Predictors and Outcomes of Coronary Artery Bypass Grafting in ST Elevation Myocardial Infarction

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Background. **Treatment of ST-elevation myocardial infarction has undergone great evolution since introduction of percutaneous coronary intervention (PCI). The purpose was therefore to assess the outcome of patients with ST-elevation myocardial infarction undergoing surgical revascularization with coronary artery bypass grafting (CABG).**

Methods. **A total of 138 consecutive patients with ST-elevation myocardial infarction underwent CABG therapy between January 2000 and January 2007 at our institution. Prospectively recorded preoperative, intraoperative, and postoperative data were retrospectively screened for in-hospital mortality and major adverse cardiac events (MACE).**

Results. **The delay between the onset of ST-elevation myocardial infarction symptoms and CABG procedures was within 6 hours in 37 patients, 7 to 24 hours in 21, 1 to 3 days in 15, 4 to 7 days in 24, and 8 to 14 days in 41 patients. Cardiogenic shock (Killip class ≥III) was present in 38 patients (28%), and 37 patients (27%) were referred for CABG after failed PCI. Overall in-hospital mortality was 8.7%, but mortality varied between 10.8% (≤6 hours), 23.8% (7 to 24 hours), 6.7% (1 to 3 days), 4.2% (4 to 7 days), and 2.4% (8 to 14 days), depending on time interval from symptom onset to operation. Overall, more nonsurvivors were women (58% versus 23%; $p < 0.01$), had higher preoperative cardiac troponin I levels (13.2 ± 9.8 versus 4.5 ± 4.2 ng/ml; $p < 0.0001$), and were more frequently in cardiogenic shock (83% versus 22%; $p < 0.0001$). Unadjusted univariable and risk-adjusted multivariable logistic regression analysis revealed age, female sex, preoperative cardiac troponin I levels, and cardiogenic shock to be the most potent predictors of in-hospital death and MACE.**

Conclusions. **CABG in ST-elevation myocardial infarction can be performed with acceptable risk by incorporating adequate management strategies. However, female sex, preoperative cardiac troponin I level, preoperative cardiogenic shock, and time to operation are major variables of mortality and morbidity results.**

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Acute coronary syndromes (ACS), ranging from unstable angina and acute myocardial infarction (AMI) without ST-segment elevation up to evolving acute myocardial infarction (AMI) with persistent ST-segment elevation, offer a challenge from the standpoint of diagnosis, treatment, and prognosis, because the clinical manifestations vary considerably. The prognosis of patients who reach a medical facility with ST-elevation myocardial infarction (STEMI) has clearly improved in the last decade, primarily owing to improvements in initial reperfusion therapy, including fibrinolysis and primary percutaneous coronary intervention (PCI) [1].

To date, coronary artery bypass grafting (CABG) for primary reperfusion therapy in patients with STEMI has largely been superseded since the introduction of primary PCI. Nonetheless, the indication for a surgical-based revascularization strategy in patients with STEMI has remained an important treatment option based on a combination of the obstructive coronary artery lesion with ongoing ischemia/infarction being not responsive to nonsurgical therapy, progressive left ventricular pump failure, or coronary stenosis compromising viable myocardium outside the initial infarct area, or as an indication after failed PCI. All of these are considered high-risk criteria according to the American College of Cardiology (ACC)/American Heart Association (AHA) guidelines [2].

Although there are a plethora of data on the clinical outcome of CABG procedures in patients with AMI in general [3–6], there are just few contemporary data in terms of prognostic factors and clinical outcome, particularly among patients referred to CABG due to ACS presenting with STEMI [7, 8]. The purpose of the present study was therefore to evaluate predictors of in-hospital morbidity and mortality and clinical outcomes in patients with STEMI who underwent surgical revascularization therapy with CABG unresponsive to maximal nonsurgical therapy.

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Patients and Methods

Patients and Study Design

From January 2000 to January 2007, 5067 consecutive patients who underwent primary isolated CABG at the West-German Heart Center Essen were studied. Of these, 623 patients had ACS, and STEMI was preoperatively identified in 138. A STEMI was assumed if patients had symptoms indicative of an ACS within the preceding 14 days with (1) new onset of chest pain or accelerating chest pain occurring at rest or with minimal exertion, alleviated by nitroglycerine or rest or both, (2) persistent ST-segment elevations of 1 mm or more on electrocardiogram (ECG), and (3) elevated serum concentrations of cardiac troponin I (cTnI) or creatine kinase (CK) in the preoperative course during hospitalization.

Patients were classified into groups according to the time interval between symptom onset and operation (≤6 hours, 7 to 23 hours, 1 to 3 days, 4 to 7 days, and 8 to 14 days). In addition, we used the Killip classification on admission to assess the severity of patient's hemodynamic condition [9]. Cardiogenic shock was assumed to be present with Killip class III or higher, which was prespecified as patients having pulmonary edema or a cardiac index of 2.0 L/(min · m^2) or less, or a systolic arterial pressure of 90 mm Hg or less, despite high-dose inotropic support (intravenous dopamine ≥ 8 μg/[kg min], dobutamine ≥ 6 μg/[kg · min], epinephrine > 0.1 μg/[kg min], or norepinephrine > 0.1 μg/[kg · min]).

Informed consent was obtained from all patients. In case of patient's unresponsiveness on admission, informed consent was obtained from the patient's relatives or during the postoperative course. The study was approved by the Institutional Review Board of the West-German Heart Center Essen. Patients were excluded from the study if any of the following criteria were present: (1) preoperative myocardial infarction without ST-segment elevations on the ECG, (2) new-onset left bundle branch block, (3) reoperations, (4) any concomi-

Table 1. Baseline Characteristics According to Survival Status

Demographics[a]	Survivors (n = 126)	Nonsurvivors (n = 12)	OR (95% CI)	*p* Value
Age, years	65 ± 11	72 ± 5	—	0.02
Gender, female	29 (23)	7 (58)	4.7 (1.2–18.7)	0.01
Weight, kg	79 ± 10	77 ± 9		0.35
Cardiovascular risk factors				
Diabetes mellitus	37 (29)	4 (33)	1.2 (0.3–4.8)	0.75
Hypertension	103 (82)	10 (83)	1.1 (0.2–7.9)	1.00
Hyperlipidemia	102 (81)	11 (92)	2.6 (0.3–57.0)	0.69
Obesity[b]	40 (32)	2 (17)	0.4 (0.1–2.2)	0.35
Smoking history	64 (51)	4 (33)	0.5 (0.1–1.9)	0.37
Comorbidities				
COPD	30 (24)	4 (33)	1.6 (0.4–6.5)	0.49
PVD	18 (14)	3 (25)	2.0 (0.4–9.3)	0.39
Renal disease[c]	20 (16)	5 (42)	3.8 (0.9–15.2)	0.04
Dialysis	2 (2)	0 (0)	0.2 (0.0–33.8)	1.00
Cardiac history				
Previous MI[d]	26 (21)	4 (33)	1.9 (0.4–7.8)	0.29
Previous PCI	45 (36)	8 (67)	3.6 (0.9–15.2)	0.06
Failed PCI	29 (23)	6 (50)	3.3 (0.9–12.9)	0.07
Previous CPR	8 (6)	3 (25)	3.3 (0.9–12.9)	0.07
Extent of CAD				
Left-main-stem disease	44 (35)	7 (58)	2.6 (0.7–10.2)	0.13
Three-vessel disease	98 (78)	10 (83)	1.4 (0.3–10.0)	1.00
Preoperative status				
LVEF	0.50 ± 0.13	0.45 ± 0.16	—	0.17
Killip class ≥III	28 (22)	10 (83)	17.5 (3.3–123.5)	<0.0001
Pre-op IABP	29 (23)	4 (33)	1.7 (0.4–6.8)	0.48
Pre-op serum marker				
cTnl, ng/mL	4.5 ± 4.2	13.2 ± 9.8	—	<0.0001
CK, U/L	121 ± 202	523 ± 314	—	0.002

[a] Continuous data are presented as mean ± standard deviation; categoric data as number (%). [b] Body mass index >30 kg/m^2. [c] Serum creatinine >0.2 μmol/L. [d] >14 days.

CAD = coronary artery disease; CI = confidence interval; CK = creatine kinase; COPD = chronic obstructive pulmonary disease; cTnI = cardiac troponin I; LVEF = left ventricular ejection fraction; MI = myocardial infarction; OR = odds ratio; PCI = percutaneous coronary intervention; PVD = peripheral vascular disease.

Table 2. Infarct-Related Coronary Artery Vessel

	Survivors, n (%) (n = 126)	Nonsurvivors, n (%) (n = 12)	OR (95% CI)	*p* Value
LAD + LCX (LM)	17 (13)	3 (25)	2.1 (0.4–10.0)	0.38
LAD	48 (38)	3 (25)	0.5 (0.1–2.3)	0.53
LCX	52 (41)	2 (17)	0.3 (0.04–1.5)	0.13
RCA	9 (7)	4 (33)	6.5 (1.3–31.1)	0.02

CI = confidence interval; LM = left main; LAD = left anterior descending; LCX = left circumflex; OR = odds ratio; RCA = right coronary artery.

tant heart operation in addition to CABG, or (5) any mechanical AMI complications.

Data Collection

The patient cohort used for this study was drawn from the West-German Heart Center cardiovascular database. This database prospectively collects a comprehensive list of prespecified data points, with more than 1800 data items per patient [10], in all of the consecutive patients undergoing CABG at our institution, including demographic, clinical, and outcome data.

Outcome Measures

All study end points used in this analysis were prespecified. The primary study end point was all-cause in-hospital mortality, which was defined as death after CABG during the index hospitalization. The secondary end point was in-hospital major adverse cardiac event (MACE) rate, including (1) low cardiac output syndrome (LCOS) with high-dose inotropic support, (2) cardiopulmonary resuscitation, or (3) new-onset ventricular arrhythmia.

Preoperative Management

Patients presenting with STEMI were treated preoperatively with (1) hemodynamic monitoring, (2) adjunctive pharmacologic therapeutic measures, using β-blockers, morphine, nitrates, and inotropic drugs when necessary, low-molecular-weight or intravenous heparin, or adenosine diphosphate-receptor antagonists, such as ticlopidine and clopidogrel, resulting in inhibition of platelet aggregation; (3) optimal timing of the operation depending on the preoperative dynamics of AMI injury, and (4) evaluation of the preoperative prophylactic use of intraaortic balloon pump (IABP), especially in high-risk patients with any or all of *(a)* impaired left ventricular function, *(b)* preoperative hemodynamic instability with necessity of inotropic support, *(c)* unstable angina despite intravenous nitroglycerin and heparin, *(d)* filiform left main-stem disease or left main equivalent or severe three-vessel disease. A venoarterial heparin-bond extracorporeal membrane oxygenation (ECMO) system was applied in patients who were refractory to inotropic drugs and IABP due to severely impaired myocardial function.

Surgical Management

Surgical revascularization was performed in all patients using median sternotomy, standard cardiopulmonary bypass (CPB) technique with ascending aortic and two-stage venous cannulation, mild hypothermia (>32°C) and cold crystalloid cardioplegic (Bretschneider) arrest. Heparin was administered to achieve an activated coagulation time exceeding 400 seconds. A maximum of myocardial protection was achieved by simultaneous administration of antegrade and retrograde cardioplegia, additional topical cooling, and additional administration of cardioplegia through each distal anastomosis. Internal thoracic artery, radial artery, and saphenous vein grafts, were used as graft conduits. Bypass graft flow was assessed of each graft by Doppler transit time flowmetry.

Protamine was administered to reverse heparin according to standard practice. Aprotinin was given before and during the operation. A dose of 500 mg aspirin was routinely administered within the first 6 hour after operation, followed by a daily dose of 100 mg. IABP support was liberally applied according to the morphology of coronary arteries, necessity of inotropic support, or hemodynamic difficulties during CPB weaning time or in the early postoperative course.

Postoperative Management

Postoperative management for high-risk CABG patients was standardized. Patients were monitored with respect to arterial pressure, pulmonary pressure, and central venous pressure. A 12-lead ECG as well as the serum

Table 3. Intraoperative Characteristics According to Survival Status

Characteristic[a]	Survivors (n = 126)	Nonsurvivors (n = 12)	OR (95% CI)	*p* Value
ACC time, min	67 ± 20	71 ± 32	—	0.32
CPB time, min	111 ± 36	136 ± 43	—	0.03
Lowest temperature, C°	31.5 ± 0.5	31.8 ± 0.6	—	0.68
Reperfusion time, min	36 ± 15	68 ± 33	—	<0.0001
Grafts per patient, n	3.1 ± 0.9	3.1 ± 1.0	—	0.88
Bypass graft flow, mL/min	64 ± 33	66 ± 35	—	0.54
IMA grafts, n	113 (90)	8 (67)	4.5 (1.0–21.0)	0.04

[a] Continuous data are data are presented as mean ± SD; categoric data as number (%).

ACC = aortic cross-clamp; CI = confidence interval; CPB = cardiopulmonary bypass; IMA = internal mammary artery; OR = odds ratio.

Table 4. Postoperative Characteristics and Adverse Events According to Survival Status

Characteristic[a]	Survivors (n = 126)	Nonsurvivors (n = 12)	OR (95% CI)	*p* Value
Post-op data				
Ventilation time, h	18 (7–49)	25 (4–122)	—	0.001
IABP support	54 (49)	11 (92)	11.6 (1.5–252)	0.005
ECMO support	1 (1)	2 (17)	22 (1.4–672)	0.03
ICU stay, d	5 (4–11)	7 (5–15)	—	0.007
Hospital stay, d	10 (8–23)	7 (5–15)	—	0.001
Adverse events, post-op complications				
LCOS	42 (33)	9 (75)	6.0 (1.4–29.7)	<0.01
CPR	4 (3)	3 (25)	10.2 (1.5–67.7)	<0.01
Sustained arrhythmia	43 (34)	7 (58)	2.7 (0.7–10.5)	0.12
Major bleeding	16 (13)	2 (17)	1.4 (0.2–7.7)	0.66
Rethoracotomy	14 (11)	3 (25)	2.7 (0.5–12.8)	0.17
Renal failure (dialysis)	48 (38)	11 (92)	17.9 (2.3–387)	<0.0004

[a] Data are presented as mean ± SD, median (25%–75% interquartile range), or number (%).

CPR = cardiopulmonary resuscitation; ECMO = extracorporeal membrane oxygenation; IABP = intra-aortic balloon-pump; ICU = intensive care unit; LCOS = low cardiac output syndrome.

biomarkers for myocardial damage, such as cTnI, and CK, were determined immediately after arrival on the intensive care unit, at 6, 12, and 24 hours postoperatively, and once daily thereafter. A does of 500 mg of aspirin was administered intravenously within the first 6 hours after operation in the absence of significant bleeding.

Statistical Analysis

Continuous data are reported as mean ± standard deviation and categoric variables by numbers and percentages. The odds ratios (OR) and 95% confidence intervals (CI) were calculated for all categoric variables. Comparisons of categoric variables between the groups were performed by exact the Pearson χ^2 test or Cochran-Armitage trend test [11], and comparisons of continuous variables between groups were analyzed by unpaired the Student *t* test. Univariable and multivariable logistic regression analyses were performed to identify preoperative independent predictors for in-hospital mortality and MACE. All preoperative predictor variables that were identified as significant at a two-tailed nominal value of $p < 0.10$ in univariable regression analyses were then entered into a multivariable logistic regression analysis model. A value of $p < 0.05$ was considered to indicate statistical significance. All statistical analyses were performed using StatXact 6.0 software (Cytel Software Corp, Cambridge, MA) and SAS 8.0 software (SAS Institute Inc, Cary, NC).

Results

The study population consisted of 138 of 5067 patients who fulfilled the inclusion criteria and were scheduled for isolated first-time CABG. As a result, 37, 21, 15, 24, and 41 patients with STEMI underwent CABG within 6 hours, 7 to 24 hours, 1 to 3 days, 4 to 7 days, and 8 to 14 days from onset of symptoms to operation, respectively. Among all STEMI patients, the preoperative characteristics categorized by in-hospital survivors versus nonsurvivors are summarized in Table 1.

Baseline Characteristics

Preoperative baseline characteristics, such as demographics, risk factors, and comorbidities of the entire study cohort, were comparable with the contemporary coronary surgical patient profile. A preoperative significant difference between survivors and nonsurvivors was observed in terms of age and gender. Nonsurvivors had renal disease more often in the preoperative course. According to cardiac history and the preoperative status

Table 5. Causes of Death

	Time to Coronary Artery Bypass Grafting				
Patient	≤6 hours	7–23 hours	1–3 days	4–7 days	8–14 days
1	LCOS	LCOS	LCOS, bleeding	LCOS	LCOS, PMI
2	LCOS, VF	LCOS	—	—	—
3	Sepsis, MOF	LCOS, bleeding	—	—	—
4	Intestinal ischemia	LV free-wall rupture	—	—	—
5	—	LCOS	—	—	—

LCOS = low cardiac output syndrome; MOF = multiorgan failure; PMI = perioperative myocardial infarction; VF = ventricular fibrillation.

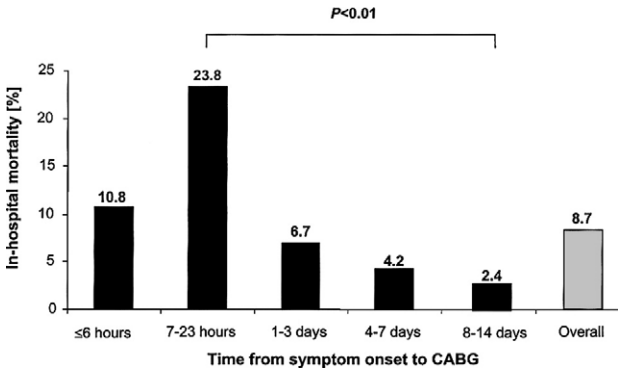

Fig 1. In-hospital mortality rates with respect to the time interval from symptom onset to coronary artery bypass grafting (CABG; black columns) and overall in-hospital mortality (gray column). A value of $p < 0.01$ (calculated by Cochran-Armitage trend test) is overall significance between a time interval of 7 to 24 hours and 8 to 14 days after symptom onset to CABG.

of the patients, nonsurvivors had more previous and failed PCIs as well as more previous cardiopulmonary resuscitation (CPR) before operation. Nonsurvivors were preoperatively found to be more frequently in cardiogenic shock, which was prespecified as Killip class III and IV [9]. The extent of preoperative myocardial injury, as measured by cTnI and CK serum levels, was significantly higher in nonsurvivors compared with the survivors (Table 1). When the distribution of the infarct-related coronary artery vessels (or culprit lesion) was compared, nonsurvivors had more frequently a right coronary artery (RCA)-related MI than survivors (Table 2).

Intraoperative Data

As summarized in Table 3 the intraoperative data were found to be significantly different according to the CPB time and reperfusion time. In addition, arterial revascularization with internal mammary grafts was applied significantly more often in survivors than in nonsurvivors.

Postoperative Outcome Data

As summarized in Table 4, most postoperative outcome measures, including ventilation time, prevalence of IABP and ECMO support, and duration of intensive care and hospital stay, were significantly different between survivors and nonsurvivors. In terms of perioperative adverse events, LCOS, CPR, as well as the incidence of postoperative renal failure was strongly associated with nonsurvival.

Therapy-refractory LCOS and cardiogenic shock resulted in 9 patient deaths in the early postoperative course. One patient had therapy-refractory ventricular fibrillation and another 2 patients died 24 and 36 hours postoperatively from progressive right heart failure and LCOS having been operated on after right coronary artery RCA-related STEMI 10 and 14 hours after symptom onset and subsequent unsuccessful PCI. Another 2 patients died in the early postoperative period from preoperative existing LCOS caused by acute stent thrombosis and unsuccessful multi-

Table 6. Logistic Regression Analysis Identifying Preoperative Predictors for In-Hospital Death and Major Adverse Cardiac Events

	In-Hospital Death[a]				MACE			
	Univariable Factors		Multivariable Factors		Univariable Factors		Multivariable Factors	
	OR (95% CI)	*p* Value	OR (95% CI)	*p* Value	OR (95% CI)	*p* Value	OR (95% CI)	*p* Value
Age, years	1.1 (0.99–1.2)	0.09	1.1 (0.9–1.5)	0.08	1.1 (1.0–1.2)	0.10	1.1 (1.0–1.3)	0.06
Gender, female	8.7 (2.0–37.9)	<0.01	8.6 (1.2–63.2)	0.03	3.4 (1.1–10.2)	0.03	4.1 (0.8–21.1)	0.14
LVEF, %	1.0 (0.9–1.1)	0.97	—	—	1.0 (0.9–1.0)	0.19	—	—
Previous MI	1.0 (0.7–2.9)	0.85	—	—	1.0 (0.7–2.9)	0.85	—	—
Previous PCI	0.3 (0.1–1.8)	0.20	—	—	0.7 (0.2–2.2)	0.58	—	—
Previous CPR	2.4 (0.4–13.9)	0.33	—	—	2.8 (0.7–11.6)	0.16	—	—
IABP, pre-op	0.9 (0.2–4.9)	0.93	—	—	2.6 (0.7–7.5)	0.19	—	—
Failed PCI	1.4 (0.4–5.5)	0.63	—	—	1.0 (0.3–3.1)	1.00	—	—
Killip class ≥III	6.8 (1.3–34.7)	0.02	6.1 (0.3–79.0)	0.22	3.1 (1.0–9.1)	0.04	1.3 (0.4–6.7)	0.72
cTnI, ng/mL	1.2 (1.1–1.3)	<0.01	1.2 (1.05–1.5)	0.01	1.3 (1.1–1.5)	<0.001	1.2 (1.1–1.7)	0.01
RCA-related MI	3.8 (1.1–24.7)	0.04	4.1 (0.6–38.2)	0.21	1.5 (0.6–3.9)	0.54	—	—
CABG interval after symptom onset								
≤6 hours[b]	0.7 (0.3–0.9)	0.03	0.8 (0.2–1.1)	0.21	0.7 (0.3–1.9)	0.44	—	—
7–23 hours[c]	3.2 (2.2–19.3)	<0.01	3.4 (1.7–21.3)	0.03	4.6 (1.1–70.3)	0.03	4.4 (0.9–62.3)	0.51
1–3 days[b]	0.9 (0.4–1.4)	0.45	—	—	0.9 (0.8–2.2)	0.52	—	—
4–7 days[b]	0.6 (0.3–0.9)	0.03	0.5 (0.3–0.8)	<0.01	1.4 (0.3–6.1)	0.68	—	—

[a] All cause of death. [b] Compared with CABG 7–23 hours after symptom onset. [c] Compared with CABG 8–14 days after symptom onset.

CABG = coronary artery bypass grating; CI = confidence interval; CPR = cardiopulmonary resuscitation; cTnI = cardiac tropinin I; IABP = intraaortic balloon pump; MACE = major adverse cardiac event; MI = myocardial infarction; OR = odds ratio; PCI = percutaneous coronary intervention; RCA = right coronary artery.

ple PCI procedure. One patient died after an emergency surgical procedure and subsequent emergency reexploration due to acute cardiac tamponade caused by left ventricular free-wall rupture of the infarct-related anterior wall. Another patient died from acute intestinal ischemia confirmed by emergency laparotomy. Another patient died 33 days after emergency CABG from severe therapy-refractory sepsis (Table 5).

As shown in Figure 1, a one-sided Cochran-Armitage trend test revealed a significant difference ($p < 0.01$) between those STEMI patients who underwent CABG therapy between 7 and 24 hours from symptom onset to revascularization and those who were postponed with conservative maximal nonsurgical therapy to 3 to 7 days or even 8 to 14 days after symptom onset. Four deaths (10.8%) occurred during hospitalization in patients operated on within 6 hours of symptom onset and five deaths (23.8%) in patients who underwent emergency CABG procedures between 7 and 23 hours from symptom onset to operation.

To further evaluate preoperative predictors of death and MACE for STEMI patients, a logistic regression analysis model was constructed. Unadjusted univariable factors predicting death and MACE were female sex, RCA-related infarctions, preoperative Killip class, and preoperative cTnI level. Risk-adjusted and independent multivariable factors predicting in-hospital death were female sex and preoperative cTnI level, and only preoperative cTnI level predicted in-hospital MACE (Table 6).

Comment

Our findings in the present study suggest that in a surgical population of patients undergoing CABG, the existence of preoperative STEMI is associated with significantly higher in-hospital mortality and a higher incidence of adverse events, such as LCOS. Moreover, the present study clearly demonstrated that increased mortality rates after CABG due to STEMI are significantly associated with several variables of risk, most notably, age, female sex, preoperative cardiogenic shock (Killip class ≥III), the degree of preoperative myocardial injury as determined by the level extent of cTnI, and time to CABG. The present study also suggests that surgical revascularization of patients presenting with STEMI can be safe and effective with concomitant perioperative management strategies. At our institution, the overall mortality rate for patients with STEMI undergoing CABG was 8.7% during the hospital stay. In-hospital mortality rates clearly varied, however, depending on the time interval from symptom onset to time of operation, with 10.8% for patients undergoing CABG within 6 hours after onset of symptoms, rising to 23.8% mortality within 7 to 24 hours after symptom onset, declining to 6.7% mortality after 1 to 3 days, and 4.2% after 4 to 7 days, and finally 2.4% after 8 to 14 days.

Although it has been shown that patients undergoing CABG due to AMI have a significantly higher risk of dying in the hospital, and there are many data on the outcomes of CABG with acute, evolving, ongoing, or previous MI in general [3–5], less data are available on the frequency and outcomes among the subgroup of patients referred to CABG therapy who have ACS presenting with ST-segment elevation [7–8].

The in-hospital mortality rate of the present study seems to be well comparable with the data of recent large-scale retrospective multicenter trials, where patients were found to have different trends in mortality with transmural versus nontransmural AMI undergoing emergency CABG, when the time course was taken into consideration [3]. Lee and colleagues [3] reported the mortality rates for CABG patients with transmural AMI to be significantly higher compared with CABG patients with nontransmural AMI; moreover, mortality remained high during the first 3 days before returning to baseline, as observed in the present study.

The optimal timing of CABG in patients with AMI remains a controversial subject, however. Acute surgical revascularization has been shown to limit infarct size and ventricular remodelling, thus preserving ventricular function [12]. Conversely, the risk of reperfusion injury is well known, subsequently leading to hemorrhagic infarction and resulting in extension of infarct size, poor infarct healing, and scar development [13], suggesting caution against early revascularization, particularly among patients within the first 3 days after transmural AMI. Our study suggests that early revascularization be performed within the first 6 hours after onset of symptoms, with an observed mortality of about 10%; or if possible, the STEMI patient should be stabilized hemodynamically with medical treatment in an attempt to postpone surgical revascularization at least for 3 days after symptom onset, thus trying to avoid the highest mortality rate of about 20% to 25% observed within the time interval of 7 to 24 hours after symptom onset.

A STEMI results when AMI is induced by total thrombotic occlusion of an epicardial coronary artery, typically caused by the abrupt rupture, erosion, or fissuring of an atherosclerotic plaque, which creates a potent stimulus for acute platelet aggregation and thrombus formation. The myocardium that is supplied by this infarct-related artery becomes ischemic, and cellular necrosis begins within minutes and progresses within several hours in a "wavefront" from endocardium to epicardium. After 3 to 6 hours of ischemia, the possibility of salvaging the ultimate myocardial infarct with early reperfusion dramatically decreases, depending on several factors, including the extent of collateral blood flow, oxygen demand during occlusion, size of perfusion territory of the area at risk, microvascular reflow after reperfusion, cellular ischemic preconditioning, and the duration of coronary occlusion itself [14, 15]. The exact timeframe is thus difficult to analyze.

The collateral blood supply is extremely variable, especially in patients with long-standing coronary artery disease. However, collateral flow is jeopardized with arrhythmias, hypotension, or the rise of left ventricular end-diastolic pressure [16]. Thus hemodynamic control and prevention of arrhythmias are vital during this immediate time after infarction. In accordance with the present guidelines of the ACC/AHA [2], patients with AMI require, first of all, aggressive medical treatment to stabilize and control the symptoms. Medical therapy

should be adjusted rapidly to relieve manifestations of ischemia and should include antiplatelet and antithrombotic therapy, β-blockers, nitrates, and calcium-channel blockers. The administration of glycoprotein IIb/IIIa inhibitors might be of importance, even in AMI patients in whom surgical revascularization is indicated, because a recent randomized trial demonstrated beneficial effects (freedom from cardiovascular death, MI, stroke) for administering clopidogrel early in non-STEMI patients, clearly equalizing the risk of life-threatening bleeding during subsequent CABG [17].

According to the initial diagnosis and subsequent risk stratification among patients with STEMI, the risk of death within 6 weeks is increased in those patients with elevated cTnI serum levels and it continues to increase as cTnI level increases [8, 18]. Moreover, cardiogenic shock, including Killip class III and IV, is the most common cause of in-hospital death and is one of the major variables of risk in AMI patients [19]. There is strong evidence that patients presenting with cardiogenic shock benefit most from early revascularization. In addition, the use of preoperative mechanical circulatory support may also play an important role by resting stunned myocardium, thus enabling myocardial recovery. The beneficial effect of preoperative IABP support on outcome in high-risk patients has clearly been demonstrated in several nonrandomized and randomized trials [20, 21].

In terms of using the optimal myocardial protection during CABG in AMI, the type of cardioplegia (blood versus crystalloid, warm versus cold) has been the subject of numerous, recent experimental and clinical studies but still remains controversial [22–24]. However, a beneficial effect has been demonstrated by using simultaneous antegrade and retrograde administration of cardioplegia [25, 26]. Whether surgical revascularization should be done on the beating heart [7] or even without CPB [27, 28] has only been analyzed observationally so far, slightly favoring CABG without CPB.

Adjunctive pharmacologic therapy and optimal cardiac protection during AMI is still a challenging field of cardiovascular research Many treatment options have been investigated experimentally to reduce myocardial infarct size. Intravenous β-blockers administered in the early hours of an MI were clearly shown to be of benefit [29]. Intravenous adenosine appeared promising for AMI patients and for myocardial protection during CABG, as did C1-esterase inhibitors [30, 31] and cariporide [32] in some studies; however, most results were negative or marginal in most medications that were studied. Moreover, no data are currently available on the optimal adjunctive pharmacologic therapy for STEMI patients undergoing CABG.

Although the present study was observational and retrospective in design and the generalizability of our experience at a single tertiary care medical center may not extend to all medical centers performing CABG, the present study clearly demonstrates several significant predictors of increased in-hospital morbidity and mortality rates among patients with STEMI undergoing surgical revascularization. CABG can, however, be performed safely and effectively with acceptable risk by incorporating adequate management strategies. Female sex, preoperative extent of acute myocardial damage, the preoperative Killip class, and time to operation seem to be major variables of mortality or major adverse cardiac events that should be necessarily considered.

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INVITED COMMENTARY

Significant recent advances have been made in strategies for managing ST-segment elevation myocardial infarction (STEMI); randomized controlled trials have guided the introduction of increasingly advanced reperfusion, revascularization, and secondary prevention strategies with resulting improvements in mortality.

Although the surgical management of patients with acute myocardial infarction has been clearly superseded by medical therapy, including percutaneous coronary intervention (PCI), a significant number of patients still require surgical intervention. Thielmann and colleagues [1] report meaningful data regarding predictors and outcome of coronary artery bypass grafting (CABG) in patients with STEMI. Prospective randomized trials comparing interventional and surgical revascularization in this field are limited, and the reasons for referral for surgical revascularization (ie, ongoing ischemia or infarction, failed PCI, hemodynamic compromise, and so forth), as well as the timing of the surgical intervention, may vary depending on logistic factors. This report provides one more indicator that CABG can be performed successfully in this difficult group of patients.

This article confirms that preoperative age, gender, the presence of cardiogenic shock, and the extent of myocardial injury are predictors of adverse outcome in this setting; however, in addition the authors were able to define the optimum timing of revascularization more clearly. According to this study, revascularization should be performed within 6 hours of the onset of symptoms (as for PCI), thus limiting the infarct size and subsequent ventricular remodeling; operative intervention at this time is associated with an acceptable, although not negligible mortality rate. Alternatively, to avoid the major reperfusion-injury potentially responsible for the dramatic increase of in-hospital mortality when CABG is performed within 24 hours, the patient should be medically stabilized and surgery delayed (if possible) for at least 24 hours and at best for 7 days.

The authors report the results of conventional CABG using cold crystalloid cardioplegia in patients with STEMI. Based on our own experience, on-pump beating or off-pump coronary artery bypass surgeries have the potential to further improve the results, particularly in the early phase after myocardial infarction. In the effort to limit infarct size and minimize in-hospital morbidity and mortality, the use of hybrid rooms that merge diagnostic and therapeutic efforts will offer important logistic and therapeutic advances. This approach will also certainly help to redefine the role of CABG in acute myocardial infarction and further improve the outcomes of patients with acute myocardial infarction.

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