Early and Mid-Term Impacts of Cardiopulmonary Bypass on Coronary Artery Bypass Grafting in Patients With Poor Left Ventricular Dysfunction — A Propensity Score Analysis —

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Background  Cardiopulmonary bypass may exacerbate myocardial damage in compromised left ventricles. Early and mid-term outcomes of off-pump coronary artery bypass grafting (OPCAB) vs on-pump coronary artery bypass grafting (On-pump CABG) were compared in patients with poor left ventricular dysfunction, using an analysis of a propensity score matching.

Methods and Results  Between December 2000 and November 2005, 1,473 patients underwent isolated coronary artery bypass grafting in our institute and 153 patients who had a left ventricular ejection fraction (LVEF) lower than 35% were enrolled. The OPCAB group contained 100 patients and the On-pump CABG group contained 53 patients. Preoperative risk factors were compared and 50 patients in each group were matched. The mean follow-up time was 35.5±17.3 months. Three deaths (3.0%) occurred in the matched cohort, with no significant difference between 2 groups. The operation time, ventilation time, intensive care unit admission time and occurrence of respiratory failure were significantly lower in the OPCAB group. The mean LVEF of the 2 groups improved significantly. The overall 6-year actuarial survival rates of the OPCAB and On-pump CABG group were 88.2% and 72.4% (p=0.2), respectively, and there were no significant differences in 6-year rates of freedom from major adverse cardiac and cerebrovascular events (p=0.97).

Conclusions  Coronary artery bypass grafting in patients with poor left ventricular dysfunction improved myocardial function. Postoperative respiratory failure was significantly related to the cardiopulmonary bypass for surgical myocardial revascularization. Off-pump and On-pump surgical revascularization resulted in equivalent mid-term outcomes. (Circ J 2007; 71: 1387–1394)

Key Words: Coronary artery bypass surgery; Heart failure; Off-pump; On-pump

Off-pump coronary artery bypass grafting (OPCAB) is an alternative to conventional cardiopulmonary bypass-supported myocardial revascularization and is becoming increasingly popular, as it allows complete myocardial revascularization with excellent surgical results in most patients.1,2 Severe left ventricular dysfunction has been reported to be an independent predictor of operative mortality in patients undergoing coronary artery bypass grafting (CABG) and patients with impaired left ventricular function undergoing revascularization on cardiopulmonary bypass (CPB) have increased mortality and morbidity when compared with patients with normal left ventricular function.3-5 Left ventricular dysfunction also often leads to low cardiac output and a high postoperative morbidity, with many patients requiring inotropic or mechanical support, and vasopressors for hours to days after surgery.6 It has been speculated that extracorporeal circulation may exacerbate myocardial damage in compromised left ventricles as a result of the activation of inflammatory mediators, the non-physiologic ventricular geometry of the empty heart impeding collateral flow to ischemic areas and worsened preservation of interventricular septal movement.7,8 It may seem advisable to avoid cardiopulmonary bypass in patients with severe left ventricular dysfunction; however, many surgeons still choose conventional CABG using a CPB machine (On-pump CABG) due to hemodynamic instability concerns such as ventricular arrhythmia, hypotension and cardiac arrest during OPCAB.

The present study evaluates the effects of cardiopulmonary bypass and the efficacy of OPCAB by comparing the short and mid term results of OPCAB and On-pump CABG in patients with severe left ventricular dysfunction with an analysis of a propensity score matching.

Methods

Patient Selection

From December 2000 through November 2005, 1,473 patients underwent isolated CABG without a concomitant operation—such as left ventricular volume reduction surgery, arrhythmia operation or valve surgery—at Yonsei Cardiovascular Center, Yonsei University College of Medicine. Preoperative and postoperative data were obtained using a...
membrane oxygenator under moderate hypothermia (32°C). CPBs were performed with a centrifugal pump and fashion for myocardial protection of the arrested heart. All the ascending aorta and right atrium. Cold blood cardiople-3 mg/k of heparin. CPB was achieved using cannulation of of OPCAB procedure. Anticoagulation was achieved using

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USA) was used during anastomoses of arteries that were placed in the posterior pericardium two-thirds of the way size of the heart were assessed, and the strategy of grafts of disease, epicardial anatomy, size of target vessels and thoracic artery. After the pericardium was opened, the extent of disease, epicardial anatomy, size of target vessels and size of the heart were assessed, and the strategy of grafts was decided. A single deep pericardial traction suture was placed in the posterior pericardium two-thirds of the way from the inferior vena cava to the left inferior pulmonary vein. Stabilization of the target arteries was accomplished using an Octopus tissue stabilizer (Medtronic, Minneapolis, MN, USA). When hemodynamic instability was expected, a Starfish heart positioner (Medtronic, Minneapolis, MN, USA) was used during anastomoses of arteries that were placed on the lateral and posterior wall of the heart. In most instances, anastomosis of the left internal thoracic artery to the left anterior descending artery was first performed using intracoronary shunts. A proximal silastic snare was used to anastomose other coronary arteries. A mixed CO2 blower and irrigation with warm saline were used to remove blood from the sites of arteriotomy.

On-Pump CABG On-pump coronary artery bypass surgery was performed through a full sternotomy incision with harvesting of the left internal thoracic artery in a skeletonized fashion. The radial artery was harvested from the non-dominant forearm using a Harmonic scalpel (Ethicon Endosurgery Inc, Cincinnati, OH, USA). The right internal thoracic artery, saphenous vein or right gastroepiploic artery were also harvested if necessary. Heparin was given at a dose of 1 mg/kg to achieve a target activated clotting time of at least 350 s before ligation of the distal internal thoracic artery. After the pericardium was opened, the extent of disease, epicardial anatomy, size of target vessels and size of the heart were assessed, and the strategy of grafts was decided. A single deep pericardial traction suture was placed in the posterior pericardium two-thirds of the way from the inferior vena cava to the left inferior pulmonary vein. Stabilization of the target arteries was accomplished using an Octopus tissue stabilizer (Medtronic, Minneapolis, MN, USA). When hemodynamic instability was expected, a Starfish heart positioner (Medtronic, Minneapolis, MN, USA) was used during anastomoses of arteries that were placed on the lateral and posterior wall of the heart. In most instances, anastomosis of the left internal thoracic artery to the left anterior descending artery was first performed using intracoronary shunts. A proximal silastic snare was used to anastomose other coronary arteries. A mixed CO2 blower and irrigation with warm saline were used to remove blood from the sites of arteriotomy.

Operative Techniques
All patients underwent general endotracheal anesthesia with continuous Swan-Ganz catheter monitoring, trans-esophageal echocardiography and arterial pressure monitoring. A thorough TEE evaluation was undertaken in each patient to assess wall motion abnormalities, the presence and degree of mitral regurgitation, severity of atherosclerotic disease of the aorta, and right and left ventricular function.

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On-Pump CABG On-pump coronary artery bypass surgery was performed through a full sternotomy incision and the graft harvesting techniques were the same as those of OPCAB procedure. Anticoagulation was achieved using 3 mg/kg of heparin. CPB was achieved using cannulation of the ascending aorta and right atrium. Cold blood cardiople-gia was delivered intermittently in antegrade and retrograde fashion for myocardial protection of the arrested heart. All CPBs were performed with a centrifugal pump and membrane oxygenator under moderate hypothermia (32°C).

Clinical Data Collection and Follow-up
Data were collected prospectively and the degree of stenosis of coronary artery disease was analyzed using coronary angiography, and the ejection fraction was calculated using echocardiography, left ventriculography or nuclear imaging studies.

One hundred and forty-one patients (92.2%) were re-evaluated with trans-thoracic echocardiography at postoperative day 5–7 before discharge form the hospital. Follow-up echocardiography occurred 1 year after the operation and every third year thereafter. One hundred and twenty-three (81 in the OPCAB group and 42 in the On-pump CABG group) among the 148 discharged survivors underwent follow-up echocardiography (83.1%). The mean duration from operation to follow-up echocardiography was 26.7±24.1 months (range, 4 to 64 months).

The blood pressure, sugar level and cholesterol level of the patient, which can affect the long-term efficacy of grafts, were strictly monitored and maintained at normal levels, with regular follow-up by cardiologists and the referred physician. Mid term follow-up was obtained for all patients using an outpatient clinic visit, telephone interview or mailed questionnaire. All patients were completed the follow up (100%). The mean follow-up was 35.5±17.3 (range, 4 to 72 months).

Definition of Terms
Perioperative myocardial infarction was diagnosed by finding at least 2 of the following 4 criteria: (1) Prolonged (>20minutes) typical chest pain not relieved by rest and/or nitrates. (2) Enzyme level elevation: either creatine kinase (CK)-MB >5% of total CK, CK greater than 2-fold normal, LDH subtype 1 LDH subtype 2; or troponin >0.2 lg/ml. (3) New wall motion abnormalities. (4) Serial ECG (at least 2 showing the above criteria within 24 hours). Postoperative respiratory failure was defined as prolonged ventilation for more than 72 h resulting from respiratory causes, newly developed pulmonary edema, adult respiratory distress syndrome, reintubation due to respiratory causes and tracheostomy. A major adverse cardiac and cerebral event (MACCE) was defined as death from all causes, non-fatal myocardial infarction, repeat revascularization using either percutaneous intervention or bypass surgery and stroke. A major adverse cardiac event (MACE) was defined as death from all causes, non-fatal myocardial infarction and repeat revascularization by either percutaneous intervention or bypass surgery. Other variables were defined according to the Society of Thoracic Surgeons Adult Cardiac Database Definition of Terms Version 2.52.1 (http://www.ctsnet.org/file/rptDataSpecifications252_1_For VendorsPGS.pdf).

Statistical Analysis
Preoperative, intraoperative and postoperative variables were compared between the 2 groups, using univariate analysis (Fisher’s exact test or chi-square test) and Student’s t-test as appropriate. A repeated measures ANOVA test was adopted for comparing changes of ejection fraction and other echocardiographic parameters at follow-up between 2 groups.
Logistic regression was used to determine a model to calculate the propensity score (the probability to be selected for On-pump CABG given a set of preoperative risk factors listed in Appendix). The effectiveness of the model was evaluated using the Hosmer and Lemeshow goodness-of-fit statistic and residual analysis. Each On-pump CABG patient was matched with the OPCAB patient with the closest propensity score.

Kaplan-Meier curves were generated, and a log-rank test was used for comparison between the 2 groups. Multivariable Cox proportional hazards regression models were used to calculate hazard ratios while adjustment was made for preoperative and intraoperative (including CPB) factors associated with mid-term mortality. The model selection was performed with a backward stepwise method, starting from all variables with \( p \leq 0.05 \) in univariate analyses. The model was then confirmed using a forward stepwise selection. All analyses were performed using SPSS 12.0 (SPSS, Chicago, IL, USA). Data were shown as the incidence (%) or the mean±the standard deviation. \( p \) values equal to or less than 0.05 indicated a significant difference, and all \( p \) values were 2-tailed.

### Results

Out of 153 patients with an LVEF \( \leq 35\% \) (100 OPCAB and 53 On-pump CABG), we were able to match 50 patients in each group successfully. Demographics and preoperative characteristics unadjusted and adjusted for the propensity score analysis are listed in Table 1. In the matched analysis, the mean age of patients was 61.7±9.3 years (61.0±9.4 in the OPCAB group and 62.4±9.3 in the On-pump CABG group, \( p = 0.48 \)). There were 69 men (69\%) and 31 women (31\%). Forty-four patients (44\%) had LVEF between 20\% and 30\%, and 6 patients (6\%) had LVEF \( \leq 20\% \). The mean LVEF was 28.4±6.2\% and there was no difference in LVEF between the groups (\( p = 0.56 \)). There were 69 men (69\%) with LVEF \( \leq 35\% \) and 31 women (31\%). Forty-four patients (44\%) had LVEF between 20\% and 30\%, and 6 patients (6\%) had LVEF \( \leq 20\% \). The mean LVEF was 28.4±6.2\% and there was no difference in LVEF between the groups (\( p = 0.56 \)).

Also there were no differences between patients characteristics with respect to smoking history, BMI, diabetes mellitus, hypercholesterolemia, renal failure, hypertension, history of CVA or TIA, chronic lung disease, peripheral vascular disease, repeat surgery, history of PTCA, emer-
The operation time was significantly longer in the On-pump CABG group. There was no significant difference in postoperative blood loss during the first 24 h or hospital stay between the 2 groups. However, need for inotropic support, ventilation time and intensive care unit stay duration were significantly lower in the OPCAB group. The distribution of distal anastomoses and complete revascularization between the groups was not significantly different between the 2 groups and is presented in Table 2.

Surgical mortality, paroxysmal atrial fibrillation, and respiratory failure did not significantly differ between the groups and is presented in Table 3. Three (3.0%) patients died in the OPCAB group. The 3 OPCAB deaths resulted from low cardiac output syndrome. Paroxysmal atrial fibrillation, ventricular arrhythmia, and postoperative stroke occurred more frequently in the On-pump CABG group, and patients with On-pump CABG group tended to have more grafts. But there was no significant difference in the number of the distal anastomoses and complete revascularization between the groups. The distribution of distal anastomoses to the various vascular territories of the heart was not significantly different between the 2 groups and is presented in Table 2.

Serum CK-MB isoenzyme immediately after operation, need for inotropic support, ventilation time and intensive care unit stay duration were significantly lower in the OPCAB group. There was no significant difference in postoperative blood loss during the first 24 h or hospital stay duration between the 2 groups.

Postoperative morbidity and mortality are reported in Table 3. Three (3.0%) patients died in the OPCAB group and 2 (3.8%) patients died in the On-pump CABG group (p=0.81). The 3 OPCAB deaths resulted from low cardiac output syndrome and consequent multi-organ failure. The 2 On-pump CABG deaths included 1 stroke and 1 low cardiac output syndrome. Paroxysmal atrial fibrillation, ventricular arrhythmia and re-exploration for bleeding occurred more frequently in the On-pump CABG group.
Impacts of CPB on CABG in Low EF Patients

Fig 1. Changes of Echocardiographic results in the propensity-matched patients. Solid line and black-colored measures: off-pump coronary artery bypass grafting (OPCAB) group; dashed line and gray-colored measures: on-pump coronary artery bypass grafting (On-pump CABG) group. The p values are the results from repeated measures ANOVA that analyzed the effect of the use of cardiopulmonary bypass. Preop., preoperative evaluation; Imm.postop., immediate postoperative evaluation; F/U, follow-up evaluation; LVEDD, left ventricular end-diastolic dimension; LVESD, left ventricular end-systolic dimension.

Fig 2. Mid-term outcomes after operation in the propensity-matched patients. Solid line, off-pump coronary artery bypass grafting (OPCAB) group; dashed line, on-pump coronary artery bypass grafting (On-pump CABG) group. MACCE, major adverse cardiac and cerebrovascular events; MACE, major adverse cardiac events.
but not significantly. There were no statistical differences in the postoperative occurrence of renal failure, intraaortic balloon pump insertion, perioperative myocardial infarction, gastrointestinal complications and stroke. The off-pump group was associated with a lower incidence of the need for ventilation more than 24 h and/or respiratory failure. After adjustment for the propensity score, the only postoperative morbidity to show a statistically significant difference was respiratory failure.

Multivariate logistic regression analysis, using the variables listed in Appendix, revealed that the independent factors for in-hospital mortality were ejection fraction (EF) less than 20% (odds ratio (OR) 11.4, 95% confidence interval (CI) 1.3–99.8, p=0.03), body surface area less than 1.6 m² (OR 10.7, 95%CI 1.1–109.0, p=0.04) and emergency operation (OR 14.1, 95%CI 1.9–103.2, p=0.009).

Eighty-two patients (42 in the OPCAB group and 40 in the On-pump CABG group) in the 100 matched patients underwent follow-up echocardiography. The mean duration from operation to follow-up echocardiography in the matched cohort was 28.8±23.5 months (range, 6 to 64 months). The changes in echocardiographic parameters of each group are shown in Fig 1. LVEF increased significantly during follow-up in both groups, and there was no significant difference between the 2 groups in the degree of changes of parameters. In terms of left atrial dimension, there were no significant changes during follow-up (Fig 1).

In the matched cohort, there were 13 late deaths in total; 4 (8.3% among the 48 survivors) in the OPCAB group and 9 (18.4% among 49 survivors) in the On-pump CABG group. The overall 6-year actuarial survival was 78.3±5.5%, and was higher in the OPCAB group (88.2±5.3% in the OPCAB group and 72.4±7.6% in the On-pump CABG group, respectively), but the difference between the 2 groups was not significant (p=0.20). There were 5 late cardiac-related deaths; 3 in the OPCAB group and 2 in the On-pump CABG group. The 6-year freedom from cardiac related death was 94.0±3.4% in the OPCAB group and 87.2±5.6% in the On-pump CABG group (p=0.52; Fig 2). No patients received surgical coronary revascularization and 11 patients needed percutaneous coronary intervention during follow-up (7 in OPCAB group and 4 in On-pump CABG group, respectively). The overall 6-year freedom from MACCEs was 52.3±9.4% and there was no significant difference between the 2 groups (46.2±19.5% in the OPCAB group and 56.5±10.4% in the On-pump CABG group, p=0.97). The overall 6-year freedom from MACCEs was 56.2±9.7% and there was no significant difference between the 2 groups (47.5±20.0% in the OPCAB group and 61.4±9.9% in the On-pump CABG group, p=0.75; Fig 2).

Multivariate Cox proportional hazard model revealed that independent variables for mid-term deaths were: age more than 65 years, peripheral vascular disease and a NYHA functional class of 3 or more (Table 4).

### Discussion

There is an increasing incidence of moderate to severe left ventricular dysfunction in patients referred for CABG due to widespread use of thrombolysis, increased surgery in patients with recent acute myocardial infarction and angioplasty, which delays surgical intervention until coronary arteriosclerosis is more extensive and left ventricular dysfunction more severe, placing patients at much higher surgical risk. While OPCAB produces local or regional ischemia, CBP with cross-clamping produces global ischemia, which proves to be detrimental in patients with left ventricular dysfunction who have minimal cardiac reserve. Indeed, left ventricular segmental wall motion has been found to be better in patients who underwent beating heart operations than with CPB. It has been reported that OPCAB in patients with low LVEF has good surgical results and is an alternative to conventional On-pump CABG, but there are few reports of mid-term and long-term results of OPCAB in these patients. The present study evaluates the efficacy and surgical results, and the mid-term clinical results of OPCAB in low LVEF patients compared with conventional On-pump CABG.

Among the 12 patients who underwent emergency operations, IABP had been inserted preoperatively in 8 patients (66.7%). We tend to use IABP rapidly in patients who require high doses of inotropic agents and also frequently in the preoperative period for patients when maximal medical therapy has failed or for patients who had a failed attempt of angioplasty. A number of published studies have expanded the potential clinical applications of IABP, to include high risk patients who undergo CABG. Dietl et al undertook a 5-year retrospective analysis of 163 consecutive CABG patients with severe ventricular dysfunction (EF<25%). Thirty-seven patients had received IABP support preoperatively, while 126 did not. The 30-day mortality rate was 2.7% among patients receiving preoperative IABP vs 11.9% in the non-preoperative IABP group (p<0.005). This increased survival when using preoperative counterpulsation support was particularly evident among patients undergoing repeat operations, patients in NYHA functional class III or IV and in those who had experienced a recent myocardial infarction or with left main coronary artery stenosis.

### Table 4 Independent Predictors for Mid-Term Mortality in Propensity-Matched Patients With Poor Left Ventricular Dysfunction (Multivariate Cox Regression Analysis)

<table>
<thead>
<tr>
<th>Coefficient</th>
<th>Standard error</th>
<th>p value</th>
<th>ORs</th>
<th>95%CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age ≥65</td>
<td>1.52</td>
<td>0.63</td>
<td>0.016</td>
<td>4.57</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>2.20</td>
<td>0.68</td>
<td>0.001</td>
<td>8.99</td>
</tr>
<tr>
<td>NYHA ≥3</td>
<td>1.23</td>
<td>0.65</td>
<td>0.047</td>
<td>3.42</td>
</tr>
</tbody>
</table>

Abbreviations see in Tables 1,3.
Impacts of CPB on CABG in Low EF Patients

Evaluation (EuroSCORE) is used as a preoperative risk index. EuroSCORE is the most efficient index for predicting the risk of cardiac operation, even in Japan. Despite an increase in the risk category of patients for CABG, mortality has tended to decline due to the use of OPCAB for high-risk patients and improvements in surgical techniques. The cohort of the present study was a high-risk group according to EuroSCORE, and achieved better results than predicted in both OPCAB and On-pump CABG.

OPCAB showed better results than On-pump CABG in terms of operation time, post-operative cardiac enzyme elevation, ventilator care period and intensive care unit stay. In a study that compared 132 On-pump CABG patients and 45 off-pump CABG patients with an ejection fraction less than 30%, Arom et al showed that patients who received OPCAB had better results in post-operative bleeding, operation time and peak cardiac enzyme level, but no difference in mortality and complications. Similar results were seen in the present study, except for the incidence rate of prolonged ventilation and respiratory failure.

The results of follow-up echocardiography showed the significant increase on LVEF. Elefteriades et al also reported that solitary CABG had benefits in patients with left heart failure. In their study, mean LVEF increased substantially from 23.3% preoperatively to 33.2% on mid-term follow-up and this change represented a 43% increase above the initial baseline value. Furthermore, CABG had many benefits for patients with heart failure, such as symptomatic improvement, reverse remodeling of left ventricular dilatation and better long-term survival compared to medical treatment.

Although much has been published on the hospital results of patients undergoing OPCAB, little has been reported on the late outcomes in patients with poor left ventricular dysfunction. Loop et al reported a similar study involving 250 patients with ejection fractions of less than 30% who received either On-pump CABG or OPCAB, the 1 year and 3 year survival was 90% and 84% respectively, and the long-term results of OPCAB were comparable to On-pump CABG. The present study showed that the 1-, 3- and 6-year survival of the matched cohort was 92%, 87% and 75%. One-, 3- and 6-year survival rates of the OPCAB group was 92%, 92% and 88% respectively, compared to 92%, 83% and 72% for the on pump CABG group. However, there was no significant difference between 2 groups in actuarial survival. Sabik et al reported that OPCAB and On-pump CABG resulted in equivalent mid-term survival, myocardial infarction and all coronary intervention, which is similar to the present study. In most series of comparisons between OPCAB and On-pump CABG in high-risk patients, there was a significant difference in the mean number of distal anastomoses. In the present study, no difference was found in the number of distal anastomosis and completeness of revascularization, and it may remove the bias of late effect of incomplete revascularization.

The use of arterial grafts in coronary artery bypass graft surgery is an important factor regarding the long term results, especially in patients with a low cardiac function and high risks. In the present study, there was a significant difference in the rates of total arterial revascularization and the number of arterial grafts. Although there may be several reasons why the total arterial revascularization did not affect late outcomes in the present study, we believe 2 are likely possibilities. The first may be that we use the left internal thoracic artery in 97% of patients. Most studies emphasized that the left internal thoracic artery is the most important factor for late results. Second, the detrimental effects of non-total arterial revascularization increase with time, and patients in this study may not have been followed long enough for differences to emerge.

Study Limitations

The present study has several limitations. First, the present study was a clinical review of patients who underwent OPCAB and On-pump CABG. Patients were not randomly assigned to either group, but instead the choice of procedure was made by the surgeon at the time of operation. Therefore, selection bias may affect our findings. To reduce the effect of selection bias on outcomes, we used propensity matching to identify well-matched off-pump and on-pump patients for comparison. Second, the size of the cohort is somewhat small for comparison, but the statistical power ([I]) of the analysis of operative outcomes, which was performed to determine whether there was enough power in this model, was 0.81. Third, we compared the changes of the echocardiographic parameters between 2 groups, but the follow-up echocardiography was performed at different time points. To reveal the exact results and fair statistical analysis, regular and serial follow-up would be needed. Despite the limitations of this retrospective, non-randomized study and the small patient numbers, the results suggest that a prospective, randomized and long-term investigation is warranted.

Conclusion

The results of our series showed relatively low in-hospital mortality and morbidity rates associated with either OPCAB or On-pump CABG in patients with severe left ventricular dysfunction. OPCAB gave better results in terms of operation time, ventilation time, intensive care unit stay and incidence of respiratory failure compared to On-pump CABG. Both surgical strategies improved myocardial function and mid-term outcomes in patients with severe left ventricular dysfunction. OPCAB and On-pump CABG show equivalent mid-term outcomes.

References


Appendix

Variables included in multivariate analysis of risk factors for early and mid-term mortality

Demography

- Age
- Sex

Preoperative risk factors

- Body mass index
- Body surface area
- Smoking History
- Diabetes mellitus
- Hypercholesterolemia
- Renal failure
- Hypertension
- History of cerebrovascular accident
- Chronic lung disease
- Peripheral vascular disease
- Previous interventions
- Redo surgery
- History of percutaneous transluminal coronary angioplasty

Preoperative cardiac status

- Unstable angina
- Myocardial infarction (<30days)
- Ejection fraction
- Left ventricular end-diastolic/end-systolic dimension
- Cardiogenic shock
- Intra-aortic balloon pump insertion
- Canadian cardiovascular society score
- New York Heart Association functional class

Extent of coronary artery occlusive disease

- Three vessel disease
- Left main disease

Operative data

- Urgent operation
- Emergent operation
- Total arterial grafting

- Use of cardiopulmonary bypass
- Use of left internal thoracic artery
- Use of greater saphenous vein
- Complete revascularization