Acute Treatment of ST-Segment-Elevation Myocardial Infarction: Is There a Role for the Cardiac Surgeon?

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Background. **Several attempts from single institutions to treat acute myocardial infarctions with bypass surgery never reached widespread acceptance in the cardiology and surgical community. Owing to a variety of new surgical techniques, this old dogma has to be reconsidered under the light of patient-adjusted optimal treatment algorithms.**

Methods. **Between August 2002 and August 2007, 112 patients, mean age of 66 years (range, 41 to 85 years), underwent emergency coronary artery bypass grafting (untreatable or rejected by the referring cardiologists within 48 hours after onset of symptoms). Thirty-seven patients (33%) exhibited cardiogenic shock, and 18 (16%) had prior cardiopulmonary resuscitation. Preoperative support by intraaortic balloon pump was initiated in only 10%, and 65% had left main stem stenosis.**

Results. **All patients showed a significant elevation of cardiac markers (creatine kinase-MB) and ST-segment elevation. The mean number of grafts was 2.4 (range, 1 to 4). The cardiopulmonary bypass time ranged from 48 to 261 minutes. Intraaortic balloon pump for weaning from extracorporeal circulation was used in 42 patients (38%); 3 patients needed extracorporeal membrane oxygenation support. Postoperative complications included rethoracotomy for bleeding in 4% and stroke in 2%. Thirty-day mortality was 20% in the whole group, 30% in the group with cardiogenic shock, and 15% in those without hemodynamic deterioration (p = 0.044). The multivariate analysis revealed the preoperative need for catecholamines as the only risk factor for 30-day mortality (odds ratio, 6.4; 95% confidence interval, 2 to 21; p = 0.002).**

Conclusions. **Emergency coronary artery bypass grafting in patients with acute myocardial infarction can be performed with acceptable results, especially in those without cardiogenic shock. Therefore, operative revascularization should not be considered only as a rescue therapy.**

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The acute coronary syndrome represents a continuum from severe, unstable angina to acute myocardial infarction. Depending on the severity of myocardial damage, a potentially life-threatening situation as a result of arrhythmias or acute heart failure may develop. In this context, it is well known that a close relationship between the duration of coronary artery occlusion and the extent of myocardial necrosis exists [1, 2]. Despite several influencing clinical factors, for example the extent of collaterals or presence of ischemic preconditioning episodes, the goal of treatment in ischemic patients is to restore timely reperfusion. Fibrinolysis, as well as primary percutaneous transluminal coronary angioplasty (PTCA), is usually favored owing to being less invasive. In fact, the term contact-to-balloon-time or door-to-balloon-time has become increasingly popular among cardiologists and has been the subject of a number of publications during the past several years [3, 4]. Daily clinical practice, however, witnesses a high proportion of patients with acute coronary syndrome presenting beyond the estimated maximal time frame of 12 hours after the onset of symptoms [5]. This has initiated a discussion concerning late myocardial salvage [6, 7]. Interestingly, surgical intervention, as a potential treatment, is not mentioned in the majority of those publications.

Indeed, acute coronary artery bypass graft surgery is usually only considered in cases of ongoing ischemia, complicated left main stem stenosis, and concomitant pathologic entities such as valve dysfunction, ventricular septum defects, ischemic mitral regurgitation, ventricular rupture, or unsuitable anatomic lesions. Early attempts at single institutions reaching back more than 25 years

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Table 1. Patient Demographics and Preoperative Data

Variable	All Patients (n = 112)	Without Shock (n = 75)	With Shock (n = 37)	*p* Value
Age (y)	66 (41–85)	67 (45–85)	66 (41–85)	0.945
Body mass index (kg/m^2)	26 (19–41)	26 (29–41)	27 (21–33)	0.371
Sex (male)	86 (77%)	57 (76%)	29 (78%)	0.972
Three-vessel disease	96 (86%)	63 (84%)	33 (89%)	0.541
Left main stem stenosis	73 (65%)	46 (61%)	27 (73%)	0.231
History of myocardial infarction	51 (46%)	33 (44%)	18 (49%)	0.678
Ejection fraction	0.36 (0.15–0.78)	0.45 (0.20–0.78)	0.30 (0.15–0.60)	<0.001
Hypertension	80 (71%)	53 (71%)	27 (73%)	0.943
Diabetes	25 (22%)	16 (21%)	9 (24%)	0.806
Hyperlipoproteinemia	50 (45%)	36 (48%)	14 (38%)	0.230
Smoking history	49 (44%)	34 (45%)	15 (41%)	0.509
Preoperative need for catecholamines	33 (29%)	3 (4%)	30 (81%)	<0.001
Preoperative ventilation	18 (16%)	1 (1%)	17 (46%)	<0.001
Preoperative resuscitation	18 (16%)	2 (3%)	16 (43%)	<0.001
Preoperative IABP	11 (10%)	3 (4%)	8 (22%)	0.004
Preoperative CK (U/L)	306 (6–7446)	253 (6–2880)	697 (73–7446)	0.001
Preoperative CK-MB (U/L)	37 (12–1096)	34 (12–339)	66 (13–1096)	0.001

CK = creatine kinase; IABP = intraaortic balloon pump.

never reached widespread acceptance. High mortality rates, which have been observed in operations early after ST-segment elevation myocardial infarction (STEMI), have discouraged a number of surgeons from intervening in the early period [8]. To this point, inconsistent data on the question of whether medical or interventional therapy is superior in the short or long term further complicate the issue [9]. Despite these data, coronary artery bypass graft surgery has been shown to improve survival in patients with unstable angina, especially in those with impaired left ventricular function [10].

In our institution, we have adjusted the policy for surgical intervention toward a more aggressive surgical treatment of acute myocardial infarctions. Rather than operating after a stabilization period of several days using an intraaortic balloon pump (IABP) as a bridge procedure, surgical intervention is performed in patients on an emergency basis. The goal, therefore, is to achieve an early and complete revascularization. Depending on the individual patient, different surgical and supportive strategies are used to improve the outcome. As STEMI is considered a challenging subset of acute coronary syndrome [11], a retrospective analysis of our institutional experience after the shift in surgical policy was performed.

Table 2. Intraoperative Data

Variable	All Patients (n = 112)	Without Shock (n = 75)	With Shock (n = 37)	*p* Value
CPB	106 (95%)	73 (97%)	33 (89%)	0.005
CPB time (min)	89 (48–261)	84 (48–261)	104 (52–236)	0.014
X-clamp (min)	39 (17–87)	39 (19–87)	39 (17–58)	0.237
Number of grafts	2 (1–4)	3 (1–3)	2 (1–4)	0.054
Number of anastomosis	3 (1–5)	3 (2–3)	2 (1–4)	0.246
IABP intraoperatively	42 (38%)	18 (24%)	24 (65%)	0.001

CPB = cardiopulmonary bypass; IABP = intraaortic balloon pump; X-clamp = cross-clamp.

Patients and Methods

The institutional review board approved this study. All patients gave written informed consent.

Patients

Between August 2002 and August 2007, 112 patients with STEMI were revascularized in the first 48 hours after the onset of symptoms in our institution and were analyzed retrospectively. Patients with ventricular septal defects, ventricular rupture, or ischemic mitral valve insufficiency were excluded from the analysis. All patients included in the analysis had true ST elevation in the electrocardiogram and were positive for troponin and creatine kinase, and interventional revascularization was considered impossible by the referring cardiologist. Because a significant number of patients were transferred from a different interventional cardiologist, the total number of patients treated interventionally or conservatively during this time frame is not known. The same is true for the questions concerning the criteria for or against surgery. The majority had triple-vessel coronary artery disease (n = 100, 89%), two thirds of patients (n = 73) had left main stem stenosis, and one third of patients (n = 37) were in cardiogenic shock (ratio of heart rate to systolic blood pressure).

Dobutamine in combinations with norepinephrine was used in the majority of cases. Dosage was adjusted to hemodynamics. Twenty-one patients underwent acute PTCA before surgery. It is important to note that none of the patients experienced a myocardial infarction as a result of PTCA. Eighteen patients (16%) were resuscitated, and the same number were ventilated. Additional patient characteristics and preoperative data are shown in Table 1.

Preoperative and Anesthesia Management

All patients received antiplatelet therapy before surgery. Only 11 patients (9.9%) had an IABP at the time of operation. In the majority of patients the introduction system was left in the femoral artery. In unstable patients, anesthesia induction was performed in the operating room. All patients received a Swan-Ganz catheter for continuous cardiac output measurements, and vasopressors (eg, norepinephrine) were given to avoid pressure drops.

Surgical Technique

The specific surgical approach was chosen according to the surgeon's preference. The majority of patients underwent operations using extracorporeal circulation and cardioplegic cardiac arrest (Table 2). Internal mammary artery grafts were combined with venous grafts for revascularization in stable patients, whereas venous grafts only were used in patients requiring resuscitation or presenting with major hemodynamic instability. Complete arterial revascularization, the main goal in our elective patients, did not play a significant role in our acute revascularization population. Assisted beating heart surgery on extracorporeal circulation was performed in 7 patients, and off-pump coronary artery bypass graft procedures were done in 3 patients. A perioperative IABP was selectively used in the early days, but now is considered a standard in surgically treated STEMI patients. Amiodarone was administrated in patients with arrhythmias, and up until 2007, high-dose aprotinin was given to reduce postoperative bleeding. At present, tranexamic acid is administered in a routine fashion.

Postoperative Management

Blood products including thrombocytes were frequently administered, especially if dual antiplatelet therapy had been initiated before surgery. Sedation was maintained until hemodynamic stabilization and reduction of the fraction of inspired oxygen to 0.4 was reached. Counterpulsation was continued for at least 48 hours or until the patient was stabilized. Patients were on therapeutic heparinization and aspirin (100 mg/d), followed by 6 months of additional clopidogrel (75 mg/d) after removal of the chest drains.

Quality of Life

A clinical follow-up, including a quality-of-life assessment, was performed in all surviving patients using the Short-Form 36 Health Survey Questionnaire (SF-36). In brief, the SF-36 consists of 36 question-based evaluations reflecting quality of life in eight different areas. Results were then compared with patients treated nonsurgically for acute STEMI.

Statistical Analysis

Data are expressed as either mean ± standard deviation, median and range, or percentage, as appropriate. Statistical analyses were performed using the Student's *t* test or Pearson test for categoric variables. Forward logistic regression was used to discriminate among risk factors for 30-day mortality. Statistical analysis was performed using SPSS 16.0 software (SPSS Inc, Chicago, IL) in cooperation with the Institute of Biometrics, Hannover Medical School.

Results

During the last several years, there was a consistently increasing caseload of surgically treated STEMI patients for the 5 years of the study (2002, n = 8; 2004, n = 21; 2007, n = 34). This may be related to a change of our policy to operate on patients even with positive enzyme levels. The effect of an increase of the number of patients presenting with acute myocardial infarction who could not be treated with percutaneous coronary intervention cannot be answered in this context.

Intraoperative Data

All patients were administered at least one antithrombotic agent, 85% received two, and 5% were given three. All patients were receiving intravenous heparin. Operations using extracorporal circulation were conducted in 106 patients (96%), and cardioplegic solution was administered in 94 patients (85%: blood, n = 60; crystalloid, n = 34). A complete revascularization was achieved in 85% of patients analyzed. Fifty-eight patients (52%) received a combination of one arterial graft (left internal mammary artery in the majority of cases) and venous grafts, and 49 patients (44%) were revascularized with venous grafts only. A complete arterial revascularization was performed in 3 patients (3%) owing to the lack of alternative graft material. The mean number of bypass grafts was 2.4 ± 0.6 (range, 1 to 4) with 3.3 ± 0.9 (range, 1 to 5) distal anastomoses. Forty-two patients (33%) received an IABP perioperatively. Temporary extracorporeal membrane oxygenation support was necessary in 3 patients. One patient died and 2 were weaned from extracorporeal membrane oxygenation after 5 and 7 days, respectively. Intraoperative times are reported in Table 2.

Adverse Outcomes

Overall 30-day mortality in the entire cohort was 20% (22 of 112 patients). In the group with cardiogenic shock, mortality was 30% (11 of 37 patients) compared with 15% (11 of 75 patients) in patients with stable hemodynamics ($p = 0.004$). Two patients (2%) experienced strokes, 1 of whom required extracorporeal membrane oxygenation support and subsequently died owing to multiorgan failure.

Postoperative Course

Three patients needed a rethoracotomy because of bleeding complications. Mean intensive care unit stay was 3.3 ±

Table 3. Univariate and Multivariate Analysis of Risk Factors for 30-Day Mortality[a]

Factor	Univariate	Multivariate
Preoperative need for catecholamines	0.013	0.002, OR 6.4, 95% CI 1.96–21.04
Preoperative cardiogenic shock	0.043	
Preoperative ventilation	0.093	
Ejection fraction	0.013	
Preoperative CK	0.017	
Preoperative CK-MB	0.009	

[a] Values are *p* values for univariate analysis, and *p* values, OR, and 95% CI for multivariate analysis.

CI = confidence interval; CK = creatine kinase; OR = odds ratio.

3.7 days. Mean IABP support in 42 patients was 2.4 ± 1.6 days. Of the total patient population, 15% had temporary neurologic dysfunction. Three survivors were on temporary dialysis, and all recovered before being discharged. Complete preoperative and postoperative echocardiographic data were available in 51 survivors (57 %). Mean ejection fraction improved from 0.38 ± 0.12 to 0.53 ± 0.16 ($p < 0.01$). Individual analysis in this group showed an improvement in 42 patients, 3 remained constant, and 6 showed a deterioration of the left ventricular function on echocardiography.

Risk Factor Analysis

Univariate and multivariate analyses of the data collected were used to determine those risk factors significantly associated with 30-day mortality (Appendix). Based on these statistics, we determined that only factors demonstrating hemodynamic instability reached significance. Importantly, the maximum preoperative creatine kinase-MB or troponin level had no impact on the survival (Table 3). The comparison of patients with and without preoperative cardiogenic shock showed a number of differences between groups (compare Tables 1 and 2).

Quality of Life Assessment

Follow-up assessment was completed in 80% of survivors. After a mean follow-up time of 68 ± 50 months, patients were evaluated with respect to their postoperative quality of life. Patients with a history of an operatively approached acute STEMI showed a significantly improved physical and mental summary score relative to patients after primary percutaneous coronary intervention for acute STEMI (Fig 1) [12].

Comment

As the life expectancy of the population continues to increase, the number of patients presenting with acute coronary syndrome will increase in the future. Acute coronary syndrome includes a broad spectrum of clinical presentations, spanning from STEMI to an accelerated pattern of angina without evidence of myonecrosis. Independent of this fact, timely reperfusion is essential for myocardial salvage as a result of prolonged myocardial ischemia [13].

Patients with STEMI usually present with an occluded coronary artery with a thrombus at the site of a ruptured plaque. Restoring coronary patency as promptly as pos-

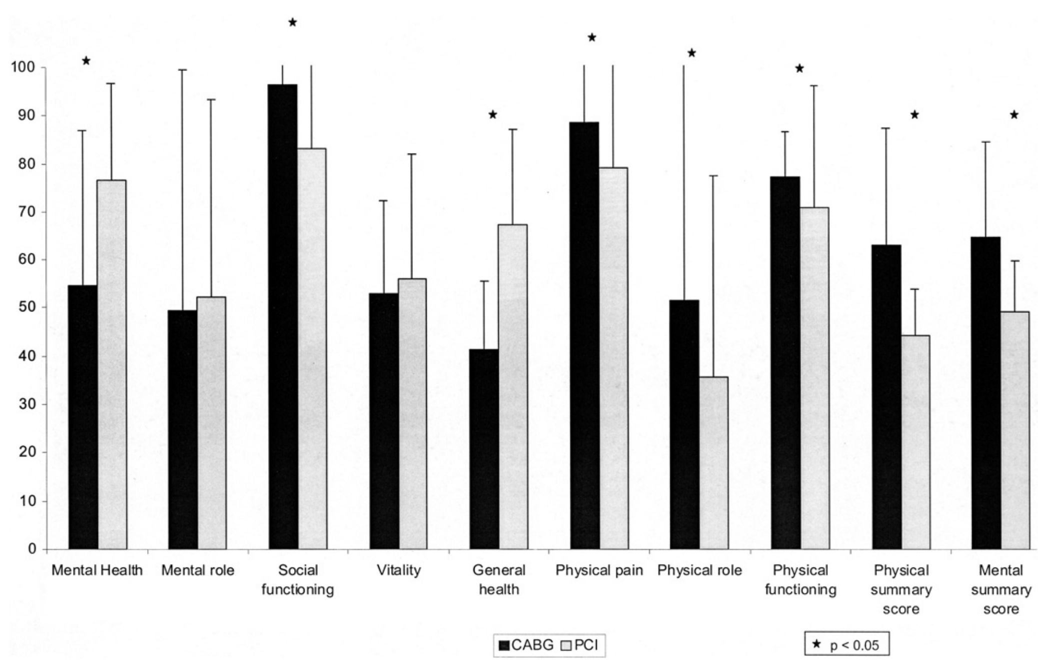

*Fig 1. Comparison of patients with an acute ST-segment-elevation myocardial infarction (STEMI) surgically (n = 72) treated with patients treated with percutaneous coronary intervention (PCI) (n = 684) for acute ST-segment-elevation myocardial infarction. Bars represent mean plus standard deviation, *p < 0.05. Eight aspects of quality of life were assessed.*

sible is considered to be a key determinant of short-term and long-term outcomes. Based on available literature, there is no clear evidence whether fibrinolysis or PTCA is a superior treatment [5]. In addition, surgical intervention is not routinely discussed as a treatment in the majority of the cardiology literature [14–16].

Is PTCA of an occluded right coronary artery in the presence of a left main stem stenosis the optimal treatment? In the acute treatment of STEMI, PTCA is concentrated on the one target vessel responsible for the ischemia or infarction. This can leave a significant number of patients with an incomplete revascularization and the necessity for further interventions. Furthermore, anticoagulation treatment, necessary with PTCA and stenting, increases the risk of perioperative bleeding, and the use of drug-eluting stents is, without a doubt, associated with potential complications owing to the need for dual antithrombotic therapy. The surgical approach allows complete revascularization and offers a variety of techniques depending on the condition and stability of the patient. The question of whether to use cardioplegia, perform assisted beating heart surgery [17], or even off-pump coronary artery bypass graft techniques is the subject of controversial discussions. Ultimately, the decision made depends on the individual patient, and on the experience and policy of the treating department. Regardless of the procedure used, it remains clear that major efforts must be undertaken to decrease the time between the onset of symptoms and catheterization. The importance of early surgical intervention has been demonstrated by Alexiou and associates [18] by determining that the time from the onset of symptoms to revascularization differed significantly between survivors and nonsurvivors. They concluded that this 6-hour difference, or "first six golden hours," was crucial as a prognostic variable in the STEMI group.

In the current study, the mortality rate of 20% for the whole group of patients is rather high. It is therefore important to distinguish between patients presenting with cardiogenic shock needing catecholamines and those with preserved hemodynamics. Results from the univariate and multivariate analysis support this observation. A review of the literature stresses that in-hospital mortality after myocardial infarction with cardiogenic shock declined in the mid-1990s; however, the overall mortality rate remains between 50% and 60% [19]. These reports, in addition to our results, demonstrate that cardiogenic shock remains the major cause of death for patients hospitalized with acute myocardial infarction [20]. Regardless, our data show that it is possible to surgically treat stable STEMI patients with an elevated but, in our opinion, acceptable operative risk. For unstable patients early admission as well as a more aggressive use of intraaortic counterpulsation may improve the outcome in this high-risk cohort.

As a result of our retrospective analysis, multiple conclusions can be drawn from the data presented. With respect to the surgical outcomes, our data may suggest a benefit to postponing surgical intervention to improve statistics. But is this to be considered optimal treatment for our patients? Data from the SHOCK trial report similar survival rates with emergency revascularization and initial medical stabilization [21]. Differences between the courses of intervention were not detected until 1 year after myocardial infarction, whereby survival rates were higher in patients who had received emergency revascularization [22]. Moreover, this subset of patients reported a better quality of life [23]. This result is in accordance with our findings, as assessed by the SF-36 survey. Our initial results are encouraging; however, a collaborative treatment approach would further aid in the improvement of treatment given to an acute STEMI patient.

The new policy at our institution, with respect to early surgical intervention, has led to the increase in patients receiving operative treatment as opposed to PTCA. To support early myocardial perfusion we modified our approach to include an aggressive and early use of the IABP. When possible, IABP is either initiated in the cardiac catheterization laboratory or during anesthesia induction before surgery. In the operating room, further myocardial ischemia can be prevented by frequent use of the beating heart technique. Counterpulsation is then continued for at least 48 hours or until echocardiographic evaluation allows for the discontinuation of support. In the case of left heart failure, an extracorporeal membrane oxygenation support system can be implanted to allow restoration of myocardial function. It is also conceivable that this more aggressive approach may improve salvage by unloading with a consecutive reduction of wall tension.

Limitations

As this study was of a retrospective nature, the number of patients with complete preoperative and postoperative echocardiographic testing was limited, making it difficult to determine the correlation between infarction, time of operation, and outcome. Furthermore, myocardial viability cannot be assessed owing to the nature of the study design. Myocardium involved in a STEMI is not necessarily damaged irreversibly, such that after STEMI, salvaged areas can become stunned as a result of transient ischemia. Thus, if a low-flow state persists without revascularization, dysfunction can continue as a result of hibernation [24]. There is evidence, however, that revascularization of this viable myocardium improves function, symptoms, and prognosis [25, 26]. There are a number of techniques available to test myocardial viability, including single-photon emission computed tomography, positron emission tomography, stress echocardiography, and magnetic resonance imaging. Unfortunately, these techniques are difficult to use in hemodynamically unstable patients needing catecholamines or counterpulsation support. Despite these difficulties, definition of salvaged areas and the respective correlations with outcomes are necessary to show a real benefit of revascularization.

Conclusions

Effective management of acute STEMI requires collaborative systems of care to ensure that patients have access to the needed services in a time frame commensurate with their clinical conditions. In our opinion, this includes not only interventional catheterization laboratories but also facilities offering a 24-hour cardiac surgical service.

In summary, this study reports that emergency coronary artery bypass graft surgery as a result of an acute STEMI can be performed with positive results, especially in patients without cardiogenic shock. Therefore, operative revascularization should not only be considered as a rescue therapy, but also as a reasonable alternative to percutaneous coronary intervention in patients with triple-vessel coronary artery disease or main stem stenosis. Nevertheless, the effect of surgical myocardial revascularization on muscle salvage has to be elucidated. Based on this, these results may also have an impact on further treatment algorithms—interventional versus surgical—in this subset of high-risk patients.

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Appendix

Factors Included in the Univariate Analysis for 30-Day Mortality

Factor	p Value
Age	0.691
Body mass index	0.320
Sex	0.586
Three-vessel disease	0.985
Left main stenosis	0.128
History of myocardial infarction	0.390
Ejection fraction	0.013
Hypertension	0.155
Diabetes	0.494
Hyperlipoproteinemia	0.758
Smoking history	0.233
Preoperative need for catecholamines	0.013
Preoperative cardiogenic shock	0.043
Preoperative ventilation	0.093
Preoperative resuscitation	0.116
Preoperative intraaortic balloon pump	0.514
Preoperative CK	0.017
Preoperative CK-MB	0.009

CK = creatine kinase.

INVITED COMMENTARY

Management of acute myocardial infarction, characterized by ST-segment elevation (STEMI) remains a vexing problem. With the advent of routine and early antiplatelet and antithrombotic drug therapy (clopidogrel, and so forth), prompt institution of intra-aortic balloon pump (IABP) support and aggressive percutaneous coronary intervention have changed the landscape of treatment. Although surgical revascularization remains a viable option, many factors have precluded widespread, early referral to the cardiac surgeon. Hagl and colleagues [1] report their experience, spanning a 5-year period, in which emergent surgical revascularization was performed on patients with STEMI. All patients were revascularized within 48 hours from the onset of symptoms. Of note, 33% of patients presented with cardiogenic shock, but only 10% had an IABP inserted prior to surgery. The overall 30-day mortality was significant at 20%, but the highest mortality occurred in patients with cardiogenic shock. This highly sick group exhibited a mortality of 27%, as compared with 8.6% in patients without shock. Still, the surgeons are to be credited in showing improved survival in shock patients when compared with historical controls.

Some daunting questions remain. Regarding the timing of surgical intervention, previous authors have demonstrated an even earlier (< 6-hour) interval to surgery can decrease mortality, but the 7-hour to 24-hour interval period may be the most dangerous [2]. With door-to-balloon time becoming a highly important marker of infarct limitation, and minimization of end-organ damage, it would seem prudent to include this tool in future management of such patients. Considerable publications have also reported the use of pharmacotherapies to aid in remodeling, limiting ischemia-reperfusion injury, and modulating the immune response. The horizon of stem-cell therapy for this subset of patients is promising, and the ability to deliver combined drug therapies with complete revascularization is a laudatory goal. The use of mechanical assist, in terms of short-term support, also seems to be gaining a foothold in the surgeon's and interventionalist's approach.

The authors are to be commended for showing that coronary bypass grafting can be safely performed within an aggressive approach to STEMI patients. The cardiac surgeon should be integrated as a fundamental part of the therapeutic armamentarium. As hybrid operating rooms are increasingly being used, a conjoined approach with cardiologists and cardiac surgeons will no doubt benefit this patient population.

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