one of more of the following: ventricular tachycardia or fibrillation or aborted sudden death, preoperative cardiac massage, preoperative ventilation before arrival in the anaesthetic room, preoperative inotropic support, intra-aortic balloon counterpulsation or preoperative acute renal failure (anuria or oliguria <10 ml/h)	Any one or more of the following: sustained ventricular tachycardia or ventricular fibrillation requiring cardioversion and/or IV amiodarone, preoperative inotropic support, preoperative intra-aortic balloon pump, or patient required cardiopulmonary resuscitation within 1 h before the start of the operative procedure
Unstable angina	Rest angina requiring iv nitrates until arrival in the anaesthetic room	Preoperative use of iv nitrates
LV dysfunction	Moderate or LVEF 30–50%; Poor or LVEF <30%	LVEF 30–50%; LVEF <30%
Recent myocardial infarction	< 90 days	< 21 days
Pulmonary hypertension	Systolic PA pressure >60 mmHg	Systolic PA pressure >30 mmHg
Emergency	Carried out on referral before the beginning of the next working day	Procedure status is emergent or salvage. *Emergent*: The patient's clinical status includes any of the following. a. Ischaemic dysfunction (any of the following): (1) ongoing ischaemia including rest angina despite maximal medical therapy (medical and/or IABP); (2) acute evolving myocardial infarction within 24 h before surgery; or (3) pulmonary oedema requiring intubation. b. Mechanical dysfunction (either of the following): (1) shock with circulatory support; or (2) shock without circulatory support. *Salvage: The patient is undergoing CPR en route to the OR or prior to anaesthesia induction*
Other than isolated CABG	Major cardiac procedure other than or in addition to CABG	Any valve procedure in addition to or separate from CABG
Surgery on thoracic aorta	For disorder of ascending, arch or descending aorta	Aortic aneurysm/dissection repair
Post-infarct septal rupture		Ventricular septal defect

lated by adding the weighted values of risk factors which are present. The genesis, growth and development of the STS database has also been described previously [5,6] and the database has already served to produce risk models for coronary surgery [7].

The American and European patient populations were compared for demographic characteristics, incidence of surgical procedures performed and prevalence of risk factors. The simple, additive EuroSCORE model was then tested on two groups of patients in the STS database: all patients who underwent adult cardiac surgery in 1995 and in the period spanning 1998 and 1999. The first was chosen because EuroSCORE was developed from a 1995 European patient cohort and the second because of greater similarity between the American and European datasets and greater recency and relevance. Nevertheless, the definitions of some of the risk variables were not identical in both Europe and America and some adjustments or approximate assumptions were made to enable complete analysis. The risk factors, together with their corresponding definitions are listed in Table 1.

Table 2
Prevalence of risk factors in Europe (EuroSCORE) and America (STS)

Risk factor	EuroSCORE prevalence (%)	STS prevalence (%)	*P*-value
N =	19 030	188 912	
Age			
Mean	62.5	64.6	<0.0001
<60 years	33.2	30.1	<0.0001
60–64 years	17.8	14.1	
65–70 years	20.7	18.4	
70–74 years	17.9	18.3	
75 + years	9.6	19.1	
Female	27.8	30.9	<0.0001
Chronic pulmonary disease	3.9	15.4	<0.0001
Extracardiac arteriopathy	11.3	19.0	<0.0001
Neurological dysfunction disease	1.4	6.3	<0.0001
Previous cardiac surgery	7.3	11.7	<0.0001
Serum creatinine >200 mmol/l	1.8	2.1	<0.0001
Active endocarditis	1.1	0.4	<0.0001
Critical preoperative state	4.1	9.0	<0.0001
Unstable angina	8.0	21.7	<0.0001
LV dysfunction			
LVEF 30–50%	25.6	37.8	<0.0001
LVEF <30%	5.8	5.2	
Recent myocardial infarct	9.7	20.9	<0.0001
Pulmonary hypertension	2.0	5.7	<0.0001
Emergency	4.9	8.6	<0.0001
Other than isolated CABG	36.4	18.8	<0.0001
Surgery on thoracic aorta	2.4	0.9	<0.0001
Postinfarct septal rupture	0.2	0.2	0.0961

Statistical analysis was by *t*-test for continuous variables and Chi square for categorical variables. *P* values under 0.05 were considered significant.

After applying the EuroSCORE algorithm to the STS data, a logistic regression of operative mortality on the resulting score was performed. This enabled the measurement of both the calibration and the discrimination of EuroSCORE on the STS population. Calibration was measured by comparing the observed mortality to the expected mortality for equal-sized quintiles of risk. Discrimination was measured by reporting the c-index of the above logistic regression model.

The c-index can be considered as a generalisation of the area under the receiver operating characteristic (ROC) curve and is calculated by analysing all possible pairs of patients that can be formed such that one patient died and the other did not. For a given pair, the predictions are said to be concordant with the outcome if the patient that died has a higher predicted probability of mortality than the patient that survived. The c-index is the proportion of these predictions that are concordant. Values of the c-index range from 0.5 (no ability to discriminate) to 1.0 (full ability to discriminate).

3. Results

3.1. Demographics

There were very important differences between the American and European surgical populations. American patients were older with proportionately more females. Europeans were twice as likely to have surgery other than isolated coronary artery bypass grafting (CABG), whereas American patients were more than twice as likely to have or be labelled as having unstable angina. American patients also had more comorbidity (respiratory, vascular, neurological and renal). Endocarditis had a higher incidence in Europe and proportionately more European patients had surgery on the thoracic aorta. All differences were highly significant ($P < 0.0001$) and the only similarity between the two populations was the percentage of patients operated for postinfarction septal rupture (0.2%). The prevalence of risk factors and the surgical profile in the two populations are detailed in Table 2.

3.2. Calibration

The EuroSCORE risk model was applied to the two STS datasets (1998–1999 and 1995). EuroSCORE predicted mortality was virtually identical to the observed mortality in 1998–1999 (3.994 versus 3.998%) and in 1995 (4.156 versus 4.156%). This predictive power was maintained when patients were divided into five approximately equal risk quintiles both in 1998/1999 and in 1995 (Tables 3 and 4) where EuroSCORE predicted mortality very accurately in all five risk groups.

Table 3
EuroSCORE predicted versus actual mortality in patients operated in 1998 and 1999 in the STS database

Quintile	Number of patients	Predicted mortality (%)	Observed mortality (%)
First	80 336	0.94	0.68
Second	80 337	1.62	1.42
Third	80 337	2.51	2.62
Fourth	80 337	4.08	4.31
Fifth	80 337	10.82	10.93
Total	401 684	3.994	3.992

3.3. Discriminatory power

The discriminatory ability of EuroSCORE on the prediction of mortality was assessed using the area under the ROC curve. The performance was good to very good throughout in all cardiac surgery as well as in the isolated CABG subset (Table 5).

4. Discussion

The originators and custodians of both the STS national database and of the EuroSCORE project share a strongly held conviction in the importance of data collection and risk stratification for proper quality assessment and outcome improvement in cardiac surgery. Multicentre databases are the cornerstone on which the quality assessment structure can be built, and centralised, risk stratified data are the essential building blocks on which analysis of quality, meaningful comparison of outcomes and, finally, improvements in outcomes can be based. This information is now an integral part of the practice of cardiac surgery. It forms part of risk assessment, surgical decision-making and the process of informed consent. Knowledge of risk and comparative outcomes is no longer an 'optional extra' in cardiac surgery: it is, and should be, as essential to the surgeon as the knowledge of surgical anatomy and techniques.

The choice of a risk model must necessarily depend on the unit and the audit resources to which it has access. Currently, hospitals range from those without even rudimentary data about numbers and types of procedures to those with full risk-stratified outcome data and the ability to perform complex Bayesian and regression analysis of outcomes. Whatever the available resources, inter-hospital and international evaluation of outcomes would strongly benefit from a universal and easily applicable risk model that can be understood by all. The simple additive EuroSCORE model has been shown to work well in both coronary surgery [8], valve surgery [9] and in overall cardiac surgery across many European countries [10]. The STS database algorithms remain proprietary and confidential. The reasons given for this are the protection of intellectual property and the encouragement of data submission. This paper demonstrates that EuroSCORE performs remarkably well in North American cardiac surgery despite substantial differences in demographic, risk and surgical characteristics between European and American patients. This performance is sustained across years, types of surgery and risk groups.

Table 4
EuroSCORE predicted versus actual mortality in patients operated in 1995 in the STS database

Quintile	Number of patients	Predicted mortality (%)	Observed mortality (%)
First	37 782	0.97	0.63
Second	37 782	1.65	1.47
Third	37 783	2.55	2.46
Fourth	37 782	4.13	4.57
Fifth	37 783	11.48	11.65
Total	188 913	4.156	4.156

Table 5
Discriminatory power of EuroSCORE mortality prediction in STS database patients

	C-index (area under ROC curve)
1995 (all patients)	0.77
1995 (CABG only)	0.78
1998/1999 (all patients)	0.77
1998/1999 (CABG only)	0.75

The additive EuroSCORE model, by virtue of its nature, tends to underestimate risk in very high-risk patients. This is not readily seen in analyses of large, multicentre databases. Some very high-risk patients may be better assessed, for individual risk prediction, by using the full logistic EuroSCORE model (www.euroscore.org).

In an ideal future world, there will be an international database of cardiac surgery to which all units will contribute data. The resources for complex and comprehensive risk analysis will be available to all, and accurate and individualised risk assessment will be within reach of every surgeon and every patient. In the meantime, there is a need for an international risk standard which can be used as a benchmark for risk assessment in inter-hospital and international studies. This study, together with previous work in Europe and elsewhere, demonstrates that EuroSCORE can provide that standard.

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Appendix A. Conference discussion

Dr B. Osswald (*Heidelberg, Germany*): The EuroSCORE has three classes for risk stratification. Did you also divide the patient groups into those three different score groups, and how did they differ from the published predictions?

Dr Nashef: I believe you are referring to the original paper in which we divided patients into three equal groups in order to validate and calibrate the system. We did not really intend these divisions to be in tablets of stone. We think the most important thing is to produce groups that are statistically comparable. For example, there is not much point in having a group of a EuroSCORE 15 and above in a single hospital because the numbers of patients would be very small and the confidence interval around any kind of prediction would be extremely wide. On this occasion, we just took the patients and divided them into five equal groups across the risk spectrum, and there is no rule that says you cannot divide them into three, four or five risk groups. The original three risk groups were purely for calibration.

Dr U. Herold (*Essen, Germany*): I would like to ask you a question about your statement that you think that the American patients are sicker, but how can you explain the circumstance that the European patients have to be operated more upon the heart? Endocarditis doesn't explain these concerns from my point of view.

Dr Nashef: I am sorry, I don't think I understood the question. Could you just repeat the question?

Dr Herold: You stated that the American patients are termed to be sicker than the European ones.

Dr Nashef: Yes.

Dr Herold: But how can you explain the circumstance that European patients have to be operated upon the heart more often than the Americans? Your explanation of endocarditis doesn't fit to this.

Dr Nashef: Yes. The European patients in general have more valve surgery; valve surgery as a group represents a higher percentage in European surgery than it does in American surgery. There is more isolated coronary artery bypass grafting in the American database, but there are more redos in America. Understandably, if you have a large population of valve patients, then a substantial number of these, well, at least a slightly larger proportion of these, would have endocarditis compared with the American group.