Severe morbidity after coronary artery surgery: development and validation of a simple predictive clinical score

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Aims To develop a predictive clinical risk score of post-operative morbidity after coronary artery bypass grafting.

Methods and Results Data were collected retrospectively from 679 patients undergoing emergency or planned bypass surgery between 1 January and 31 December 1996. The incidence of morbidity was 23%. Multivariate stepwise logistic regression analysis on two-thirds of the patients identified eight independent risk factors for severe morbidity. Six of these were pre-operative: symptomatic right heart failure, previous ventricular arrhythmias, previous coronary bypass surgery, chronic pulmonary disease, ST changes on pre-operative electrocardiogram, body mass index <24 kg · m⁻², and two were intra-operative factors: the surgeon who operated, and the cardiopulmonary bypass time. A predictive clinical risk score was developed with the six pre-operative risk factors. The negative predictive value of the model is 87% and the area under the receiver operating characteristic curve is 0.77. When tested on the remaining patients not used for developing the model, the area under the curve is 0.65.

Conclusion This pre-operative risk score provides a simple method of risk stratification for patients undergoing coronary artery surgery. However, as for all predictive models, the performance of the score decreases when applied to a population other than that used to develop it. (Eur Heart J 1999; 20: 960–966)

Key Words: Risk factors, coronary artery bypass surgery, morbidity, mortality, logistic models, clinical prediction rule.

Introduction

The ability to predict the outcome of coronary artery bypass graft surgery has always been of interest to physicians and their patients. The patient’s underlying question is ‘what are my chances?’ and the physicians ask ‘is this type of surgery the best solution for my patient?’. Over the past 10 years, attempts have been made to predict operative mortality during this procedure[1–3]. However, the incidence of mortality, which is less than 4%, does not seem to be correlated with the complication rates or length of hospitalization. This has led to the suggestion that morbidity may be a more valid end-point[4]. Several models have been developed for assessing the post-operative morbidity risks[8–11], but morbidity is a subjective end-point, unlike mortality which is objective. We investigated the development of a pre-operative clinical risk score predicting severe post-operative morbidity (including mortality) following coronary artery bypass graft surgery, after having identified risk factors for this severe morbidity.

Methods

We retrospectively collected data for 43 pre-operative and four intra-operative clinical variables for 679 consecutive patients undergoing coronary artery bypass graft surgery in our institution between 1 January and 3 December 1996. Patients undergoing coronary artery bypass graft surgery at the same time as cardiac or non-cardiac surgery were excluded. The variables were selected, based on a review of the literature, discussion with the participating physicians, and the data available...
in the patients’ files. If data for any variable were missing for more than 10% of the patients, the variable was excluded from the analysis.

Definition of severe morbidity

Severe morbidity was defined as mortality, or one of following 10 non-fatal adverse events occurring within the post-operative hospital period: low cardiac output (measurement of cardiac indexes) requiring inotropic agents for more than 24 h; necessity of intra-aortic balloon pump in the event of critical cardiac output status; myocardial infarction (increase in creatine phosphokinase-MB >1000 IU with dissociation of the transaminases (aspartate aminotransferase >70 IU ) and a new Q wave on the electrocardiogram); mechanical ventilation for more than 48 h; serious pneumonia; other serious infections (mediastitis, wound infection or bacteraemia requiring intravenous antibiotic treatment); acute renal failure (witnessed by the need to initiate haemodialysis for the first time or by an important increase in the concentration of serum creatinine requiring other specific therapy and a longer stay in intensive care); excessive bleeding (transfusion of more than 6 units of packed red blood cells); unplanned return to surgery (for any surgical procedure performed during the hospital period after coronary artery bypass graft surgery); or central nervous system complication (stroke with permanent cerebral deficit).

Analyses

First, patients with no severe post-operative morbidity were compared with those who had, by univariate analysis for each of their characteristics using the data for all patients. Continuous variables were analysed using the Student’s t-test and discrete variables were analysed using the chi-square test (or Fisher’s exact test for variables with an expected frequency of at least 5). The threshold of statistical significance was set at a p value of ≤0·05. Odds ratios were calculated to estimate the degree of association between morbidity and each significant variable.

Secondly, the database was divided randomly into a ‘calculation group’ (two-thirds of the patients), and a ‘validation group’ (one-third of the patients). After the elimination of the highly correlated significant variables, the other significant variables (identified in the univariate analysis) were included in the multivariate analysis (stepwise, logistic regression technique). For example, the variable ‘symptomatic left heart failure’ was retained in the analysis whereas ‘specific therapy for congestive heart failure’ was removed. The calculation group was used to develop the regression model and the clinical risk score, and the validation group to verify the validity of the score. The dependent variable was severe morbidity.

In the first multivariate analysis, we identified all the peri-operative independent risk factors (pre-operative and intra-operative factors), and in the second analysis we used only the pre-operative variables to develop the predictive pre-operative clinical risk score.

Development of clinical severity score

Each independent pre-operative risk factor was given a score between 2 and 7, depending on its degree of statistical significance in the logistic model. Positive and negative predictive values of the clinical score were calculated with various possible cut-off points. Next, the predictive power of the score was tested by calculating the area under the receiver operating characteristic (ROC) curve[12,13]. A ROC curve is a graphical representation of the relation between the true-positive rate (i.e., the sensitivity of the test) and the false-positive rate (i.e., 1 minus the specificity of the test) and is commonly used to estimate the predictive power of a statistical model. The true-positive rate is plotted on the y-axis, and the false-positive rate is on the x-axis. A good measure of test accuracy is the area underneath the resulting curve, which may vary between 0·5 and 1·0. An area of 0·5 under the ROC curve indicates that the predictive power is poor, and for a perfect diagnostic test (i.e., sensibility=specificity=1) this area would be 1·0. We constructed two ROC curves, the first to assess the predictive power of the score in the calculation group and then its reproducibility when applied to the verification group. To complete the analysis, we compared the odds ratio (and its 95% confidence interval) for each independent risk factor (in the calculation group), with the odds ratio (and its 95% confidence interval) for the same variables in the verification group.

Results

The main clinical characteristics for the patient are summarized in Table 1. The overall operative mortality rate was 2·5% (17/679). Almost half of the deaths followed a cardiac event. The severe morbidity rate was 23·0% (Table 2). The mean length of stay in an intensive care unit was 2·8 days and only 5·7% of the patients stayed more than 7 days. The mean length of the post-operative hospital stay was 13·5 days ± 6·5 (SD). Most patients (77%) had left hospital 2 weeks after the operation. A statistically significant correlation with the occurrence of severe morbidity in the whole group was observed for 24 of the 47 variables investigated by univariate analysis (Table 3). Symptomatic left heart failure was found to be a significant risk factor but, when the analysis was restricted to pure left ventricular dysfunction (i.e., excluding patients with symptomatic right heart failure), the significance disappeared. Symptomatic right heart failure was not related to chronic obstructive pulmonary disease, since only one of the 16 patients with symptoms of right ventricular dysfunction
also had chronic pulmonary disease. Patients with previous percutaneous transluminal coronary angioplasty, carotid stenosis, or a cardiothoracic index of at least 0.5, showed a non-significant trend for a higher morbidity rate. On the other hand, diabetes mellitus, hyperlipidaemia, arterial hypertension, or angiographic left main

Table 1 Main preoperative characteristics in 679 patients undergoing coronary artery bypass graft surgery

<table>
<thead>
<tr>
<th>Variables</th>
<th>(% and numeric values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years; mean ± SD)</td>
<td>63.9 ± 9.5</td>
</tr>
<tr>
<td>Males</td>
<td>85.3 (579/679)</td>
</tr>
<tr>
<td>Emergency or urgent operation</td>
<td>24.3 (165/679)</td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>55.1 (372/675)</td>
</tr>
<tr>
<td>Unstable angina</td>
<td>29.1 (197/678)</td>
</tr>
<tr>
<td>Class III or IV of the CCS angina</td>
<td>65.8 (432/657)</td>
</tr>
<tr>
<td>Reoperation (CABG)</td>
<td>4.3 (29/679)</td>
</tr>
<tr>
<td>Previous PTCA</td>
<td>12.8 (83/650)</td>
</tr>
<tr>
<td>Arrhythmias</td>
<td>8.5 (57/674)</td>
</tr>
<tr>
<td>ST changes on pre-operative ECG</td>
<td>16.4 (104/636)</td>
</tr>
<tr>
<td>Symptomatic left heart failure</td>
<td>17.2 (116/675)</td>
</tr>
<tr>
<td>Symptomatic right heart failure</td>
<td>2.4 (16/663)</td>
</tr>
<tr>
<td>Coronary artery involvement</td>
<td></td>
</tr>
<tr>
<td>Left main</td>
<td>25.1 (173/679)</td>
</tr>
<tr>
<td>3 vessel</td>
<td>69.1 (469/679)</td>
</tr>
<tr>
<td>2 vessel</td>
<td>25.5 (173/679)</td>
</tr>
<tr>
<td>1 vessel</td>
<td>5.4 (37/679)</td>
</tr>
<tr>
<td>Left ventricular ejection fraction (%; mean ± SD)</td>
<td>59 ± 15</td>
</tr>
<tr>
<td>≥ 50%</td>
<td>77.4 (503/650)</td>
</tr>
<tr>
<td>35-49%</td>
<td>16.6 (108/650)</td>
</tr>
<tr>
<td>&lt;35%</td>
<td>6.0 (39/650)</td>
</tr>
<tr>
<td>Arterial hypertension</td>
<td>51.8 (345/666)</td>
</tr>
<tr>
<td>Hyperlipidaemia</td>
<td>52.9 (355/671)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>21.9 (148/676)</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>18.1 (122/673)</td>
</tr>
<tr>
<td>Previous stroke</td>
<td>6.9 (47/676)</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>12.4 (84/676)</td>
</tr>
<tr>
<td>Serum creatinine ≥ 150 μmol.·l⁻¹</td>
<td>8.1 (55/675)</td>
</tr>
</tbody>
</table>

SD=standard deviation; CCS=Canadian cardiovascular society classification; CABG=coronary artery bypass graft surgery; PTCA=percutaneous transluminal coronary angioplasty; ECG=electrocardiogram.

Table 2 Incidence of post-operative major complications and number of events

<table>
<thead>
<tr>
<th>Complication</th>
<th>Incidence (% and values)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incidence (%) and values (n=679 patients)</td>
<td></td>
</tr>
<tr>
<td>Post-operative mortality</td>
<td>2.5 (17)</td>
</tr>
<tr>
<td>Reoperation</td>
<td>8.2 (56)</td>
</tr>
<tr>
<td>Mechanical ventilation &gt;48 h</td>
<td>7.1 (48)</td>
</tr>
<tr>
<td>Excessive bleeding</td>
<td>6.2 (42)</td>
</tr>
<tr>
<td>Low cardiac output</td>
<td>5.7 (39)</td>
</tr>
<tr>
<td>Pulmonary infection</td>
<td>4.9 (33)</td>
</tr>
<tr>
<td>Other major infection</td>
<td>4.7 (32)</td>
</tr>
<tr>
<td>Post-operative myocardial infarction</td>
<td>4.4 (30)</td>
</tr>
<tr>
<td>Renal failure</td>
<td>2.2 (15)</td>
</tr>
<tr>
<td>IABP required</td>
<td>2.1 (14)</td>
</tr>
<tr>
<td>Stroke</td>
<td>0.7 (5)</td>
</tr>
<tr>
<td>Other or unknown</td>
<td>5.2 (35)</td>
</tr>
<tr>
<td>Number of events for 156 patients (23% of total)</td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>34.6</td>
</tr>
<tr>
<td>2</td>
<td>28.2</td>
</tr>
<tr>
<td>3</td>
<td>19.2</td>
</tr>
<tr>
<td>≥4</td>
<td>17.9</td>
</tr>
</tbody>
</table>

IABP=intra-aortic balloon pump.
coronary artery stenosis were not significantly correlated with severe morbidity.

**Risk prediction model**

Eight independent risk factors for severe morbidity were identified by the logistic regression analysis (Table 4). Two intra-operative risk factors were identified: the cardiopulmonary bypass time and the surgeon operating. We could not consider this latter variable as a specific pre-operative variable because many patients who underwent urgent or emergency coronary artery bypass graft surgery did not choose their surgeon. For this reason we performed a second logistic regression analysis excluding these two variables to estimate the pre-operative clinical risk score based on six weighted risk factors (see Table 5). Although the theoretical maximum score was 22, the maximum score observed was 13 for one patient. The threshold that yielded the smallest false-negative results (i.e., a high negative predictive value), and good combined sensibility and specificity, was a score equal to 2. In the calculation group, 45% of patients had a positive score (2 or higher) and only 9% had a score of 5 or higher. Patients with a score of 0 had a low (13%) probability of severe post-operative morbidity, but as the score increased the probability also increased (Table 5). With this type of prediction score, the false-negative rate should be as low as possible, since predicting no severe morbidity, even though it will occur, is much more serious than predicting morbidity that will not occur. With the threshold score of 2 the sensitivity was 72%, the specificity was 63%, the positive predictive value was 42% and the negative predictive value was 87%. The area under the ROC curve, which determined the predictive power of our model in the calculation group was 0.77 (Fig. 1).

### Table 3 Significant risk factors in univariate analysis (n=679; all patients)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Major morbidity</th>
<th>P</th>
<th>OR</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptomatic right heart failure</td>
<td>&lt;10⁻⁶</td>
<td>11:16</td>
<td>(3:55–35:17)</td>
<td></td>
</tr>
<tr>
<td>Cardiopulmonary bypass time</td>
<td>0:00002</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Left ventricular dysfunction</td>
<td>0:0002</td>
<td>2:49</td>
<td>(1:62–3:83)</td>
<td></td>
</tr>
<tr>
<td>ST segment changes on pre-operative ECG</td>
<td>0:0001</td>
<td>2:55</td>
<td>(1:57–4:15)</td>
<td></td>
</tr>
<tr>
<td>Dyspnoea (NYHA Classification)</td>
<td>0:00035</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Reoperation (CABG)</td>
<td>0:0004</td>
<td>3:87</td>
<td>(1:73–8:67)</td>
<td></td>
</tr>
<tr>
<td>Ventricular arrhythmias</td>
<td>0:0005</td>
<td>5:31</td>
<td>(1:86–15:16)</td>
<td></td>
</tr>
<tr>
<td>CHF medication</td>
<td>0:0008</td>
<td>2:19</td>
<td>(1:37–3:48)</td>
<td></td>
</tr>
<tr>
<td>Aortic cross clamp time</td>
<td>0:001</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Haemodialysis</td>
<td>0:002</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Anaemia</td>
<td>0:002</td>
<td>3:08</td>
<td>(1:43–6:62)</td>
<td></td>
</tr>
<tr>
<td>Mitral insufficiency</td>
<td>0:003</td>
<td>2:02</td>
<td>(1:25–3:27)</td>
<td></td>
</tr>
<tr>
<td>Left ventricular ejection fraction</td>
<td>0:006</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>0:007</td>
<td>1:95</td>
<td>(1:19–3:19)</td>
<td></td>
</tr>
<tr>
<td>Serum creatinine ≥ 150 μmol.l⁻¹</td>
<td>0:01</td>
<td>2:05</td>
<td>(1:15–3:67)</td>
<td></td>
</tr>
<tr>
<td>Unstable angina</td>
<td>0:02</td>
<td>1:57</td>
<td>(1:08–2:35)</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0:03</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Urgent surgery</td>
<td>0:03</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Body mass index &lt;24 kg. m⁻²</td>
<td>0:03</td>
<td>1:55</td>
<td>(1:03–2:33)</td>
<td></td>
</tr>
<tr>
<td>Previous myocardial infarction</td>
<td>0:04</td>
<td>1:47</td>
<td>(1:02–2:12)</td>
<td></td>
</tr>
<tr>
<td>Surgeon</td>
<td>0:04</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Atrial arrhythmia</td>
<td>0:04</td>
<td>1:95</td>
<td>(1:01–3:77)</td>
<td></td>
</tr>
<tr>
<td>Angina CCS classification</td>
<td>0:05</td>
<td>*</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>0:05</td>
<td>1:55</td>
<td>(1:01–2:41)</td>
<td></td>
</tr>
</tbody>
</table>

OR=odds ratio; CI=confidence interval; ECG=electrocardiogram; NYHA=New York Heart Association; CABG=coronary artery bypass graft; CHF=congestive heart failure; CCS=Canadian Cardiovascular Society.

*OR not available (continuous variable or qualitative variable with several classes).
Validation results

The verification group consisted of one-third of the population, 226 patients. The rate of severe morbidity was similar to that observed in the calculation group. The area under the ROC curve was 0·65, less than that observed in the calculation group. With the same threshold score of 2 the sensitivity decreased to 63%, and the specificity to 57%. The positive predictive value was low (23·8%), although the negative predictive value remained high (88·0%).

Discussion

In previous studies the post-operative mortality rate was low (less than 4%), and relatively stable after coronary artery bypass graft surgery[1–3,14–18], whereas the morbidity rate was higher, ranging from 7 to 33%[4,10,11,19,20]. In our population of 679 patients, the severe post-operative complication rate was 23·0%. This variability may be explained by one or more reasons.

- When continuous or discrete variables are changed into binary data (i.e., absence or presence of morbidity), information can be lost. In addition, cumulative error may introduce bias in the model depending on whether variables with a high rate of missing values are excluded or not.
- Outcomes can differ between centres[16], and populations.
- Differences in reporting methods and definitions can influence the frequency of complications. For example, Tu et al.[8] defined severe morbidity as a stay of at least 6 days in an intensive care unit. Using this definition, the rate in our population would have been only 6%, whereas with our definition it was 23%. Also, Magovern et al.[20] used seven types of events in their definition, whereas we used 11. Harmonization of definitions would facilitate the meaningful comparison of results from different studies.

Using several of the best known models of morbidity and mortality after cardiac surgery published since 1989[1,2,4,5,8–11,19,20] and ours, giving 11 models, we identified 40 different independent morbidity and/or mortality risk factors. The number of independent risk factors in each model ranged from 6 to 15, and none of the factors was present in all models. Only six independent risk factors were present in more that five of the models: sex, age, emergency, reoperation, left ventricular dysfunction and diabetes. From the 40 factors, 14 were reported only once in different studies, for several possible reasons. First, the objectives and methods in the various studies were different; some were interested in mortality while others were interested in morbidity, or morbi–mortality. Some of the models concerned only coronary artery bypass graft surgery, whereas some were for other cardiac surgery, including valve replacement. These latter studies obviously identified different risk factors[4,19]. Second, the hierarchical nature of clinical data is often not taken into account in these models[21]. Statistical significance (P values) is often not related to clinical (or biological) significance[22]. For example, our most significant predictor (signs of symptomatic right heart failure) was present in only 2·4% of the population. A similar situation was found by Magovern et al. and Christakis et al. with their most significant risk factors being present in about 2% and 6% of their respective populations[19,20]. Thus, statistically significant predictors are not very common, and common predictors are not very statistically significant[23]. Third, when elaborating logistic regression models choices have to be made to improve the stability of the model. Some

Table 5  Clinical pre-operative scoring system and probability of severe morbidity

<table>
<thead>
<tr>
<th>Factor</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Symptomatic right heart failure</td>
<td>7</td>
</tr>
<tr>
<td>Ventricular arrhythmias</td>
<td>4</td>
</tr>
<tr>
<td>Reoperation (CABG)</td>
<td>4</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease</td>
<td>3</td>
</tr>
<tr>
<td>Body mass index &lt;24</td>
<td>2</td>
</tr>
<tr>
<td>ST changes on pre-operative ECG</td>
<td>2</td>
</tr>
</tbody>
</table>

Score  Observed morbidity (%)

<table>
<thead>
<tr>
<th>Score</th>
<th>Observed morbidity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>2</td>
<td>41</td>
</tr>
<tr>
<td>3</td>
<td>53</td>
</tr>
<tr>
<td>4</td>
<td>63</td>
</tr>
<tr>
<td>5</td>
<td>68</td>
</tr>
<tr>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>7</td>
<td>85</td>
</tr>
<tr>
<td>≥8</td>
<td>100</td>
</tr>
</tbody>
</table>

CABG=coronary artery bypass graft; ECG=electrocardiogram.

Figure 1  Receiver operating characteristic (ROC) curves showing the predictive power of the model for post-operative morbidity after coronary artery bypass grafting, for the calculation group (——; ROC=0·77) and the verification group (– – –; ROC=0·65).

Validation results

The verification group consisted of one-third of the population, 226 patients. The rate of severe morbidity was similar to that observed in the calculation group. The area under the ROC curve was 0·65, less than that observed in the calculation group. With the same threshold score of 2 the sensitivity decreased to 63%, and the specificity to 57%. The positive predictive value was low (23·8%), although the negative predictive value remained high (88·0%).
variables have to removed, although they may have been found to be statistically significant in a univariate analysis, because they prevent the convergence of the multivariate analysis. On the other hand, some non-significant variables introduced into the logistic model may change the result of the analysis by transforming previous independent risk predictors to non-significant factors. In addition, the stability of a logistic model is often changed by the association of variables that are too highly correlated (e.g. dyspnoea and congestive heart failure therapy).

The aim of a pragmatic approach is to build a practical decision-making tool based on an assessment of the patient’s pre-operative risk factors, to aid in the decision to operate or not. The objectives of a cognitive approach is to identify which factors (pre-, intra-, or post-operative) determine the prognosis of severe morbidity. The area under the ROC curve (0.77) suggests that the predictive power of our clinical risk score is good, but far from perfect. This difference between the predicted and the observed morbidity is called the residual variance. Since most of the previous models had similar ROC values, of between 0.7 and 0.8[5, 8, 9, 11, 20], it would seem that we cannot reduce this residual variance for three main reasons. The first is the difficulty of predicting the occurrence of haemorrhagic and infectious events. For example, despite a clinical risk score of 0, 26 patients presented serious events that were unexpected according to our model: these are considered as ‘false negatives’. Most of these events (71%) were infections or haemorrhages. The second is just chance and biological diversity which may explain part of this variability. And the third is that the pragmatic approach does not take into consideration intra- and post-operative risk factors. However, the cognitive approach which uses these factors cannot be used as a decision-making aid for the choice to operate or not. Few studies report such intra-operative or post-operative data, however, Christakis et al[19] reported that type of myocardial protection was a significant risk factor in multivariate analysis. Although we did not identify any reports on morbidity for coronary artery bypass graft surgery by surgeon, many authors have reported differences in fatal outcomes associated with individual medical centres and surgeons[16, 24]. Others have demonstrated lower operative mortality for surgeons and institutions performing more operations[25]. However, a recent analysis found that combined surgeon-specific and institution-specific factors explained less than 10% of the observed mortality[26]. An exhaustive cognitive approach, not yet performed, should include pre-operative and intra-operative variables, as well as post-operative hospital management data to assess accurately the risk of major morbidity after coronary artery bypass graft surgery.

The predictive power of our clinical risk score in the verification group was not as good as in the group used to develop the model. A similar reduction in predictive power has been observed elsewhere for other predictive scores[14, 27]. It has been suggested that differences in sample size and event rates partly explain this poor reproducibility[28]. In the same way, the higher the amount of data put into a model, the more it will reflect the particular population on which it is based, and the less it will be applicable to a new population[22].

Conclusions

This study presents a simple, practical clinical risk score to predict post-operative outcome after coronary artery bypass graft surgery. This six-variable model shows good, but not perfect, agreement between the predicted and the observed morbidity rates. This score has a high negative predictive value, which may be useful as one element to take into consideration when deciding to operate or not. We suggest that patients with none of the six independent risk factors can undergo surgery without major concern; however, this predictive risk score, like others, has limits when applied to a population different from that on which it is based.

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