CORONARY ARTERY BYPASS WITHOUT CARDIOPULMONARY BYPASS FOR PATIENTS WITH ACUTE MYOCARDIAL INFARCTION

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Objective: Between January 1992 and December 1994, 57 patients having an acute myocardial infarction with coronary anatomy suitable for coronary artery bypass grafting without cardiopulmonary bypass underwent this procedure within 1 week of the infarction. We describe the surgical results of these high-risk patients. **Methods:** The study population included 43 male patients (75%) and 14 female patients (25%) whose mean age was 58.5 ± 10.4 years. Thirty-two patients (56%) underwent emergency bypass grafting within 48 hours of an acute myocardial infarction, 4 of them (12.5%) as a bailout procedure after complicated percutaneous transluminal coronary angioplasty. Of these 32 patients, 7 patients (22%) were in cardiogenic shock, and 10 patients (31%) required preoperative intra-aortic balloon pump. Twenty-five patients (44%) underwent coronary bypass grafting 2 to 7 days after an acute myocardial infarction. The mean number of grafts per patient was 1.8 (range, 1-4), and the internal thoracic artery was used in 47 patients (82%). Only 7 patients (12%) received grafts to a circumflex marginal branch. **Results:** Operative mortality was 1.7% (1 patient), and the mean postoperative hospital stay was 6.8 ± 3 days. One- and 5-year actuarial survivals were 94.7% and 82.3%, respectively. Angina returned in 7 patients (12%), 1 of whom underwent reoperation. Multivariate analysis revealed renal failure and preoperative cardiogenic shock to be independent predictors of overall mortality. Old myocardial infarction and operation within the first 48 hours were independent predictors of overall unfavorable outcome events. **Conclusions:** These results suggest that coronary artery bypass grafting without cardiopulmonary bypass is a relatively low-risk procedure for patients having an infarction with coronary anatomy suitable for this technique. (J Thorac Cardiovasc Surg 1999;118:50-6)

In the early days of coronary artery bypass grafting (CABG), surgical intervention within the first months of an acute myocardial infarction (AMI) was associated with increased mortality rates of 15% to 20%.¹ Surgical deaths of patients having AMI then

decreased with the improvement in myocardial preservation techniques and intra-aortic balloon counterpulsation.²

Experience with early surgical revascularization (3 to 6 hours after AMI) began in 1971. Berg and colleagues³ reported a hospital mortality rate of 5.5% and 1-year mortality rate of 6.3%. De Wood and colleagues⁴ demonstrated a high incidence of intracoronary occlusive thrombus during the first few hours of an evolving AMI. Fresh thrombi were also removed from the coronary arteries of patients undergoing emergency CABG shortly after the appearance of symptoms.⁴ Enthusiasm for emergency CABG in evolving AMI has diminished with the advent and widespread use of intravenous thrombolytic therapy and percutaneous transluminal coronary angioplasty (PTCA).⁵ However, the failure of these measures in several cases and the appearance of

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Received for publication Sept 17, 1998; revisions requested Nov 4, 1998; revisions received March 3, 1999; accepted for publication March 3, 1999.

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0022-5223/99 \$8.00 + 0 12/1/98437

Table I. Patient characteristics and overall (early and late) mortality rates (n = 57)

Factor	Prevalence		Death with factor		Death without factor		P value
	n	% of n	n	%	n	%	
Age ≥ 70 y	12	21	4	33	5	11	.06
Female gender	16	28	3	20	6	15	.702
Left main stenosis	5	9	1	20	8	15	.787
Unstable angina	51	91	8	16	1	17	.339
AMI <48 h	32	56	7	22	2	8	.154
Old MI	31	56	7	23	2	8	.070
Complicated PTCA	13	23	3	23	6	14	.412
EF ≤ 35%	19	33	4	21	5	13	.441
Congestive heart failure	23	42	4	17	5	16	.861
Cardiogenic shock	8	14	3	38	6	12	.069
IABP	14	43	4	29	5	12	.202
Diabetes mellitus	10	18	2	20	7	15	.688
Hypertension	21	37	3	14	6	17	.812
Stroke	1	2	—	—	—	—	—
PVD	4	7	1	25	8	15	.600
Calcified aorta	4	7	1	25	8	15	.600
Chronic renal failure	2	4	2	100	7	13	.023
Severe COPD	3	5	0	0	9	17	.441
Emergency surgery	35	62	8	23	1	5	.065
Nonused ITA	11	20	3	27	6	13	.245
Single graft	22	39	3	14	6	17	.724
Circumflex marginal graft	7	12	1	14	8	16	.907

EF, Ejection fraction; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; ITA, internal thoracic artery.

postinfarction angina reestablished the importance of CABG in the treatment of AMI.

Over the past few years, we have adapted a technique of performing CABG without cardiopulmonary bypass (CPB) and evaluated our use of it, especially in patients at high risk for conventional CABG. Among these high-risk patients, many were emergency cases after an AMI; some had cardiogenic shock, and some had intra-aortic balloon counterpulsation and were in a compromised hemodynamic condition before the operation. Another group consisted of patients with an AMI whose condition had failed to respond to or had a contraindication to thrombolytic therapy. Altogether, a cohort of 57 patients underwent CABG without CPB within the first week of AMI between 1992 and 1994; this report describes their operative and late results.

Patients and methods

Between January 1992 and December 1994, 310 patients underwent CABG without CPB. One of us (R.M.) performed all the operations. This group comprises 16% of 1919 isolated CABG operations that had been carried out in our institution during this period. Fifty-seven patients with AMI underwent CABG without CPB within 1 week of the infarct. Most of the 1245 patients admitted with AMI to our intensive coronary care unit from 1992 through 1994 were treated conservatively (n = 734 patients) or with thrombolytic therapy (n =

425 patients). Only 67 patients were referred for CABG surgery, of whom 57 patients underwent operation without CPB (the preferred method at that time). Only 10 patients underwent CABG with CPB because it was not technically possible to perform the operation without it (4 patients underwent CABG plus mitral valve repairs and 6 patients had disease involving marginal branches of the circumflex artery, which were not suitable for operation without CPB). Thus the selection of patients was by virtue of the patient's anatomic condition. Of the 57 patients with AMI who underwent operation without CPB within 1 week of the infarction, 32 procedures were emergency operations performed during the first 48 hours of an evolving AMI. Of these 32 patients, 7 patients (22%) were in cardiogenic shock, 4 patients (12.5%) underwent bailout PTCA, and 10 patients (1%) required a preoperative intra-aortic balloon pump (IABP). The remaining 25 patients underwent operation between 2 and 7 days after the AMI, 1 patient (4%) with cardiogenic shock and 4 patients (16%) with preoperative IABP support. Patient characteristics are listed in Table I.

The diagnosis of AMI was made by the conventional electrocardiographic and enzyme criteria and was confirmed by coronary angiography that showed an occluded vessel with a regional wall motion abnormality on the left ventriculogram. Early reperfusion for AMI during those years was done by means of thrombolytic therapy or, in suitable cases, with primary PTCA. Surgical reperfusion was reserved for patients with a contraindication for thrombolytic therapy and signifi-

cant wall motion abnormalities on echocardiography, for patients with cardiogenic shock, and for patients with hemodynamic instability. Two other groups of patients were those with ongoing pain after late admission to the emergency department (more than 6 hours after onset of pain) and patients with post-AMI angina with left ventricular dysfunction and a large area of myocardium at risk.

After cardiac catheterization, surgical intervention in those patients was a second option after PTCA or a first option for patients with coronary lesions not suitable for primary PTCA (these included left main complicated lesions 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 will profit from avoiding CPB. Feasibility of the procedure was determined by the size (diameter, ≥ 1.5 mm) and accessibility of the vessel and the number of the coronary vessels to be bypassed. When there was greater potential benefit from avoiding CPB, a lesser degree of feasibility was accepted.

Surgical technique. General anesthesia was induced with midazolam (Dormicum; Hoffmann-LaRoche Ltd, Basel, Switzerland) and moderate dose (20-30 $\mu\text{g/kg}$) fentanyl (Bearyl; Abic, Netanya, Israel). Anesthesia was maintained with inhalational agents (halothane or isoflurane) and fentanyl (100 $\mu\text{g/h}$). Body hypothermia was avoided by adjusting room temperature, placing the patient on a warming mattress, and infusing warm solutions. The major hemodynamic consideration was to maintain systemic blood pressure above 100 mm Hg to maintain adequate coronary perfusion. Neither β -blockers or calcium channel blockers were used to slow the heart rate. Heparin was administered in a dose of 2 to 3 mg/kg weight before the internal thoracic artery and/or the saphenous veins were harvested to keep activated clotting time greater than 400 seconds. After heparinization, all the blood was collected with a pump suction to a cardiomy reservoir and immediately returned to the patient through a central venous line. Heparin was reversed with protamine at the end of the procedure.

The operation was usually performed through a midline sternotomy. To facilitate exposure of the circumflex coronary territory, 3 patients underwent operation through a left thoracotomy, and 1 patient underwent reoperation through a midline sternotomy with extension of the incision to the fifth left intercostal space. In the former approach, proximal anastomosis of vein grafts was performed on the descending aorta, whereas in the latter it was performed on the ascending aorta. Exposure of the marginal branches of the circumflex coronary system was achieved by gentle, gradual rotation of the heart.

Hemodynamic instability, which primarily occurred during exposure of the marginal branches of the circumflex coronary artery, was managed by rapid fluid administration, use of dobutamine or epinephrine, infusion of glucose-insulin-potassium solution, prior grafting of the internal thoracic artery to the left anterior descending coronary artery whenever necessary, or most effectively, intraoperative insertion of

an IABP for the duration of distal anastomosis construction. This was done either through the groin or, preferably, through the ascending aorta. For this purpose, in 4 patients the IABP was inserted intraoperatively after midline sternotomy and removed before sternal closure. Exposure and fixation of the anastomotic site were achieved with numerous superficial (4-0 silk) sutures. Deep sutures (3-0 Ti-Cron polyester fiber; Davis & Geck, Danbury, Conn) were used to retract the right coronary artery. A hemostatic tourniquet (5-0 polytetrafluoroethylene [PTFE*] or Prolene [Ethicon, Inc, Somerville, NJ]) and spurts of air were used to obtain a bloodless anastomotic field. The hemostatic sutures were tightened just after arteriotomy to shorten the regional ischemic time. Distal anastomosis was performed with 7-0 or 8-0 Prolene continuous suture, and proximal anastomosis was performed with 5-0 Prolene suture, with a partial occluding clamp. In cases of a calcified aorta, every effort was made to use pedicled in situ arterial grafts. In some patients, however, it was possible to palpate a skip area on the ascending aorta that could serve as a site for 1 proximal vein graft anastomosis, on the cupula of which other proximal anastomoses were constructed. To better detect skip areas, blood pressure was temporarily reduced by partial inflow occlusion with a cotton tape snare around the inferior vena cava.

Statistical analysis. Late follow-up was achieved by telephone questionnaire. Postoperative survival is expressed by the Kaplan-Meier method, and survival curves were compared by the log-rank test. The χ^2 test was used to compare discrete (categorical) variables, and the t test was used to compare continuous variables. Data are expressed as mean $\pm$ SD. To predict death and unfavorable outcome events by various risk factors, logistic regression analysis was used. Hazard ratio (HR) and 95% confidence interval (CI) were evaluated. Because one of the aims was to evaluate the association between each risk factor and survival time (controlling for other risk factors), Cox's proportional hazard model was used. All analyses were performed by SAS software (SAS PC, Version 6; SAS Institute, Cary, NC).

Results

The mean number of grafts per patient was 1.8. Only 12% of the patients received a graft to a marginal branch of the circumflex artery. Approximately 35% (20 patients) received incomplete revascularization as a result of our not grafting the circumflex marginal branches (these patients had either very large hearts, which did not permit adequate rotation for exposure of the circumflex marginals, or they had marginal branches, less than 1.5 mm in diameter). Thus in spite of the fact that we had only 8 patients (15%) with single-vessel disease, 22 patients (39%) received a single graft. The remaining 14 patients had incomplete revascularization. Another reason for the relatively low per-

*W.L. Gore & Associates, Inc, Flagstaff, Ariz.

centage of circumflex marginal graftings stems from the fact that during the study period 10 patients in whom a graft to the distal circumflex system was essential were preselected to undergo operation with CPB. Ischemic time for grafting either the left anterior descending artery coronary system or the right coronary artery system was 9 ± 4 minutes (mean $\pm$ SD), and for the marginal branches of the circumflex system it was 14 ± 5 minutes (mean $\pm$ SD; Table II).

One patient (1.7%) died perioperatively (during hospitalization or within 30 days of operation). There were no strokes, sternal infections, or fatal AMIs in this series.

Hospital stay was 7 ± 2 days (mean $\pm$ SD), and the median stay was 6 days.

Late follow-up (1-69 months after the operation; mean, 46 ± 9 months) was achieved in 54 of the 56 hospital survivors (96%). During this period, 8 patients (14%) died, and 5 deaths (9%) were cardiac related. One patient (1.7%) had a nonfatal MI as the result of incomplete revascularization; in 7 patients (12%), angina returned. Only 4 of the 7 patients with early return of angina underwent postoperative coronary recatheterization because the conditions of the other 3 patients were well controlled medically, and they were not referred for this procedure. In 2 of those 4 patients, the grafts were completely occluded; in 2 patients, all grafts were patent, and postoperative PTCA was performed in the native coronary arteries. One of the 4 patients who underwent catheterization later underwent reoperation.

Two patients (4%) were found to have new symptoms of congestive heart failure as the result of a perioperative or late postoperative MI, and 1 of them eventually died. Of 54 hospital survivors who were available for follow-up, 43 patients (79%) had an uneventful outcome and are currently feeling well.

Analysis of mortality and morbidity. Univariate analysis (Table I) and Cox regression analysis of overall (early and late) mortality events revealed several risk factors to be associated with decreased survival. Preoperative cardiogenic shock had an HR of 20.1 (95% CI, 2.2-201). Chronic renal failure had an HR of 56.2 (95% CI, 2.3-136.7). Of all risk factors (Table III), the independent risk factors for overall unfavorable outcome events were old MI (HR, 6.2; 95% CI, 1.4-25.7) and operation within the first 48 hours of an evolving MI (HR, 6.2; 95% CI, 1.4-28.8).

Kaplan-Meier analysis of the entire cohort showed 1- and 5-year actuarial survival of $95\% \pm 4\%$ and $82\% \pm 6\%$, respectively (Fig 1). Five-year actuarial survival of patients who underwent operation during the first 48 hours of an evolving MI was only $77\% \pm 9\%$ compared

Table II. Operative data

	CABG within 48 hr of AMI* (%)	CABG between 2-7 d after AMI† (%)	Total‡ (%)
No. of grafts			
1	9 (28)	12 (48)	21 (36)
2	17 (53)	9 (36)	26 (46)
3	5 (15)	4 (16)	9 (15)
4	1 (3)	0 (0)	1 (2)
Mean $\pm$ SD	2.0 ± 0.8	1.6 ± 0.7	1.8 ± 0.8
Use of ITA	24 (75)	23 (92)	47 (82)
Circumflex marginal graft	3 (9)	4 (16)	7 (12)
Anastomosis time (min)			
LAD or RCA	8 ± 4	9 ± 4	8 ± 4
Circumflex marginal graft	11 ± 2	16 ± 4	14 ± 5
Reoperative CABG	0 (0)	1 (4)	1 (2)

ITA, Internal thoracic artery; LAD, left anterior descending artery; RCA, right coronary artery.

*n = 32.

†n = 25.

‡n = 77.

with $91\% \pm 5\%$ in those who underwent operation between 2 and 7 days after AMI. However, the difference in late survival did not reach statistical significance (Fig 2).

Discussion

The early mortality rates in 57 patients who underwent operation in this series during the first week after AMI was 1.7%. Only 1 of 32 patients (3.1%) who underwent operation during the first 48 hours of an evolving MI died. Moreover, all 8 patients in this study with cardiogenic shock and all 13 patients who underwent operation after failed PTCA survived.

Several large series of CABG without CPB (beating heart surgery) were reported during the 1980s and the beginning of the 1990s.⁶⁻⁹ Gundry and associates¹⁰ recently reported that 7-year survival and cardiac death rates were similar for patients who underwent CABG with and without CPB. However, twice as many patients in the beating heart group required recatheterization and reintervention as the result of an inferior graft patency rate that may be related to snare injury in patients who underwent operation without CPB. Widespread use of the beating heart technique followed the advent of minimally invasive surgery and the introduction of the various new retractors and stabilizers,^{11,12} which may enhance future patency rates of beating heart operations. Although the adverse effects of CPB are minor and reversible in most patients, these effects may be of major importance, irreversible, and even fatal in high-risk patients.¹³ It is therefore reason-

Table III. Total unfavorable events ($n = 57$)

Factor	Prevalence		Unfavorable event with factor		Unfavorable event without factor		P value
	<i>n</i>	% of <i>n</i>	<i>n</i>	% of <i>n</i>	<i>n</i>	% of <i>n</i>	
Age ≥ 70 yr	12	21	4	33	11	24	.534
Female gender	16	28	4	25	11	27	.888
Left main stenosis	5	9	1	20	14	27	.737
Unstable angina	51	91	13	26	2	33	.787
AMI < 48 h	32	56	12	38	3	12	.03
Old MI	31	56	13	42	2	8	.001
Complicated PTCA	13	23	3	23	12	27	.763
EF $\leq 35\%$	19	33	6	32	9	24	.523
Congestive heart failure	23	42	6	26	9	28	.867
Cardiogenic shock	8	14	4	50	11	22	.101
IABP	14	43	6	42	9	21	.161
Diabetes mellitus	10	18	2	20	13	28	.617
Hypertension	21	37	3	14	12	33	.115
Stroke	1	2	—	—	—	—	—
PVD	4	7	1	25	14	26	.951
Calcified aorta	4	7	1	15	14	26	.951
Chronic renal failure	2	4	2	100	13	24	.06
Severe COPD	3	5	0	0	15	28	.288
Emergency surgery	35	62	12	34	3	17	.085
Nonused ITA	11	20	5	46	10	22	.109
Single graft	22	39	4	18	11	31	.269
Circumflex marginal graft	7	12	2	29	13	20	.885

EF, Ejection fraction; PVD, peripheral vascular disease; COPD, chronic obstructive pulmonary disease; ITA, internal thoracic artery.

able to assume that avoiding CPB may be advantageous for certain subgroups of patients, especially those with risk conditions for conventional CABG. A major technical limitation of the use of the beating heart technique involves revascularization of the circumflex marginal. In those patients with marginal diameters greater than 1.5 mm and relatively small hearts, we can rotate the heart and perform the anastomosis. When the heart is larger than normal, it is easier to rotate the heart after the insertion of an IABP into the aorta. In spite of our belief that this is a safe procedure, for most of our patients who have significant disease of the circumflex, we do prefer using CPB. Having said that, because of the risk associated with the use of CPB in certain patients, we sometimes do incomplete revascularization and do not perform circumflex anastomosis to avoid the use of the pump. In our previous report, we showed that avoiding the use of CPB may minimize the impact of several conventional risk factors on operative mortality rates.¹⁴ In our opinion, an important indication for CABG without CPB is an AMI. Early reports suggested that emergency CABG for an AMI was associated with a high operative mortality rate, ranging from 9% to as high as 60%.¹⁵⁻¹⁹ More recently, with improved anesthetic and surgical

techniques, supportive pharmacologic therapy, and myocardial preservation, the perioperative mortality rate associated with emergency CABG in selected patients with AMI has fallen markedly.²⁰

CABG performed within the first few hours of an AMI can be safe and have good results. Several articles²⁰⁻²² advocating surgical revascularization within 6 hours of AMI have shown improved hospital mortality rates (3.8% vs 8%) and improved 10-year mortality rates (8.2% vs 21%) in patients who underwent operation within 6 hours, as compared with those patients whose operation was delayed longer than 6 hours after an AMI.²¹⁻²⁴ Conversely, medically treated patients had a 16% hospital mortality rate and an additional 14% mortality rate at 1 year.²⁰

With the advent and widespread use of intravenous thrombolytic therapy or balloon angioplasty in patients with an evolving AMI, enthusiasm for emergency CABG in this setting has diminished. However, there continue to be several situations that require emergency or urgent surgical revascularization. For example, failure of thrombolytic agents and PTCA with acute occlusion may require surgical intervention. Additionally, early CABG for postinfarction angina has become common practice in the treatment of AMI.

Fig 1. Survival curve (Kaplan-Meier) of the entire group.

Fig 2. Survival curves by timing of revascularization.

The optimal timing of operation after AMI remains undecided. Nunley and associates²³ found significant differences in outcome that depended on the time interval from AMI to operation; the mortality rate of patients who underwent operation within the first 48 hours of an AMI was 7.7% compared with 0% after the first 48 hours. Creswell and colleagues²⁵ suggested that the optimal timing is at least 2 weeks after AMI. In their study, mortality rates of patients who underwent operation within this 2 weeks was 6.5% compared with 2.9% in patients who underwent operation between 2 and 6 weeks after the AMI. In a recently published study of 1299 patients who underwent operation after an AMI in 19 Seattle-area hospitals, there was no difference in hospital mortality rates of patients who underwent operation during the first 24 hours after admission compared with those who underwent operation later during their hospital course (8.3% vs 7.2%; $P = .60$).²⁶

Today, most patients are referred to the cardiac surgeon well after 6 hours have passed because they had an AMI. The reported overall mortality rates in these patients has varied: 3.4%,²⁷ 5%,²⁴ 7.2%,²⁶ 8.4%,²⁸ and 16%.²⁹ It is generally thought that the outcome in these patients may depend on factors such as the timing of the operation, left ventricular function, the presence of collaterals, and hemodynamic instability. In light of the better results obtained in the present study with the beating heart technique, the revascularization method appears to have contributed to improve the surgical outcome.

Our study showed that timing, in and of itself, is not a significant predictor of early or late mortality rates of CABG without CPB after AMI.

All patients who had an AMI in this report underwent

operation after the first 6 golden hours of an evolving MI, and these results are comparable with those of De Wood and colleagues,²¹ which had been achieved within the first 6 hours (3.8%) and may be better than those achieved with CPB in patients who underwent operation after the first 6 hours.²⁴⁻²⁶

Our mean follow-up period for this study was 4 years, a relatively long time for patients who had undergone CABG without CPB,¹⁰ and included most (96%) of the patients. The good results of CABG without CPB in the patients with cardiogenic shock or IABP compared favorably with results of patients with cardiogenic shock who underwent operation by Sergeant and colleagues³⁰ within the first 6 hours of an AMI. However, the late results of this subgroup in our study were not as good. Three of the 8 patients (37%) with cardiogenic shock died between 1 and 5 years after the operation, and cardiogenic shock before the operation was found to be an important risk factor for overall mortality rates.

Timing of CABG after an AMI was found in our study to be related to postoperative unfavorable events; operations conducted within the first 48 hours were associated with an increased risk of such occurrences.

The term *unfavorable events* describes the sum of deaths, return of angina, reintervention, postoperative AMI, and appearance of new symptoms of congestive heart failure. The number of patients in each group was relatively small, which explains why the sum of unfavorable events appears to be a more sensitive indicator of poorer outcome than postoperative deaths. The poorer outcome of patients who underwent operation in the first 48 hours is probably related to surgical urgency. However, on the basis of the results reported earlier in

this article, it may be prudent to postpone CABG without CPB to beyond the first 48 hours whenever clinically possible.

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