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The role of EuroSCORE in patients undergoing off-pump coronary artery bypass.

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Follow-up papers - Cardiac general

The role of EuroSCORE in patients undergoing off-pump coronary artery bypass


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Abstract

Introduction: European System for Cardiac Operative Risk Evaluation (EuroSCORE) has been used to predict the postoperative mortality rate for patients undergoing open-heart surgery. The contributions of EuroSCORE in off-pump coronary artery bypass grafting (CABG) has not yet clearly elucidated. Methods: Consecutive patients of isolated off-pump CABG performed from 2000 when we start performing ‘routine’ off-pump procedures were stratified using the additive EuroSCORE. Incidence of postoperative mortality, morbidity, and recovery were assessed, and compared to an historical cohort of on-pump procedures performed between 1991 until 1998 when CABG had been routinely performed under on-pump. Results: There were 1318 patients in the off-pump and 1162 patients in the on-pump group. EuroSCORE of the off-pump group was significantly higher than that of the on-pump group. In both the on- and off-pump groups, mortality, total incidence of major complications, heart failure, and renal failure, and three parameters of recovery time were well correlated with EuroSCORE; however, the discriminatory power of the EuroSCORE model was always better in the on-pump group than in the off-pump group. Stroke was correlated with EuroSCORE only in the on-pump group. Pneumonia, mediastinitis postoperative myocardial infarction, or mediastinitis was not correlated with EuroSCORE in either group. In the off-pump group, postoperative major complication was reduced and postoperative recovery was shortened significantly, compared to those in the on-pump group. Conclusion: In off-pump CABG, EuroSCORE can, but not as good as in on-pump CABG, predict mortality, certain major postoperative complications, and postoperative recovery. This suggests off-pump technique appears to modify the risk stratification of the patients undergoing CABG.

Keywords: EuroSCORE; Complication; Coronary artery disease; Off-pump

1. Introduction

European System for Cardiac Operative Risk Evaluation (EuroSCORE) is a risk calculation system to predict perioperative mortality of patients undergoing cardiac surgery. EuroSCORE was developed in the late 1990s in Europe [1], and was quickly accepted in other countries [2–4]. Recently, we found EuroSCORE was well correlated with postoperative complications and recovery in those who undergo on-pump coronary artery bypass grafting (CABG) [5, 6].

Off-pump CABG has been performed more often in the last two decades. Avoidance of cardiopulmonary bypass (CPB) could reduce aortic cannulation-related complications such as stroke, and could reduce CPB circuit-related complications, such as inflammatory surge or multiorgan dysfunction [7]. Many studies showed that off-pump CABG provided shorter recovery time than on-pump CABG [7].

These benefits of off-pump CABG were clearer in high-risk patients [8, 9], and a cross-sectional EuroSCORE value was used to identify these high risk patients. However, outcome distribution between on- and off-pump CABG along with EuroSCORE could differ depending on complications or recovery parameters. We studied the outcomes of patients who had undergone on- and off-pump CABG to evaluate the relationship between each outcome and EuroSCORE.

2. Methods

Consecutive cases of isolated CABG performed between 1991 and 2006 at our hospital group were placed into the systematic database, which was approved for research by the internal review board. Off-pump CABG was introduced into our institution in 1992; however, utilization was limited to the coronary anatomy, patient comorbidities and surgeon’s preference until 1998. Advances in the off-pump technique allowed off-pump bypass to be performed routinely since 2000, except for patients with unstable hemodynamics at the time of surgery, redo CABG, and/or resident teaching cases. There was one year of transition from routine off-pump to off-pump procedure. Between
1991 and 1998, a total of 1462 CABG procedures were performed, and among these off-pump CABG was performed in 116 patients (7.9%). Between 2000 and 2006, a total of 1337 CABGs were performed, and among these on-pump CABG was performed in 134 patients (10.0%). Since this study compared the outcomes of routine on- and off-pump CABG, these 116 off-pump cases from the early period of study and 134 on-pump cases from the late period of study were excluded from this analysis.

Additive EuroSCORE was calculated for each patient based on the original EuroSCORE criteria [2]. Zero score was given for factors that did not apply to isolated CABG, such as active endocarditis, other than isolated CABG, surgery on the thoracic aorta, or postinfarct septal rupture. The score for pulmonary hypertension was not analyzed into this study due to the lack of data on preoperative pulmonary artery pressure. EuroSCORE equal or above 10 was found in a relatively small number of patients (28 patients in the early period, 41 patients in the late period group) and the range of EuroSCOREs spread widely between 10 and 17; thus these outlying patients were excluded from the analyses; however, this was marked as a reference point.

Postoperative mortality, morbidity (bleeding requiring reoperation, postoperative heart failure requiring inotropic support for > 5 days, mediastinitis with deep sternal infection, pneumonia, postoperative new Q-wave myocardial infarction, renal failure that newly required temporary or permanent dialysis, and postoperative stroke confirmed by CT-scan) and postoperative recovery time [intubation time, intensive care unit (ICU) stay and postoperative length of stay] were analyzed for each EuroSCORE (0–9). Major complications included, in addition to those cited above, critical arrhythmia (ventricular fibrillation, recurrent ventricular tachycardia, bradycardia requiring a permanent pacemaker), pulmonary emboli, respiratory failure requiring prolonged ventilator support for > 5 days, reintubation or tracheostomy, sepsis, and acute graft occlusion. These outcomes were compared between the on-pump CABG group and the off-pump CABG group.

Patient demographics were presented as mean ± standard deviation (S.D.) or percentage as appropriate. Comparisons of the demographics were performed with Student t-test for continuous variables, and χ²-test or Fisher’s exact test for categorical variables. The adequacy of the correlation between each outcome and EuroSCORE was assessed by the correlation coefficient (r). If correlations were adequate with r-value above 0.60 and P < 0.05, the receiver operating characteristics (ROC) curve and area under the curve was calculated. An area of 1.0 under the ROC curve indicates perfect discrimination, whereas an area of 0.50 indicates complete absence of discrimination. The discriminative power of the model considered excellent if area under ROC curve > 0.8, and area under ROC curve > 0.7 is considered acceptable for clinical purposes. If a particular outcome and EuroSCORE were correlated adequately in both the on- and off-pump group, logistic analyses for categorical variables or least square methods for continuous variables were performed to detect distribution differences between the on- and off-pump groups. All statistical analyses were performed using JMP software (SAS institute, Cary, NC).

3. Results

A total of 1318 on-pump and 1162 off-pump patients were available for analyses. Baseline demographics of the patients in the on- and off-pump groups are shown in Table 1. EuroSCORE of the off-pump group (3.5 ± 2.3) was significantly higher than that of the on-pump group (2.9 ± 2.2, P < 0.0001). The number of distal anastomoses did not significantly differ between the on- and off-pump groups.

### Table 1

<table>
<thead>
<tr>
<th>Patient factors</th>
<th>On-pump</th>
<th>Off-pump</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n = 1318</td>
<td>n = 1162</td>
<td></td>
</tr>
<tr>
<td>Age (mean years ± S.D.)</td>
<td>63.5 ± 9.2</td>
<td>66.5 ± 9.7</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Female sex</td>
<td>294</td>
<td>256</td>
<td>22.0</td>
</tr>
<tr>
<td>Chronic pulmonary disease</td>
<td>59</td>
<td>4.5</td>
<td>39</td>
</tr>
<tr>
<td>Extracardiac arteriopathy</td>
<td>86</td>
<td>6.5</td>
<td>96</td>
</tr>
<tr>
<td>Neurological dysfunction</td>
<td>122</td>
<td>9.3</td>
<td>152</td>
</tr>
<tr>
<td>Previous cardiac surgery</td>
<td>31</td>
<td>2.4</td>
<td>31</td>
</tr>
<tr>
<td>Serum creatinine &gt; 200 μmol/l</td>
<td>49</td>
<td>3.7</td>
<td>61</td>
</tr>
<tr>
<td>Critical preoperative stay</td>
<td>12</td>
<td>0.9</td>
<td>2</td>
</tr>
<tr>
<td>Cardiac factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unstable angina</td>
<td>193</td>
<td>14.6</td>
<td>279</td>
</tr>
<tr>
<td>LV dysfunction (EF 30–50%)</td>
<td>242</td>
<td>18.4</td>
<td>200</td>
</tr>
<tr>
<td>LV dysfunction (EF &lt;30%)</td>
<td>27</td>
<td>2.0</td>
<td>21</td>
</tr>
<tr>
<td>Recent myocardial infarction</td>
<td>56</td>
<td>4.2</td>
<td>39</td>
</tr>
<tr>
<td>Operative factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emergent surgery</td>
<td>99</td>
<td>7.5</td>
<td>141</td>
</tr>
<tr>
<td>EuroSCORE (mean ± S.D.)</td>
<td>2.9 ± 2.2</td>
<td>3.5 ± 2.3</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Other factors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>532</td>
<td>40.4</td>
<td>542</td>
</tr>
<tr>
<td>Bilateral internal mammary artery use</td>
<td>281</td>
<td>21.3</td>
<td>530</td>
</tr>
<tr>
<td>Distal anastomosis (mean ± S.D.)</td>
<td>3.4 ± 1.1</td>
<td>3.5 ± 1.4</td>
<td>0.1785</td>
</tr>
</tbody>
</table>

S.D., standard deviation; EuroSCORE, European System for Cardiac Operative Risk Evaluation.
Table 2
Correlation score (r) between each complication and EuroSCORE. If there is an adequate correlation, the area under the receiver operating characteristics (ROC) curve was calculated

<table>
<thead>
<tr>
<th>Complication</th>
<th>On-pump r</th>
<th>P-value</th>
<th>ROC</th>
<th>Off-pump r</th>
<th>P-value</th>
<th>ROC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death</td>
<td>0.638</td>
<td>0.0471</td>
<td>0.923</td>
<td>0.662</td>
<td>0.0371</td>
<td>0.669</td>
</tr>
<tr>
<td>Major complications</td>
<td>0.952</td>
<td>0.0001</td>
<td>0.712</td>
<td>0.760</td>
<td>0.0108</td>
<td>0.592</td>
</tr>
<tr>
<td>Congestive heart failure</td>
<td>0.882</td>
<td>0.0007</td>
<td>0.856</td>
<td>0.688</td>
<td>0.0028</td>
<td>0.763</td>
</tr>
<tr>
<td>Renal failure</td>
<td>0.802</td>
<td>0.0052</td>
<td>0.901</td>
<td>0.810</td>
<td>0.0045</td>
<td>0.824</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>0.542</td>
<td>0.1054</td>
<td>0.558</td>
<td>0.0937</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroke</td>
<td>0.863</td>
<td>0.0013</td>
<td>0.744</td>
<td>0.347</td>
<td>0.3259</td>
<td></td>
</tr>
<tr>
<td>Mediastinitis</td>
<td>0.280</td>
<td>0.4333</td>
<td>0.441</td>
<td>0.2015</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bleeding</td>
<td>0.530</td>
<td>0.1146</td>
<td>0.448</td>
<td>0.3237</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perioperative myocardial infarction</td>
<td>0.034</td>
<td>0.947</td>
<td>0.503</td>
<td>0.1380</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intubation time</td>
<td>0.844</td>
<td>0.0021</td>
<td>0.933</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ICU stay</td>
<td>0.865</td>
<td>0.0012</td>
<td>0.928</td>
<td>0.0001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postoperative stay</td>
<td>0.981</td>
<td>0.0001</td>
<td>0.896</td>
<td>0.0005</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

ICU, intensive care unit; EuroSCORE, European System for Cardiac Operative Risk Evaluation.

Fig. 1. (a) The relationship between mortality and EuroSCORE. Solid line with closed circles indicates the off-pump group, and dashed line with open circles indicates the on-pump group. Mortality and EuroSCORE were well correlated in both the on-pump group ($y = e^{0.10x - 2.10}$), and the off-pump group ($y = e^{0.10x - 0.9}$). The distributions in the on- and off-pump groups did not significantly differ. (b) The relationship between major complications and EuroSCORE. Solid line with closed circles indicates the off-pump group, and dashed line with open circles indicates the on-pump group. Major complications and EuroSCORE were well correlated in both the on-pump group ($y = e^{0.10x - 0.9}$), and the off-pump group ($y = e^{0.10x - 0.9}$). The on-pump group showed a significantly decreased incidence of major complications. EuroSCORE, European System for Cardiac Operative Risk Evaluation.

Fig. 2. (a) The relationship between postoperative heart failure and EuroSCORE. Solid line with closed circles indicates the off-pump group, and dashed line with open circles indicates the on-pump group. Postoperative heart failure and EuroSCORE were well correlated in both the on-pump group ($y = e^{0.10x - 0.9}$), and the off-pump group ($y = e^{0.10x - 0.9}$). The off-pump group showed a significantly decreased incidence of postoperative heart failure. (b) The relationship between postoperative renal failure and EuroSCORE. Solid line with closed circles indicates the off-pump group, and dashed line with open circles indicates the on-pump group. Postoperative renal failure and EuroSCORE were well correlated in both the on-pump group ($y = e^{0.10x - 0.9}$), and the off-pump group ($y = e^{0.10x - 0.9}$). The distributions of both the on- and off-pump groups did not significantly differ. EuroSCORE, European System for Cardiac Operative Risk Evaluation.
Results of correlation and ROC analyses are shown in Table 2. The incidence of postoperative mortality (Fig. 1a), major complications (Fig. 1b), heart failure (Fig. 2a), and renal failure (Fig. 2b) were positively correlated with EuroSCORE in both the on-pump and off-pump group. The area under the ROC curve indicated that the on-pump group showed better correlation with EuroSCORE than the off-pump group in terms of mortality, major complications, heart failure, and renal failure. Intubation time (Fig. 3), ICU stay (Fig. 4), and length of stay (Fig. 5) were also positively correlated with EuroSCORE in both groups. The incidence of stroke was correlated with EuroSCORE in the on-pump group but not in the off-pump group. Postoperative pneumonia, postoperative bleeding, mediastinitis and myocardial infarction were not correlated with EuroSCORE in either group. Thus, postoperative mortality, major complication, heart failure, renal failure, intubation time, ICU stay, and length of stay were placed into the model to compare differences in distribution in relation to the EuroSCORE between the on- and off-pump groups.

Results of logistic analyses and least square methods are shown in Table 3. The distribution curves did not significantly differ for mortality or renal failure between the on- and off-pump groups. Off-pump CABG showed a significantly reduced incidence of postoperative major complications and heart failure compared to that in the on-pump group. These differences are well appreciated in high-EuroSCORE patients. Off-pump CABG significantly shortened the intubation time, ICU stay, and postoperative length of stay.

4. Discussions

4.1. Patients

Patients who underwent off-pump CABG demonstrated significantly higher EuroSCORE. Patients in the off-pump group were older and more likely to have preoperative morbidities. Despite the more complicated preoperative medical problems, the number of anastomoses performed during off-pump CABG was similar to that during on-pump.

4.2. Mortality

Our observations of mortalities confirmed the previous studies, which demonstrated that the correlation between EuroSCORE and mortality after off-pump CABG [10, 11], although the correlation was not good enough to predict mortality as on-pump group. Our ROC analyses demonstrated correlation was better in the on-pump group than in the off-pump group. This was most likely due to the fact that EuroSCORE was designed based on on-pump surgeries [1]. We also found a low mortality rate in patients with a EuroSCORE below 5 and an acute increase in the mortality
rate for those with a EuroSCORE of 6 or above in both the on- and off-pump groups. In fact, EuroSCORE 6 has often been used to identify high-risk patients [9, 12].

4.3. Major complications

The incidence of major complications in the off-pump group was much lower than that in the on-pump group, and it was well correlated to EuroSCORE, although the discriminative power was better in the on-pump group. In the low-risk group (EuroSCORE 0–3), the major complication rate of the on- and off-pump group was similar. Then in the mid-risk group (EuroSCORE 4–6), the major complication rate in the on-pump group became higher while that in the off-pump group remained low. Finally, in the high-risk group (EuroSCORE 7 and higher), the major complication rate was increased in both the on- and off-pump groups; however, the incidence of major complications in off-pump group was always lower than that in the on-pump group for each EuroSCORE.

4.4. Other complications

The distribution of heart failure relation to EuroSCORE was similar to that of major complications. In the on-pump group, the incidence was baseline in the low-risk group, linearly increased in the mid-risk group, and then increased in a curvilinear manner in the high-risk group. In the off-pump group, the incidence of heart failure remained at baseline in the low- and mid-risk groups, then increased linearly in the high-risk group. We consider that the greatest benefit of off-pump CABG, probably avoidance of CPB, decreases incidence of postoperative heart failure in high-risk patients.

EuroSCORE was well correlated to postoperative renal failure on ROC analyses in both the on- and off-pump group, although the pattern of distribution was similar between the on- and off-pump groups. These data imply that higher EuroSCORE patients carry greater risks of postoperative renal failure regardless of whether the surgical technique is on- or off-pump CABG.

The incidence of postoperative stroke correlated with EuroSCORE in the on-pump group only but not in the off-pump CABG group. Avoiding manipulation to the aorta and introduction of an aorta-non-touch technique using in-situ grafts could contribute to the markedly lower incidence of stroke in the off-pump group [13].

The incidence of pneumonia or mediastinitis was not correlated with EuroSCORE in either the on- or off-pump group. Risk factors for these infections could be diabetes and/or perioperative blood sugar; however, these valurables are not considered during the calculation of EuroSCORE. Similarly, postoperative bleeding most likely related to preoperative use of antiplatelet agent [14] or technical issues, while postoperative myocardial infarction most likely related to technical issues rather than patient factors. Therefore, these complications were not related to EuroSCORE in either the on- or off-pump group.

4.5. Prediction of the outcome after off-pump CABG

As shown in the ROC analyses, the discriminated power of EuroSCORE model in off-pump CABG was inferior to that of on-pump CABG. Off-pump technique itself was acting as a modification factor of EuroSCORE. The difference of off-pump from on-pump surgery is including avoidance of cannulation, avoidance of CPB, avoidance of induced cardiac arrest. During on-pump CABG, the myocardium is always protected from ischemia/reperfusion injury by infusion of cardioplegia. On the other hand, during anastomosis of off-pump CABG, regional ischemia may occur depending on the coronary anatomy, and systemic hypotension may also occur because of heart displacement during anastomoses. Hemodynamics management of off-pump CABG is more tedious and complicated than that of on-pump CABG. We speculate that these varieties of conditions occurring off-pump CABG may modify the risk stratification of EuroSCORE and may contribute that the off-pump group had weaker discriminative power of the EuroSCORE to predict postoperative outcome than the on-pump group.

4.6. Postoperative intubation, ICU stay and postoperative hospital stay

These three parameters of postoperative recovery were well correlated with EuroSCORE in both the on- and off-pump groups. The off-pump group showed significantly faster recovery than the on-pump group, which has previously been demonstrated in many studies [7, 12, 15, 16]. The shorter hospital stay in the off-pump group may reflect the lower rate of major complication in the off-pump group than in the on-pump group.

| Table 3 |
| Estimated value calculated by logistic analyses or least square methods |

| Death | 0.32 (0.78 to 1.47) | 0.5613 | 0.55 (0.30 to 0.80) | <0.0001 |
| Major complications | 0.79 (0.53 to 1.06) | <0.0001 | 0.28 (0.23 to 0.34) | <0.0001 |
| Congestive heart failure | 1.60 (0.84 to 2.47) | <0.0001 | 0.62 (0.46 to 0.78) | <0.0001 |
| Renal failure | 0.39 (1.32 to 0.47) | 0.3864 | 0.61 (0.41 to 0.83) | <0.0001 |
| Intubation time | –5.44 (–6.16 to –4.72) | <0.0001 | 1.99 (1.85 to 2.15) | <0.0001 |
| ICU stay | –1.23 (–1.31 to –1.15) | <0.0001 | 0.23 (0.22 to 0.25) | <0.0001 |
| Postoperative stay | –6.98 (–7.33 to –6.63) | <0.0001 | 0.96 (0.88 to 1.03) | <0.0001 |

*ICU, intensive care unit; EuroSCORE, European System for Cardiac Operative Risk Evaluation.*
4.7. Study limitation

This was a retrospective, non-randomized, observational study. The off-pump group was compared to an historical cohort of the patients who underwent on-pump CABG. Additive EuroSCORE was used for simplicity of calculation rather than logistic EuroSCORE which requires computer software, accepting the risk of additive EuroSCORE may underestimate patient risk in high-risk patients [17]. Fortunately, our analyses excluded patients with high EuroSCORE (10 or above), which may minimize the effects of additive versus logistic EuroSCORE. We used exponential transformation \( y = e^{ax^2} \) of the estimate curve to show a better correlation between EuroSCORE and each complication.

5. Conclusion

EuroSCORE can predict mortality, certain major postoperative complications, and postoperative recovery in those who undergo not only on-pump but also off-pump CABG. The discriminatory power of the EuroSCORE model was always better in the on-pump group than in the off-pump group. This may suggest off-pump method itself may play a role in risk stratification of the patient undergoing CABG. Despite of the lower discriminative power observed off-pump CABG group, our study clearly demonstrated that off-pump CABG reduced the incidences of major complications, especially postoperative heart failure. The benefit of off-pump CABG could be recognized even in mid-risk patients, and became more significant in high-risk patients. The recovery time was shorter after off-pump CABG for each EuroSCORE group.

References


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