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Emergency myocardial revascularization for acute myocardial infarction: survival benefits of avoiding cardiopulmonary bypass☆

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Abstract

Objective: Emergency coronary artery bypass grafting (CABG) for acute myocardial infarction (AMI) is associated with increased operative mortality. It has been suggested that this mortality might be reduced by performing the operation without cardiopulmonary bypass (CPB). **Methods**: Between January 1992 and April 1998, 77 patients underwent emergency CABG within 48 h of AMI. Thirty seven were operated on with CPB, and 40 without CPB. The two groups were similar regarding age, gender, left-ventricular ejection fraction (EF) and preoperative use of intra-aortic balloon pump (IABP; 50%). The mean number of grafts/patient was 3 in the CPB group, and 1.9 in the No-CPB group ($P < 0.0001$). **Results**: Operative mortality in the CPB group was 24% (nine of 37) compared to 5% (two of 40) without CPB ($P = 0.015$). Follow-up ranged between 6 and 66 months. There were no late deaths in the CPB group compared to nine (22%) in the No-CPB group ($P < 0.0066$). Patients operated on with CPB had lower rates of recurrent angina (0 versus 15%; $P = 0.04$) and re-interventions (0 versus 15%; $P = 0.04$). **Conclusions**: Our experience suggests that CABG without CPB is the preferred method of myocardial revascularization, due to the fact that it carries lower mortality than CABG with CPB. The trade-off includes increased rates of recurrent angina, re-interventions and late mortality.

Keywords: Acute myocardial infarction; Emergency coronary artery bypass grafting

1. Introduction

Recent improvements in myocardial-preservation techniques and the use of intra-aortic balloon counter-pulsation have afforded greater safety to operations with cardiopulmonary bypass (CPB) [1]. However, the mortality of emergency patients operated on after acute myocardial infarction (AMI) remains relatively high [2–5].

De Wood et al. demonstrated that the first few hours of evolving AMI were associated with a high incidence of intracoronary occlusive thrombus. They also removed fresh thrombi from the coronary arteries of patients undergoing emergency bypass operations [6].

The Spokane experience with early revascularization (3–6 h) was started in 1971, and was reported in 1975 by Berg et al. [7]. Hospital mortality was 5.5%, and 1-year mortality was 6.3%.

However, enthusiasm for emergency coronary artery bypass grafting (CABG) in evolving AMI has diminished due to the complicated logistics required to achieve early surgical revascularization, together with the advent and widespread use of intravenous thrombolytic therapy and percutaneous balloon angioplasty (PTCA) [8]. Failure of thrombolytics and PTCA, as well as post-infarction angina, have renewed the role of CABG in the treatment of patients with AMI.

In order to reduce the risk and damaging effect of CPB, we adopted the technique of CABG without CPB, and evaluated it in 40 consecutive emergency cases following AMI. This group of patients was compared to a similar group of 37 patients operated on during the same time period with CPB. The operative and late results of these 77 patients are the basis of this report.

2. Patients and methods

Between January 1992 and April 1998, 160 patients underwent CABG within 1 week of AMI. Seventy seven of them underwent emergency operations for evolving

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AMI, performed during the first 48 h after onset of pain. Forty of these emergency patients were operated on without CPB (No-CPB), and 37 with CPB (CPB).

The diagnosis of AMI was made by conventional electrocardiographic and enzyme criteria, and confirmed by coronary angiography which showed occluded vessel(s) with a regional wall-motion abnormality on the left ventriculogram. Early reperfusion for AMI during those years was done with thrombolytic therapy, or, in suitable cases, with primary PTCA. Surgical reperfusion was reserved for patients with contraindication for thrombolytic therapy and significant wall-motion abnormalities on echocardiography, for patients in cardiogenic shock, or those with hemodynamic instability. Two other groups of patients had either ongoing pain after late admission to the emergency room (more than 6 h after the onset of pain) or post-MI (myocardial infarction) angina with left ventricular (LV) dysfunction and a large area of myocardium at risk.

After cardiac catheterization, surgical intervention was a second option after PTCA, or the first option for patients with coronary lesions unsuitable for primary PTCA (including left main, complicated and multiple lesions). The decision to perform CABG without CPB was primarily based on the potential benefit of avoiding CPB, under the assumption that the higher the risk from conventional CABG, the greater the patient would benefit by avoiding CPB. Feasibility of the procedure was determined by the size (diameter > 1.5 mm) and accessibility of the vessel, and the number of coronary vessels to be bypassed. When there was greater potential benefit from avoiding CPB, patients who did not meet these criteria were also accepted for surgery without CPB.

2.1. Surgical technique

General anesthesia was induced with midazolam (Dormicum, Hoffmann–LaRoche Ltd, Basel, Switzerland) and a moderate dose (20–30 μg/kg) of fentanyl (Beatryl, Abic, Netanya, Israel). Anesthesia was maintained with inhalational agents (halothane or isoflurane) and fentanyl (100 μg/h). Body hypothermia in patients operated on without CPB was avoided by adjusting room temperature, placing the patient on a warming mattress and infusing warm solutions. The major hemodynamic consideration in this subgroup of patients was to maintain systemic blood pressure above 100 mmHg in order to maintain adequate coronary perfusion. Neither beta nor calcium channel-blockers were used to slow the heart rate. Heparin was administered in a dose of 2–3 mg/kg weight before dividing the distal end of the internal thoracic artery (ITA). The ITA was dissected as a skeletonized artery [9] before heparin administration to decrease the risk of damage and hematoma formation in the region of the side branches during dissection.

All patients were operated upon through a mid-line sternotomy. Hemodynamic instability was maintained in 18 (45%) of the No-CPB patients by preoperative or intraoperative insertion of an intra-aortic balloon pump (IABP) for the duration of distal-anastomosis construction. This was done either through the groin or, preferably, through the ascending aorta. For this purpose, the IABP was inserted intraoperatively after the mid-line sternotomy, and removed before sternal closure. Exposure and fixation of the anastomotic site were achieved with CTS retractors and stabilizers (CTS, CardioThoracic Systems, Inc, Cupertino, CA). Hemostatic tourniquet (4-0 Prolene) and spurts of air were used to obtain a bloodless anastomotic field. Hemostatic sutures were tightened just after the arteriotomy to shorten regional ischemic time. Distal anastomosis and composite arterial anastomosis [10] were performed with continuous 8-0 Prolene sutures. When the aorta was calcified, every effort was made to use pedicled arterial grafts. In five patients of the No-CPB group a mini-composite [11] arterial graft was used and both ITAs were harvested in two patients.

Operations in the second group were performed with CPB (CPB group). The myocardial-preservation technique involved intermittent antegrade and retrograde warm cardioplegia (30–32°C) [12]. All patients were treated with a high-dose intravenous infusion of isosorbide dinitrate (Isoket) (4–20 mg/h) during the first 24–48 h, postoperatively. Systolic blood pressure was maintained above 100–120 mmHg [10].

2.2. Statistical analysis

Data are expressed as mean ± standard deviation, or proportions, as appropriate. The Chi-square test or Fisher exact test for small expected cell sizes were used for discrete variables. Two sample *t*-tests or the non-parametric Mann–Whitney test were used to compare continuous variables according to the distribution.

Multivariate 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 7.5 software.

3. Results

Preoperative clinical characteristics of the two patient groups are summarized in Table 1. There were no differences between the two groups besides a higher rate of failed PTCA and a higher number of patients with single-vessel disease in the no-pump group.

Operative data are summarized in Table 2. Since 40% of the no-pump group received a single graft, the mean number of grafts/patient in this group was only 1.9. Only 8% 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.

Table 1
Patient characteristics[a]

	CABG with CPB ($n = 37$)	CABG without CPB ($n = 40$)	*P*-value
Male	23 (62)	31 (77)	–
Female	14 (38)	9 (23)	–
Age (years ± SD)	66 ± 10	62 ± 13	–
Age > 70 years	14 (38)	10 (25)	–
EF < 25%	14 (38)	13 (33)	–
Preoperative IABP	22 (59)	18 (45)	–
Cardiogenic shock	17 (46)	15 (38)	–
Left main	12 (32)	6 (15)	–
One vessel	3 (8)	11 (28)	0.0563
Two vessels	10 (27)	12 (30)	–
Three vessels	12 (32)	11 (28)	–
Anterior-wall MI	24 (65)	28 (70)	–
Inferior-wall MI	13 (35)	12 (30)	–
Preoperative thrombolysis	6 (16)	7 (18)	–
Complicated PTCA	5 (13)	12 (30)	0.03

[a] Figures in parentheses represent percentage values.

Operative mortality was lower in the no-pump group (5%, two patients) than in the CPB group (24%, nine patients). Both deaths in the no-pump group were due to low-cardiac output and expansion of anterior-wall MI. All nine deaths in the CPB group were patients with a very low ejection fraction (EF), who could not be weaned from extracorporeal circulation, despite inotropic and IABP support. In order to check if the higher incidence of early mortality in the no-CPB group was a consequence of the differences between groups in preoperative or operative variables (i.e. number of vessels, failed PTCA, construction of graft to circumflex marginal and the number of grafts performed), a multivariate logistic regression analysis was performed, including first the variables to be controlled as covariates and then the operative technique. The model showed that even after controlling for these variables, there was still a statistically significant difference in the incidence of early mortality between the groups ($P = 0.0279$, $OR = 6.12$, 95% CI, 1.21–30.83). Moreover, there was no correlation between the above variables and the incidence of early mortality. The postoperative course of the No-CPB patients was relatively uncomplicated. Almost all were extubated within 6 h of arrival in the intensive care unit, and postoperative inotropic catecholamine support was given to only six of the 18 patients who were supported preoperatively with IABP (33%) for low-cardiac output. In contrast, CPB patients (100%) were supported postoperatively with catecholamines ($P = 0.04$). Only two of the No-CPB patients (5%) required postoperative support with IABP, whereas all 22 CPB patients who had preoperative IABP support required postoperative IABP ($P = 0.01$).

Late follow-up (1–7 years) was available in all survivors (Table 3). During this period, nine No-CPB patients died (23%), and only one in the CPB group. Four of the No-CPB patients who died and one from the CPB group had preoperative cardiogenic shock. Angina returned in six (15%) patients of the No-CPB group, all had re-interventions, two of whom had to undergo re-operation. Angina returned in only two (5%) of the CPB group patients. None of them had to undergo re-operation.

Newly-developed congestive heart failure (CHF) or increase in the severity of CHF (grades III or IV) were more common among No-CPB patients (Table 3).

One-year survival in the No-CPB patients was 87.5%, and 4-year survival including operative mortality was 77%. One-year survival of the CPB patients was 75.5%, and 4-year survival was 72% (Fig. 1). The difference in long-term survival between the two groups was not statistically significant (log-rank test).

Table 2
Operative data[a]

	CABG with CPB	CABG without CPB	*P*-value
Number of grafts			
One	2 (5)	16 (40)	–
Two	8 (22)	18 (45)	–
Three	18 (49)	5 (13)	–
Four	7 (19)	1 (3)	–
Five	1 (3)	0	–
Graft/patient (mean ± SD)	2.98 ± 0.9	1.9 ± 0.9	0.0001[b]
Use of IMA[c]	32 (86)	31 (78)	–
Circumflex marginal graft	32 (86)	3 (8)	0.0008[d]
Reoperative CABG	4 (11)	1 (3)	–

[a] Figures in parentheses represent percentage values.
[b] Mann–Whitney test.
[c] IMA, internal mammary artery.
[d] Fisher exact test.

Table 3
Results[a]

	CABG with CPB	CABG without CPB	*P*-value
Early mortality	9 (24)	2 (5)	0.01
Anterior MI	6/24 (25)	2/28 (7)	0.07
Inferior MI	3/13 (23)	0/12 (0)	–
1 vessel	1/3 (33)	1/11 (9)	–
1 graft	1/2 (50)	1/16 (6)	–
2–4 grafts	8/34 (23)	1/24 (4)	–
Marginal	6/32 (19)	1/3 (33)	–
Complicated PTCA	2/5 (40)	0/12 (0)	–
Late mortality	1 (3)	9 (23)	0.006
Recurrent angina	2 (5)	6 (15)	–
Re-interventions	0	6 (15)	0.04
Congestive heart failure	5 (14)	10 (25)	–

[a] Figures in parentheses represent percentage values.

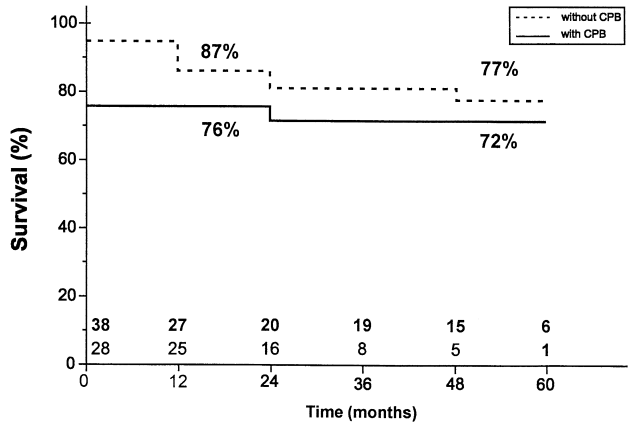

Fig. 1. Survival curves (Kaplan–Meier) by the method of revascularization.

4. Discussion

Widespread use of myocardial revascularization without CPB occurred with the advent of minimally-invasive surgery (MID CABG) and the introduction of various new retractors and stabilizers [13,14]. Although the adverse effects of CPB are minor and 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 may be advantageous in this subgroup of patients.

In our previous report, we showed that an important indication for CABG without CPB was AMI [15]. The mortality rate of AMI patients operated on without CPB in this report was low; however, no effort was made to compare the results in this subset of patients to those obtained with the modern, conventional techniques of CABG with CPB [12].

With the advent and popular use of intravenous thrombolytic therapy and PTCA in patients with evolving AMI, the enthusiasm for emergency CABG in this setting has diminished. However, several situations still exist that require emergent or urgent surgical revascularization, such as failure of thrombolysis and PTCA with acute occlusion.

Most AMI patients are currently referred to the cardiac surgeon well after the first six golden hours of symptom-onset. Overall mortality in these patients, as reported in the literature, has varied: 3.4% [5], 5% [16], 7.2% [3], 8.4% [17], 16% [18]. It is generally thought that the outcome in these patients may depend on factors such as timing of operation, LV function, presence of collaterals and hemodynamic instability. In this report, we showed that the important determinant of operative mortality in this subset of patients requiring emergency revascularization is the surgical technique used.

Although the two groups differ in the total number of grafts and the number of grafts to circumflex marginal's for technical reasons, early mortality in 40 patients operated on without CPB was significantly lower than the mortality of those operated on with CPB (5 versus 24%, $P = 0.01$). This difference in the proportion of mortality is still significant after controlling for baseline differences between groups. The surgical technique used was especially important in patients referred for surgery who were in cardiogenic shock. None of the cardiogenic-shock patients operated on without CPB died, compared to eight of the 17 operated on with CPB ($P = 0.007$). The good results of CABG without CPB in patients with cardiogenic shock or IABP compared favorably with the results of those patients operated on within the first 6 h of AMI [4]. Moreover, 11 of the 15 cardiogenic-shock patients in the No-CPB group (73%) are alive four years postoperatively, compared to only eight of the 17 (47%) patients in the CPB group.

An important finding of this report is that the long-term results of patients operated on without CPB are not better than the results of those operated on with CPB. Ninety percent of the patients who survived CABG with CPB are angina-free, they have a considerably lower rate of re-interventions, and their 4-year survival (including operative mortality) is similar to that of patients operated on without CPB.

The short-term survival benefit obtained by avoiding CPB is disappointing. The increased late mortality may be related to the 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 et al. [19].

In conclusion, our operative results suggest that when it is possible to operate without CPB, the beating-heart technique is better than CABG with CPB for AMI patients referred for emergency CABG.

The better patency rate and the more complete revascularization that may be achieved with the new generation of stabilizers and retractors or with hybrid procedures may improve long-term results [20].

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Appendix A. Conference discussion

Dr L. von Segesser *(Lausanne, Switzerland)*: As time is such an important issue here, can you remind us your definition of AMI? Is 48 h, for instance, within pain or hospitalization or diagnosis or consulting of the surgeon?

Dr Locker: The diagnosis of AMI was made by conventional criteria, ECG and enzymes, and confirmed by coronary angiography, which showed an occluded vessel or vessels with regional wall-motion abnormality in the left ventriculogram.

Dr von Segesser: I agree completely, but when you say less than 48 h after AMI in this group, is it 48 h after the onset of pain or after established diagnosis, for instance?

Dr Locker: It is 48 h from onset of pain.

Dr J. Vaage *(Stockholm, Sweden)*: You didn't explain how and why the decision was made to do the surgery on pump or without pump.

Dr Locker: It is an important question. The decision was made by the assumption that avoiding CPB may give a potential benefit in high-risk patients. So the greater the risk, the higher the potential benefit and the patient's benefit avoiding CPB.

Dr Vaage: I am still not sure that I really understand it. If I saw your slides correctly, you actually had patients with more one- or two-vessel disease in the off-pump surgery than in the on-pump surgery. That's one thing. So maybe you actually have been looking at different patient populations with a different distribution of coronary atherosclerosis.

The second question I would like to ask is about your myocardial protection. I am extremely sceptical to, in patients like this, using intermittent warm cardioplegia. These are, for the first thing, typical cases for doing retrograde cardioplegia. Also, using the intermittent and warm cardioplegia in the already energy-depleted myocardium may not be the optimal way to do it.

Dr Locker: To your first question, it's true, more patients with single-vessel disease were operated on without CPB, but when you take all the confounding variables and put them in a multivariant logistic regression analysis, after controlling these variables, there is still a significant difference between the two groups in early mortality.

Dr A.M. El Gamel *(London, UK)*: I am quite interested to see that there was a higher incidence of arterial revascularization in the group that you put on bypass, and I wonder if the surgical strategy of the surgeons who did the operation on bypass was quite different from the group without, and if the same surgeon was on both sides or did cases on both sides, or are all these cases done by a different surgeon, because the conclusion to condemn the bypass, the reason for increased mortality, would be invalid if other factors were not justifiable?

Also, your cross-clamp time must be longer when you did more grafts on the bypass side, so the heart was more ischemic as well. So, have you looked at the ischemic time and the length of the operation in total?

Dr Locker: Sure, we looked at ischemic time, and it was not out of proportion with the time that is conventional. The question about the different surgeons, the same team made the operations, with pump and with no pump.

Dr El Gamel: Did you take the mammary artery while you were on bypass in patients who were hemodynamically unstable?

Dr Locker: Yes.