Is emergency and salvage coronary artery bypass grafting justified? The Nordic Emergency/Salvage coronary artery bypass grafting study

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Abstract

OBJECTIVES: According to the EuroSCORE-II criteria, patients undergoing emergency coronary artery bypass grafting (CABG) are operated on before the beginning of the next working day after decision to operate while salvage CABG patients require cardiopulmonary resuscitation en route to the operating theatre. The objective of this multicentre study was to investigate the efficacy of emergency and salvage CABG.

METHODS: A retrospective analysis of all patients that underwent emergency or salvage CAGB at four North-European university hospitals from 2006 to 2014.

RESULTS: A total of 614 patients; 580 emergency and 34 salvage CABG patients (mean age 67 ± 10 years, 56% males) were included. All patients had an acute coronary syndrome: 234 (38%) had an ST segment elevation myocardial infarction (STEMI) and 289 (47%) had a non-STEMI. Haemodynamic instability requiring inotropic drugs and/or intra-aortic balloon pump preoperatively occurred in 87 (14%) and 82 (13%) of the patients, respectively. Three hundred and thirty-one patients (54%) were transferred to the operating room immediately after angiography and 205 (33%) had a failure of an attempted percutaneous coronary intervention. Cardiopulmonary resuscitation within 1 h before the operation was performed in 49 patients (8%), and 9 patients (1%) received cardiac massage during sternotomy. Overall 5-year survival rate was 79% for emergency operations and 46% for salvage operations. Only one out of 9 patients receiving cardiac massage during sternotomy survived.

CONCLUSIONS: Early mortality in patients undergoing emergent and salvage CABG is substantial, especially in salvage patients. Long-term survival is acceptable in both emergent and salvage patients. Life-saving emergency and salvage CABG is justified in most patients but salvage patients have dismal prognosis if cardiac massage is needed during sternotomy.

Keywords: CABG • Revascularization • Emergency • Salvage • Complications • Survival

INTRODUCTION

Over the past decade, percutaneous coronary intervention (PCI) has become the primary treatment, not only for acute coronary syndrome (ACS) patients with ongoing ST segment elevation myocardial infarction (STEMI) regardless of the extension of the coronary artery disease, but also for non-STEMI (NSTEMI) or unstable angina pectoris (UAP) patients with single- or double-vessel disease [1–3]. Coronary artery bypass grafting (CABG) is reserved for patients with multivessel disease or left main stem stenosis, and is most often performed as an elective or semi-acute procedure after stabilization of acute ischaemic symptoms [1–3]. However, emergency CABG may be necessary in patients with ongoing myocardial ischaemia when PCI is unsuccessful or not suitable.

Emergency and salvage CABG are relatively rare procedures, especially salvage CABG [4]. There have been very few reports on outcome after emergency and salvage CABG, and most studies have only included a few patients from single institutions. The early mortality for emergency and salvage CABG is highly variable (2–30%) and markedly higher than for elective procedures (1–3%) [5–10].

A high rate of complications after emergency and salvage CABG is to be expected. In an attempt to justify the use of CABG in these
patients, we investigated the outcome of emergency and salvage CABG in a contemporary multicentre study.

METHODS

Study design and definitions

We performed a retrospective cohort study of patients who underwent emergency and salvage CABG between 1 January 2006 and 31 December 2013 at four Nordic university hospitals in Sweden, Finland and Iceland. Emergency and salvage CABG was defined according to the EuroSCORE-II criteria [11]. Emergency operation is an operation performed before the beginning of the next working day after the decision to operate was made while salvage operation is an operation in a patient requiring cardiopulmonary resuscitation (CPR) en route to the operating theatre or prior to induction of anaesthesia. This does not include CPR following induction of anaesthesia. Ethical permission was obtained locally for each of the participating centres before the study started.

Data collection

Clinical data was collected through medical records and 75 variables were registered for each patient. Patient data included age, gender, diabetes, hypertension, smoking at the time of surgery, history of chronic kidney disease requiring dialysis, extracardiac arteriopathy, chronic obstructive pulmonary disease (COPD), previous stroke, previous myocardial infarction (MI), recent MI (<90 days), previous cardiac surgery, previous PCI and left ventricular ejection fraction (LVEF). Intraoperative factors such as the use of cardiopulmonary bypass and cross-clamp time were registered, as well as the number of distal anastomoses and the use of arterial grafts. Information on the severity of coronary artery disease was obtained from angiography reports, and EuroSCORE-II and logistic EuroSCORE were calculated for all patients. Preoperative use of inotropic agents and insertion of an intra-aortic balloon pump (IABP) was also registered.

Definitions

Hypertension was defined as the current use of hypertensive medication and diabetes was defined as a diagnosis of diabetes in medical records or current use of oral medication and/or insulin. Extracardiac arteriopathy was defined as having a history of claudication, carotid occlusion or stenosis, amputation for arterial disease, or previous or planned intervention on the abdominal aorta, limb arteries or carotid arteries. COPD was defined as long-term use of bronchodilators or steroids for lung disease. Complete revascularization was defined as when a patient has all major coronary arteries with a significant stenosis (intraluminal stenosis >50%) on angiography grafted. In-hospital mortality was defined as death following the operation during the hospital stay.

Outcome variables

The primary end-point of the study was in-hospital mortality and survival at 1 year and 5 years postoperatively. Secondary endpoints were early postoperative complications including new onset atrial fibrillation, stroke, deep sternal wound infections, reoperation for bleeding, gastrointestinal complications and de novo dialysis postoperatively. Chest tube output was recorded for the first 12 h and number of red blood cell (RBC) units transfused was also recorded.

Follow-up

Population registries and hospital data were used to evaluate 1- and 5-year survival of patients as of 1 March 2014.

Statistical analysis

Emergency and salvage patients were compared using Student’s t-test for continuous variables and χ² or Fisher’s exact test for categorical variables. The Kaplan–Meier method was used to generate survival curves and the survival of emergency and salvage patients was compared with the log-rank test. Logistic regression was performed to identify independent risk factors for in-hospital mortality in emergency patients (salvage patients were excluded). Odds ratios (ORs) are reported for the logistic regression model, with 95% confidence intervals. Cox proportional hazards regression was used to identify risk factors for overall mortality and hazard ratios (HRs) and 95% confidence intervals were calculated. Stepwise backwards elimination was used in both regression models. All statistical tests were two-sided and P-values of <0.05 were considered significant. Statistical analysis was performed with R software version 3.2.1 (The R Foundation, Vienna, Austria, 2014).

RESULTS

Preoperative demographics

Altogether, 614 patients were included in the study; 580 emergency procedures (94%) and 34 salvage procedures (6%). The number of emergency and salvage CABG per year did not differ significantly during the study period.

Preoperative demographics are given in Table 1. The mean age of patients was 67 years (range: 31–87 years) and 56% were males. Almost one-third of patients had diabetes (29%), 61% had hypertension and 15% had extracardiac arteriopathy. Median EuroSCORE-II for patients was 4.5% with 7% of patients having a EuroSCORE of >20%. Median logistic EuroSCORE was 16.5%.

Indications for the procedure are shown in Fig. 1. The most common indication was a NSTEMI (47%), whereas 38% of the patients had a STEMI and 15% had UAP that was refractory to medical treatment. Left main stem stenosis was present in 52% of cases and 68% of the patients had three-vessel coronary artery disease. Sixteen percent of patients had a LVEF of less than 30%. One-third of the patients (33%) had a failure of attempted PCI and 7% had a serious PCI complication requiring emergency surgery. In 54% of cases, the patients were transported immediately to the operating theatre following angiography or PCI. Preoperative inotropic agents were used in 14% of cases, 13% had an IABP inserted preoperatively and 8% required CPR within an hour before the operation. Cardiac massage during sternotomy was performed on 9 patients (1%).

Intraoperative data

Intraoperative data is given in Table 2. A beating heart technique was used in 23 patients (4%), including 18 patients who underwent...
Off-pump coronary artery bypass grafting and where the procedure was performed with CPB but on a beating heart. The left internal mammary artery (LIMA) was used in 80% of cases (82% for emergency procedures and 47% for salvage procedures), and the median number of distal anastomoses was 3 (range: 1–7).

Complete revascularization was achieved in 85% of patients; 86% for emergency procedures and 79% for salvage procedures.

Postoperative complications

Postoperatively, 127 patients (21%) required an IABP and 256 patients (42%) required the use of inotropic agents after surgery. The number of patients with a new onset of AF was 186 (30%), and 37 patients (6%) had a postoperative stroke during their hospital stay. Reoperation for bleeding was required in 94 patients (15%); the mean number of RBC units transfused was 5, and 26 patients (4%) had a deep sternal wound infection. Eleven patients (2%) needed extracorporeal membrane oxygenation (ECMO) postoperatively, most often directly after the revascularization procedure. Gastrointestinal complications occurred in 11 patients (2%), including intestinal ischaemia in 5, gastrointestinal bleeding in 3 and ischaemic pancreatitis, hepatic failure and cholecystitis in 1 patient each.

In-hospital mortality and 5-year survival

Mean follow-up was 4.3 years (range: 0–8.3 years). Of the 614 patients, 91 died during their stay in hospital (15%) and 144 patients died during follow-up. Four patients were lost to follow-up. The in-hospital mortality was 13% for emergency operations (77/580) and 41% for salvage procedures (14/34). As given in Table 3, the main independent risk factors for in-hospital mortality were age, diabetes, extracardiac arteriopathy and poor LVEF.

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Figure 2 shows that 1-year survival for emergency operations was 85%, when compared with 50% for salvage operations. Furthermore, 5-year survival for emergency and salvage operations was 79 and 46%, respectively. Table 4 shows the independent predictors for overall mortality; age, diabetes, extracardiac arteriopathy and poor LVEF increased mortality.

Outcome following salvage operations

Thirty-four patients underwent a salvage CABG (mean age 64 years; 50% males). The median EuroSCORE-II for these patients...
was 17.7% whereas the median logistic EuroSCORE was 36.1%. Most of these patients (76%) were transported directly from angiography to the operating theatre after a PCI had been attempted. In half of these patients, PCI had failed or included a serious PCI complication, such as rupture of a coronary vessel with or without cardiac tamponade. The mean number of RBC units transfused for these patients postoperatively was 14 and 18% of them required a reoperation due to bleeding. Six of the 34 patients needed ECMO (18%) and all but one died within 30 days. The in-hospital mortality for these patients was high (41%), with a 1-year postoperative mortality of 50%. Eight of the 9 patients that received cardiac massage at the time of sternotomy died in the early postoperative period. The single survivor lived at least 22 months.

### DISCUSSION

We investigated the outcome after emergency and salvage CABG in a contemporary cohort of patients collected retrospectively from four Nordic university hospitals. The main finding was that despite the high in-hospital mortality, long-term survival was acceptable after both emergency and salvage CABG. However, the small subgroup of patients that needed cardiac massage during sternotomy had a bad outcome with 89% operative mortality. A 5-year survival of 79% for emergency operations indicates that patients who survive the early operative period have a remarkably good long-term prognosis. In comparison, the reported 5-year survival for non-emergency CABG is ≏92% [12, 13]. As expected, the long-term survival for patients who underwent salvage operations was lower, with 46% surviving for 5 years. If the patient survives the early hospital period due to potentially fatal conditions such as cardiac tamponade and haemodynamic compromise requiring extracorporeal support, long-term survival is more than encouraging.

Overall in-hospital mortality in our study was 15%, which is comparable with that in previous studies (2–30%) [6–9]. The considerable variation is most likely due to differences in patient groups; some studies have only included NSTEMI or STEMI

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**Table 2:** Intraoperative data for patients undergoing emergency or salvage coronary artery bypass grafting

<table>
<thead>
<tr>
<th>Intraoperative data</th>
<th>All patients (n = 614)</th>
<th>Emergency (n = 580)</th>
<th>Salvage (n = 34)</th>
<th>P-value emergency versus salvage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beating heart technique</td>
<td>23 (4%)</td>
<td>20 (3%)</td>
<td>3 (9%)</td>
<td>0.129</td>
</tr>
<tr>
<td>Use of LIMA</td>
<td>493 (80%)</td>
<td>477 (82%)</td>
<td>16 (47%)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Distal anastomoses (median, range)</td>
<td>3 (1–7)</td>
<td>3 (1–7)</td>
<td>3 (1–6)</td>
<td>0.09</td>
</tr>
<tr>
<td>Cross-clamp time, min (median, range)</td>
<td>48 (12–162)</td>
<td>48 (12–162)</td>
<td>53 (17–106)</td>
<td>0.55</td>
</tr>
<tr>
<td>Cardiopulmonary bypass time, min (median, range)</td>
<td>78 (25–300)</td>
<td>77 (25–300)</td>
<td>111 (52–270)</td>
<td>0.002</td>
</tr>
<tr>
<td>Complete revascularization</td>
<td>524 (85%)</td>
<td>497 (86%)</td>
<td>27 (79%)</td>
<td>0.306</td>
</tr>
<tr>
<td>Cardiac massage during sternotomy</td>
<td>9 (1%)</td>
<td>0 (0%)</td>
<td>9 (26%)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Mean ± standard deviation, median and range, number (%).

LIMA: left internal mammary artery.

**Table 3:** Risk factors for in-hospital mortality in patients who underwent emergency coronary artery bypass grafting (multiple logistic regression)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Odds ratio (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (per year)</td>
<td>1.09 (1.05–1.14)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Extracardiac arteriopathy</td>
<td>3.10 (1.55–6.15)</td>
<td>0.001</td>
</tr>
<tr>
<td>LVEF &lt;30%</td>
<td>3.19 (1.42–7.25)</td>
<td>0.005</td>
</tr>
<tr>
<td>Preoperative inotropic drugs</td>
<td>2.25 (1.07–4.64)</td>
<td>0.030</td>
</tr>
<tr>
<td>Preoperative IABP</td>
<td>3.70 (1.74–7.90)</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Salvage patients were excluded from the analysis.

IABP: intra-aortic balloon pump; LVEF: left ventricular ejection fraction.

**Table 4:** Risk factors for long-term mortality in patients who underwent emergency coronary artery bypass grafting (Cox proportional hazards model)

<table>
<thead>
<tr>
<th>Risk factor</th>
<th>Hazard ratio (95% CI)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>1.06 (1.03–1.09)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diabetes</td>
<td>1.74 (1.19–2.55)</td>
<td>0.005</td>
</tr>
<tr>
<td>Extracardiac arteriopathy</td>
<td>2.03 (1.33–3.10)</td>
<td>0.001</td>
</tr>
<tr>
<td>LVEF &lt;30%</td>
<td>3.16 (1.84–5.43)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Preoperative inotropic drugs</td>
<td>1.73 (1.08–2.78)</td>
<td>0.023</td>
</tr>
</tbody>
</table>

Salvage patients were excluded from the analysis.

LVEF: left ventricular ejection fraction; LIMA: left internal mammary artery.

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Figure 2: Cumulative survival in patients that underwent emergency (red line) or salvage (blue line) CABG operations. CABG: coronary artery bypass grafting.
patients, whereas others have also included patients with unstable angina [14–16]. In our study, different types of ACS were not significant risk factors for mortality in the multivariable regression analysis. The in-hospital mortality in our study may be associated with the higher number of females included in the present study when compared with others (44 vs 20–36%). The unadjusted 30-day mortality after conventional CABG in women is approximately double that in men but in our study the unadjusted in-hospital mortality was 17% for women and 13% for men (P = 0.27) [17, 18]. Furthermore, female gender was not an independent predictor of in-hospital mortality or overall survival in our study.

In-hospital mortality for salvage CABG was markedly higher than that for emergency CABG (41 vs 13%). EuroSCORE II in these patients seems to underestimate their operative risk, as the median value was 4.3 and 17.7% for emergency and salvage patients, respectively. The logistic EuroSCORE, however, predicted 36.1% mortality within 30 days for salvage patients, which is close to the actual in-hospital mortality rate in the present study (41%). On the other hand, the median logistic EuroSCORE for emergency patients was 16.0% compared with the actual mortality of 13%.

As presented in Table 1, the preoperative characteristics of patients with salvage and emergency CABG were mostly similar, although patients undergoing salvage CABG more often had LVEF <30% (50 vs 14%) and more often required preoperative inotropic agents (47 vs 12%). This is reflected by poor baseline hemodynamics associated with the dismal early survival. Patients who underwent salvage CABG also had a higher percentage of PCI complications (18%) than patients who underwent emergency CABG (7%); dissections of a coronary artery or cardiac tamponade necessitated immediate surgery. The decision to operate had to be made on a case-by-case basis, since patients have been shown to benefit from early revascularization when compared with medical therapy alone during cardiogenic shock [19].

Previous studies have also found that the main risk factors for in-hospital mortality in emergency and salvage CABG include cardiogenic shock or poor left ventricular output and ST-segment elevation [7, 16]. A study by Thielmann et al. [20] found that preoperative cTnl levels could predict the risk of in-hospital mortality in patients undergoing emergency CABG for NSTEMI and STEMI. In the present study, age, extracardiac arteriopathy, poor LVEF (>30%) and preoperative use of inotropic agents and IABP were found to be independent risk factors for in-hospital death. Preoperative Tnl levels were only available in a limited subset of the patients in the present study, and were therefore not included in the risk factor analysis.

Interestingly, diabetes seems to be a risk factor for poor overall survival with a HR of 1.74. However, the risk of diabetes was non-significant for in-hospital mortality. Studies have shown that patients with diabetes have an increased risk for long-term mortality after CABG, with an even higher risk if other comorbidities such as extracardiac arteriopathy or renal disease are also present. There is a debate in the literature whether diabetes is an independent risk factor for operative mortality after CABG [21, 22].

The use of inotropes and IABP reflects the level of acuteness and most often the presence of cardiogenic shock together with poor left ventricular output. Although the patients were operated on urgently, 85% of them achieved complete revascularization. Furthermore, the patients received 3.2 distal anastomoses on average, which is very similar to the number in elective CABG procedures. The LIMA was used in 80% of cases, which is less frequent than in elective CABG (90–95%) [11]. This is explained by the condition of the patients and the need for early haemodynamic support with CPR; LIMA was only used in 47% of the patients undergoing salvage CABG. We believe that this low use of LIMA is justified in these patients as the procedure is life-saving on very unstable patients where speed and efficiency are important.

In 15% of the patients, reoperation was needed for bleeding, which contrasts with the figure of 3–5% in patients with elective operations [23, 24]. This is most likely due to the ongoing use of dual antiplatelet treatment in ACS patients which increases the risk for bleeding complications considerably [25].

The present study has important limitations. The retrospective study design has a risk of selection bias and a risk of unregistered confounders. Only 34 patients underwent salvage CABG, which would reduce the statistical power for this subgroup of patients. Detailed data about preoperative myocardial injury markers are lacking and the study sample is not large enough for meaningful comparisons of subgroups regarding on-pump/off-pump operations.

In conclusion, emergency and salvage CABG is most often performed because of ongoing NSTEMI or STEMI. One-third of patients had a PCI failure prior to surgery. Although in-hospital mortality in these high-risk patients is high, the long-term survival is encouraging. The dismal outcome after acute MI with sustained ischaemia and/or comprised haemodynamics justifies emergency and salvage CABG.

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**REFERENCES**


