Myocardial Revascularization for Acute Myocardial Infarction: Benefits and Drawbacks of Avoiding Cardiopulmonary Bypass

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Background. Coronary artery bypass grafting (CABG) for acute myocardial infarction (AMI) is associated with increased mortality compared with CABG in non-AMI patients. Operating without cardiopulmonary bypass (CPB) might reduce this mortality.

Methods. Between January 1992 and December 1998, 225 patients underwent CABG within 7 days of AMI, 119 with CPB and 106 without. The two groups were similar regarding age, gender, left ventricular dysfunction, and incidence of cardiogenic shock. Mean number of grafts per patient was 3.1 in the CPB group, and 1.7 in the no-CPB group (p < 0.0001).

Results. Operative mortality in the CPB group was 12% compared with 3.8% without CPB (p = 0.027). Independent predictors of operative mortality were preoperative use of intraaortic balloon counterpulsation (IABP), non-use of internal thoracic artery (ITA) to the left anterior descending artery, and the use of less than three grafts.

Mortality of patients operated on with CPB within 48 hours of AMI was significantly higher (16.5% vs 4.3%, respectively; p = 0.044). However, patients operated on after 48 hours had similar mortality (5.8% vs 3.4%, respectively). Follow-up ranged from 6 to 84 months. Five-year survival (Kaplan-Meier) of both groups was similar (81%). Patients operated on with CPB had similar rates of recurrent angina; however, they had lower prevalence of reinterventions (0.8% vs 6.3%; p = 0.03).

Conclusions. Our study suggests that CPB can be used safely for most patients referred for CABG within the first week of AMI. However, for emergency patients operated on within the first 48 hours of symptom onset, we advocate avoiding CPB because it is associated with lower operative mortality.


Widespread use of intravenous thrombolytic therapy and primary balloon angioplasty in patients with an acute myocardial infarction (AMI) [1, 2] diminished enthusiasm for emergency coronary artery bypass grafting (CABG) in this setting. However, several situations remain that require emergency or urgent surgical revascularization after thrombolytic therapy or primary percutaneous balloon angioplasty (PTCA) [3]. For example, failure of thrombolytic agents and PTCA with acute occlusion may require surgical intervention. In addition, early CABG for postinfarction angina has become common practice in the treatment of AMI.

The mortality of emergency patients operated on after AMI remains relatively high [4, 5]. Although the adverse effects of cardiopulmonary bypass (CPB) are reversible in the majority of patients, these effects may be of major importance, irreversible, and even fatal in patients referred for surgery with evolving MI. It is reasonable to assume that avoiding CPB and its associated deleterious effects may be advantageous in this subgroup of patients.

Over the past few years, we have adapted a technique of performing CABG without CPB and evaluated our experience, especially in patients at high risk for conventional CABG. Among these high-risk patients, many were emergency cases after an AMI; some were in cardiogenic shock, and some had IABP and were in a compromised hemodynamic condition before the operation. Another group consisted of patients with AMI who had failed to respond to or had a contraindication to primary PTCA or thrombolytic therapy. Altogether, a cohort of 106 patients underwent CABG without CPB within the first week of AMI between 1992 and 1998.

This report describes their operative and late outcome, and compares them with 119 AMI patients operated on with CPB during the same period.

Patients and Methods

The cohort for this study consisted of 225 patients who underwent CABG within 1 week of AMI in our institution between January 1992 and December 1998. Patients were divided into two groups according to whether or not they had CPB: 119 did (the CPB group) and 106 did not (the OPCAB group).
Acute myocardial infarction was diagnosed by conventional electrocardiographic and enzyme criteria, and confirmed by coronary angiography that revealed occluded vessel(s) with a regional wall-motion abnormality on the left ventriculogram. Thrombolytic therapy or, in suitable cases, primary PTCA was the procedure used for early reperfusion for AMI during the study period. Patients with contraindication for thrombolytic therapy and significant wall-motion abnormalities on echocardiography, those in cardiogenic shock, or those with hemodynamic instability, underwent surgical reperfusion. There were two other groups of patients: one had ongoing pain after late admission to the emergency room (>6 hours after onset of pain) and the other had post-MI angina with left ventricular (LV) dysfunction and a large area of myocardium at risk.

All patients underwent cardiac catheterization. Surgical intervention was a second option after PTCA, whereas it was the first option for patients with coronary lesions unsuitable for primary PTCA (these included left main, complicated, and multiple lesions). The same surgical team performed all the operations in this study, and the decision to perform CABG without CPB (OPCAB) was based primarily on the surgeon's preference. The feasibility of performing the OPCAB procedure was determined by the size (diameter >1.5 mm) and accessibility of the vessel, and the number of coronary vessels to be bypassed. Patients whose characteristics did not meet these criteria, and for whom it was considered that there was greater potential benefit by avoiding CPB, were accepted for OPCAB surgery.

All patients underwent general anesthesia induced with midazolam (Dormicum; Hoffman-LaRoche Ltd., Basel, Switzerland) and a moderate dose (20 to 30 μg/kg) of fentanyl (Beatryl; Abic, Netanya, Israel). Anesthesia was maintained with inhalational agents (halothane or isoflurane) and fentanyl (100 μg/hour). Body hypothermia in the OPCAB patients was avoided by the usual methods (e.g., adjusting room temperature, placing the patient on a warming mattress, and infusing warm solutions). Neither beta nor calcium channel-blockers were used to slow the heart rate, with the intent of maintaining systemic blood pressure above 100 mm Hg in order to maintain adequate coronary perfusion. Heparin (2 to 3 mg/kg per body weight) was administered before dividing the distal end of the internal thoracic artery (ITA). Heparin was administered only after the ITA was dissected as a skeletonized artery [6] in order to decrease the risk of damage and formation of hematoma around the artery's side branches during the dissection.

A midline sternotomy was performed routinely on all patients. Hemodynamic stability (no changes in blood pressure or filling pressure, including drop in systolic pressure below 90 mm Hg) was maintained in 37 (31%) of the CPB patients and in 21 (20%; p = 0.05) of the OPCAB patients by preoperative or intraoperative insertion of an IABP. The indication for preoperative IABP insertion included cardiogenic shock (systolic blood pressure <90 mm Hg, cardiac index <1.8 L/min [2], urine output <20 mL/hour, and systemic vascular resistance >2100 dynes·s·cm⁻²), hemodynamic instability, unstable angina, and severe (>90% stenosis) left main disease. Among the 21 OPCAB patients with IABP: 16 were in cardiogenic shock; in 5 of these patients IABP was administered intraoperatively through the ascending aorta after median sternotomy because they suffered from severe peripheral vascular disease. In the remaining 11 patients IABP was inserted through the groin. All 16 patients in cardiogenic shock and with IABP-tolerated tilting, and not one required conversion to operation with CPB. In addition, the IABP was inserted in through the ascending aorta to facilitate tilting, stabilization, and exposure during the operation in 5 OPCAB patients who were not in a state of cardiogenic shock. Specifically, IABP was inserted in those patients intraoperatively after midline sternotomy and removed before sternal closure.

In the OPCAB group, myocardial preservation was achieved by fixating sutures (4–0) at the beginning of the study period, and with CTS stabilizers (CardioThoracic Systems, Inc, Cupertino, CA) thereafter. A bloodless anastomotic field was ensured by hemostatic tourniquet (4–0 Prolene) and spurs of air. Hemostatic sutures were tightened directly following arteriotomy in order to reduce regional ischemic time. Distal anastomosis and composite arterial anastomosis were performed with continuous 8–0 Prolene sutures. Every effort was made to use pedicled arterial grafts in patients with heavily atherosclerotic and calcified aortas.

Statistical Analysis
Data are expressed as mean ± standard deviation, or proportions, as appropriate. The χ² test or Fischer's exact test for small expected cell sizes were used for discrete variables. Two sample t tests or the nonparametric Mann-Whitney test were used to compare continuous variables according to the distribution. Multivariable logistic regression analysis was used to predict operative mortality by various risk factors. The odds ratio (OR) and 95% confidence intervals (CI) are given. Postoperative survival is expressed by the Kaplan-Meier method, and survival curves were compared by the log-rank test. All analyses were performed using SPSS 9 software (Chicago, IL).

Results
Preoperative clinical characteristics of the two patient groups are displayed in Table 1. The two groups were similar with regard to most preoperative risk factors; however, more patients in the CPB group were older than 70, and more patients required preoperative insertion of IABP. More patients in the OPCAB group had...
single-vessel disease, and more patients in the CPB group had triple-vessel disease. The prevalence of congestive heart failure, anterior wall MI, and old MI was higher in the OPCAB group.

Operative data are summarized in Table 2. Because 47% of the OPCAB group received a single graft, the mean number of grafts/patient in this group was only 1.7. The prevalence of bilateral ITA grafting was significantly lower in the OPCAB group, and only 11.5% of these patients received a graft to a circumflex marginal branch. This relatively low percentage stems from the preselection of a high proportion of patients in whom the circumflex marginal graft was critical, for surgery with CPB during the study period.

Operative mortality in the CPB group was 12% (14 of 119) compared with 3.8% (4 of 106) in the OPCAB group (p = 0.027). Multivariable regression analysis, including all preoperative and operative variables, revealed preoperative use of IABP (OR = 8.13, 95% CI 2.14–3.07) and construction of one or two grafts (for one graft OR = 4.0, 95% CI 2.15–7.40, and for two grafts OR = 2.1, 95% CI 1.94–2.32) to be independent predictors of mortality. The use of internal thoracic artery (ITA) as a graft to the left anterior descending artery (LAD) was associated with decreased operative mortality (6.1% vs 20.7%, p = 0.007), and in multivariable analysis, ITA to LAD was found to be an independent predictor of decreased mortality (OR = 0.18, 95% CI 0.03–1.03). The year of operation, use of CPB, number of diseased vessels, comorbidity, and timing of operation were not found to be independent predictors of operative mortality; however, in the subgroup of patients operated upon within the first 48 hours of AMI (“emergency” patients), the use of CPB was found to be an independent predictor of operative mortality.

Mortality of “emergency” patients operated on with CPB within 48 hours of acute MI was significantly higher (16.5% vs 4.4%, respectively; p = 0.044; Table 3). AMI patients operated on after 48 hours had similar mortality (5.8% vs 3.4%, respectively).

In order to check if the higher incidence of early mortality in the “emergency” patients in the CPB group was a consequence of the differences between groups in preoperative or operative variables (ie, year of operation, gender, use of IABP, preoperative ITA use, diabetes, COPD, and ejection fraction), the use of CPB was found to be an independent predictor of operative mortality. The prevalence of bilateral ITA grafting was significantly lower in the OPCAB group, and only 11.5% of these patients received a graft to a circumflex marginal branch. This relatively low percentage stems from the preselection of a high proportion of patients in whom the circumflex marginal graft was critical, for surgery with CPB during the study period.

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age > 70 years, number of vessels, preoperative use of IABP, location of AMI, old MI, CHF, use of ITA or BITA, construction of graft to circumflex marginal, and the number of grafts performed), a multivariable logistic regression analysis was performed, including first the variables to be controlled as covariates and then the operative technique (use or nonuse of CPB). The model illustrated that even after controlling for these variables, there was still a statistically significant difference in the incidence of early mortality of “emergency” patients between the groups (p = 0.0072, OR = 3.23, 95% CI 1.3–6.59).

Late follow-up (2 to 9 years) was available in all survivors. It was longer for the OPCAB patients (started in 1992) than for the CPB patients (started in 1995). However, the inclusion of the year of operation as a covariate in the multivariable analysis did not affect the results. During the follow-up period (Table 3), 16 OPCAB patients (15%) and 10 CPB patients (8.4%) died. Four of the late mortalities occurred in patients operated on in cardiogenic shock (2 OPCAB and 2 CPB patients). In the “emergency” subgroup, late mortality was higher in the OPCAB patients (19% vs 10.5%); however, the difference in late mortality did not reach statistical significance. Angina returned in 8 patients (8.2%) of the OPCAB group: 7 patients had reinterventions, 2 patients had to undergo reoperation. Angina returned in 5 patients (4.2%) of the CPB group patients, and only 1 patient had to undergo reintervention (Table 3) (p = 0.028).

When excluding operative mortality, 5-year actuarial survival (Kaplan-Meier) of patients operated upon with CPB was better (93% vs 84.3%, p = 0.07, log-rank test; Fig 1). However, when operative mortality was included in the analysis, 5-year survival was similar (81% vs 81%; Fig 2).

**Comment**

The major findings of the present study are that OPCAB surgery is associated with decreased operative mortality.
in patients operated on within the first 48 hours of AMI. However, avoiding CPB in those AMI patients operated upon after the first 48 hours did not exhibit any survival benefit.

The optimal timing of operation after AMI remains indecisive. Nunley and associates [9] found significant differences in outcome that depended on the time interval from AMI to operation; the mortality rate of AMI patients who underwent surgery within the first 48 hours of AMI was 7.7%, compared with 0% after 48 hours. Creswell and colleagues [10] reported that mortality rates of patients who underwent surgery within 6 hours after onset of AMI symptoms was 9.1%, 8.3% in those undergoing surgery within 6 hours to 2 days, and 5.2% within 2 to 14 days after AMI. In a recently published multicenter analysis [11] of 44,365 patients who underwent CABG after AMI, hospital mortality decreased considerably with increasing time interval between CABG and AMI: 11.8%, 9.5%, and 2.8% for less than 6 hours, 6 hours to 1 day, and longer, respectively.

Most AMI patients are currently referred to the cardiac surgeon well after the “first six golden hours.” Varying reports of overall mortality in these patients exist: 3.1% [11]; 5% [12]; 7.2% [13]. It is generally considered that the outcome in these patients may depend on factors such as timing of operation, LV function, presence of collaterals, and hemodynamic instability.

In a former report [14], we demonstrated that an important determinant of operative mortality in the subset of AMI patients requiring emergency revascularization within the first 48 hours is the surgical technique used. Our study indicates that timing in itself is not a significant predictor of early or late mortality in OPCAB patients. However, it is a significant predictor in patients operated on with CPB.

The beneficial effect of avoiding the use of CPB in AMI patients operated on within the first 48 hours of symptom onset was demonstrated recently in a smaller cohort of AMI patients [14]. In that report, operative mortality of emergency AMI patients operated upon without CPB was 5% compared with 24% in the subgroup of patients operated on with CPB. The trade-off of avoiding CPB was increased angina recurrence, increased rate of reinterventions, and increased late mortality.

Independent predictors of operative mortality in the current report were preoperative use of IABP, nonuse of ITA to the LAD, and the use of less than three grafts.

Increased mortality of AMI patients operated on with CPB in our report was mainly due to excessive mortality in emergency patients and in hemodynamically compromised patients operated on with the support of IABP. Therefore, it is clear that when a nonemergent patient is referred to surgery after the first 48 hours of symptom onset, the use of CPB is not deleterious, and should be considered in view of the better long-term results.

This study suggests that the use of ITA to LAD has a strong protective effect on perioperative mortality in AMI patients (OR = 0.18, 95% CI 0.03–1.03). There have been numerous reports comparing the ITA to venous conduits. These studies have demonstrated improved long-term patency [13, 15, 16] and survival [17, 18] with ITA use. However, the short-term effects of ITA use as a conduit for CABG have only recently been evaluated. Using the Society of Thoracic Surgeons’ National Cardiac Surgical Database, Edwards and coworkers [19] studied the impact of ITA conduits on operative mortality in 38,578 patients undergoing CABG from 1987 to 1991. The operative mortality of patients receiving an ITA graft was significantly less than that of patients receiving venous conduits only. Similar findings were recently reported in the Northern New England Cardiovascular Disease Study Group by Leavitt and colleagues [20].

The importance of complete myocardial revascularization on the outcome of CABG procedures has been well known from the beginning of the 1980s [21]. However, deleterious effects of complete revascularization were most pronounced in patients in whom the LAD zone or multiple vascular zones were not revascularized, not very common situations today, as reported in a recently published series of CABG [22–24]. These studies primarily address the issues of long-term effects and event-free survival of complete revascularization in the context of expanding the use of multivessel revascularization with stents and balloon angioplasty. Revascularization of the remote areas and the infarct zone in patients with acute MI is a special clinical and physiologic situation. This might explain the findings of our study, which demonstrated for the first time that the use of three or more grafts (suggesting more complete revascularization) was associated with lower operative mortality.

Late survival (including operative mortality) of the two groups was similar due to better survival of patients who survived the operation with CPB (late mortality 8.4% vs 15%, p = 0.117). More patients of the CPB group are angina-free at the time of latest follow-up (2 to 9 yeas), and only 1 patient underwent reintervention compared with 7 patients of the OPCAB group (p = 0.028). The short-term survival benefit obtained by avoiding CPB is disappointing. The increased late mortality may be related to incomplete revascularization or the inferior patency rate of anastomoses performed on the beating heart. An explanation similar to ours for the increased prevalence of cardiac events was suggested recently by Gundry and associates [25].

Limitations

This is a nonrandomized study, and several important variables were found to differ between the two groups; however, they had no statistical effect on the results.

In conclusion, our study suggests that CPB can be used in most patients referred for CABG within the first week of acute MI; however, for emergency patients operated on within the first 48 hours of symptom onset, we advocate avoiding CPB. The improved techniques of OPCAB surgery (stabilizers, IABP, and suction devices) enable more complete revascularization. This might improve early and late outcome of this subset of emergent AMI patients.
References

INVITED COMMENTARY

We are often confronted with the patient who requires surgical revascularization early after acute myocardial infarction (MI). As we all know, operation in this setting can be associated with high morbidity and mortality rates. The optimal timing of coronary artery bypass (CAB) has received much attention, but no consensus has emerged. Studying the issues related to CAB early after acute MI is difficult because of the many variables (ie, patient-related, surgeon-related, and institution-related) that influence the clinical outcome.

The report by Locker and colleagues [1] is the third report from this group that describes their experience with off-pump coronary artery bypass (OPCAB) for patients with acute MI. The authors have made careful observations and report a significantly lower operative mortality rate for patients having OPCAB, rather than standard on-pump CAB within the first 48 hours after acute MI. Beyond 48 hours, there was no difference in the operative mortality rate for the two operative approaches. The actuarial 5-year survival rate and the frequency of recurrent angina were similar for the two groups. Interestingly, patients in the on-pump CAB group were less likely to require re-intervention (surgical or interventional) during late follow-up. This finding suggests there may be a trade-off in which OPCAB is associated with better early but worse late results. Could this finding be due to a sacrifice in the technical quality of OPCAB bypasses and reduced graft patency over time?

The authors’ observations in this report are important, but in a retrospective study design we must always ask if the two study groups are similar in all regards other than the operative approach. The authors note several differences between the two groups in their report; and there are undoubtedly other, unmeasured, differences as well. At this point, how should we choose the best operation for our patient who needs CAB early after acute MI? The