

# Preoperative Cardiac Troponin I to Assess Midterm Risks of Coronary Bypass Grafting Operations in Patients With Recent Myocardial Infarction

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**Background.** The optimal timing for coronary artery bypass grafting (CABG) in patients with recent acute myocardial infarction (AMI) is unclear. Cardiac troponin I (cTnI) is a widely accepted biomarker of myocardial damage. The objective of this study was to determine whether preoperative cTnI values could be used to determine risk stratification for CABG operations in patients with recent AMI.

**Methods.** Evaluated were 184 patients who sustained an AMI within 21 days of undergoing nonurgent CABG operations. They were divided into two groups according to their preoperative cTnI values: 117 patients with cTnI of 0.15 ng/mL or less and 67 with cTnI exceeding 0.15 ng/mL. Associations between study variables and events were assessed with logistic regression modelling. Time from AMI to operation was evaluated to define preoperative cTnI variation.

**Results.** Values of cTnI tended to decrease when the interval between AMI and the operation increased. Pre-

operative cTnI values were significantly associated with a higher incidence of major postoperative complications (low cardiac output syndrome, intraaortic balloon pump necessity, mechanical ventilation >72 hours, acute renal failure, in-hospital mortality). Perioperative myocardial damage was more pronounced in patients with cTnI exceeding 0.15 ng/mL. Multivariate analyses revealed cTnI exceeding 0.15 ng/mL was an independent predictor for 6-month mortality (odds ratio, 3.7;  $p = 0.043$ ).

**Conclusions.** Preoperative cTnI exceeding 0.15 ng/mL in patients with recent AMI undergoing CABG is associated with higher postoperative myocardial damage and is a strong determinant of postoperative morbidity and mortality within the 6-month period.

(Ann Thorac Surg 2010;89:696–703)

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Optimal timing of coronary artery bypass grafting (CABG) operations in patients with recent acute myocardial infarction (AMI) is unclear. Several studies have demonstrated that CABG performed close to an AMI event carries a higher risk of postoperative morbidity and death than operations performed at a later date [1, 2]. However, the reason why delaying the CABG renders the operation safer has not been explained. The question remains: What is the optimal time for CABG operations in patients with recent AMI under relatively stable clinical conditions and an angiographic indication for surgical revascularization?

Cardiac troponins have become the gold standard for detecting myocardial damage [3] and for diagnosis and risk stratification in patients with acute coronary syndrome (ACS) [4, 5].

Cardiac troponin assessments have also been adopted to define the perioperative risks in patients undergoing

CABG after recent ACS. A few studies have documented that elevated preoperative cardiac troponin I (cTnI) levels are associated with increased operative death and adverse events after emergency CABG [6–9]. Other studies have demonstrated that increased postoperative myocardial damage, evaluated by cTnI values, is associated with increased postoperative death and morbidity [10–12]. The influence of elevated preoperative cTnI values on midterm postoperative outcome has not been reported nor has the reason behind the negative prognostic value of preoperative elevated cTnI been clearly elucidated.

The primary aim of the present study was to verify the influence of preoperative cTnI values on the incidence of major postoperative complications and 6-month mortality of patients who sustained an AMI within 21 days before undergoing CABG in stable clinical conditions. The relationship between preoperative cTnI values and the interval between AMI and the operation has been evaluated. We also documented the effect of preoperative cTnI values on postoperative cTnI release to identify the potential pathophysiology of adverse outcome in patients with a recent AMI.

Accepted for publication Nov 30, 2009.

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## Material and Methods

The approval of the local ethic committee was obtained before our study was conducted, and in accordance with our local ethic committee policy, individual consents were waived.

This was a single-center, retrospective, and observational study that used clinical and laboratory data prospectively recorded in our institutional database. From January 2005 to December 2007, 184 patients with recent AMI (onset < 21 days) underwent elective, isolated, first-time CABG operations with cardiopulmonary bypass. The study excluded emergency operations (eg, cardiogenic shock, intraaortic balloon pump [IABP], or patients otherwise requiring an immediate operation), repeat operations, combined procedures, and off-pump procedures.

### Patients

The patients arrived at Policlinico Hospital of Bari directly in the Emergency Department or from different cardiology units without coronary angiography facilities within the geographic area. AMI was suspected by evaluating symptoms and electrocardiogram abnormalities and confirmed by cTnI measurements. Coronary angiog-

raphy was performed in the Division of Cardiology within 48 hours of the onset of AMI. The operations were indicated by the severity of coronary stenosis or by postinfarction angina, or both.

Patients were considered nonemergency cases because they had stable clinical conditions and were subsequently transferred to the Division of Cardiac Surgery without discharge home. The waiting period from diagnosis to operation depended on a variety of casual factors, including the surgical waiting list, concomitant disease needing preoperative evaluation, and preangiography aggressive antiplatelet therapy. The exact time from AMI to operation was evaluated by reviewing patients' medical records.

For the purposes of our study, these patients were divided in two groups according to their preoperative cTnI value. The low cTnI group consisted of 117 patients who had preoperative cTnI of 0.15 ng/mL or less (cTnI ≤ 0.15 ng/mL). The high cTnI group consisted of 67 patients who had preoperative cTnI exceeding 0.15 ng/mL (cTnI > 0.15 ng/mL). A cTnI value of 0.15 ng/mL is the value used to confirm the diagnosis of AMI at our Pathology Unit [13]. Clinical management was not influenced by preoperative cTnI values neither perioperatively nor after hospital discharge.

Table 1. Preoperative Patient Characteristics Based on Preoperative Cardiac Troponin I Values

Variable	All Patients	Pre-op cTnI, ng/mL		p Value
		≤0.15	>0.15	
Patients, totals	184	117	67	
Males, No. (%)	139 (76)	93 (79)	46 (69)	0.10
Age, mean ± SD, y	65 ± 9	64 ± 9	66 ± 9	0.24
BMI, mean ± SD, kg/m <sup>2</sup>	27 ± 4	26 ± 4	27 ± 4	0.10
Hypertension, %	69	67	73	0.36
Diabetes Mellitus, %	43	44	43	0.97
Hypercholesterolemia, %	71	73	67	0.43
Statin therapy, %	54	57	48	0.21
Smoking history, %	54	58	46	0.12
COPD, %	21	25	15	0.12
Unstable angina, %	35	23	55	<0.001
Ejection fraction, mean ± SD	0.45 ± 0.09	0.45 ± 0.09	0.44 ± 0.09	0.80
CA stenosis > 50%, %	10	9	10	0.82
Cerebrovascular accident, %	4	4	4	0.95
Peripheral vascular disease, %	11	11	12	0.86
Renal disease, %	5	6	4	0.66
Acute myocardial infarction, No. (%)				<0.001
≤7 days	46 (25)	12 (10)	34 (51)	
8–14 days	43 (23)	26 (22)	17 (25)	
>14 days	95 (52)	79 (68)	16 (24)	
EuroSCORE, mean ± SD				
Logistic	8.94 ± 9.65	7.27 ± 7.08	11.85 ± 12.52	0.002
Additive	6.65 ± 2.93	6.05 ± 2.63	7.70 ± 3.15	<0.001
Pre-op cTnI, mean ± SD, ng/mL	1.19 ± 3.61	0.03 ± 0.04	3.21 ± 5.44	...

BMI = body mass index; CA = carotid artery; COPD = chronic obstructive pulmonary disease; cTnI = cardiac troponin I; EuroSCORE = European System for Cardiac Operative Risk Evaluation; SD = standard deviation.

### Study Objectives

The primary objective of our study was to evaluate the effect of preoperative cTnI values on the incidence of major postoperative complications and 6-month mortality rates in clinically stable patients undergoing CABG operations. A major postoperative complication is considered the occurrence of at least one of the following: low cardiac output syndrome, IABP necessity, mechanical ventilation lasting longer than 72 hours, acute renal failure, and in-hospital death. The second objective was to verify the effect of preoperative cTnI values on postoperative cTnI values.

### Definitions

Hypertension was defined as blood pressure exceeding 140/90 mm Hg or needing antihypertensive medications. Patients who had a history of diabetes were considered diabetic. Hypercholesterolemia was defined as cholesterol level greater than 200 mg/dL. Smoking history was defined as any current or past form of tobacco use. Preoperative renal disease was defined as serum creatinine exceeding 2.0 mg/dL. On-going refractory angina that required the use of intravenous nitrate therapy for control was regarded as unstable angina.

Death within the same hospital admission, regardless of the cause, was defined as operative mortality. Cardiac death was regarded as any death due to cardiac causes, including sudden death. Low cardiac output syndrome was defined as the need for postoperative inotropic support or an IABP for more than 12 hours to maintain systolic blood pressure greater than 90 mm Hg, mean blood pressure greater than 60 mm Hg, or the cardiac index greater than 2.2 L/min/m<sup>2</sup>, despite sufficient volume substitution.

Extubation criteria were hemodynamic stability, absence of surgical bleeding, consciousness, and optimal blood gas measurements with a fraction of inspired oxygen of 0.3 or less. Cerebrovascular disease was regarded as any transient ischemic attack, reversible ischemic neurologic deficit, or stroke. Acute renal failure was defined as new onset of postoperative creatinine exceeding 2.0 mg/dL or an increase of creatinine levels greater than twofold compared with preoperative creatinine levels or requirement of dialysis. Allogenic red blood cells were transfused if the hemoglobin value was less than 8 g/dL.

### Surgical Management

Our surgical approach was always a median sternotomy. Heparin was given (300 U/Kg), and CPB was established with ascending aorta and two-stage venous cannulation using moderate hypothermia (34°C), a centrifugal pump, and uncoated tubing system with membrane oxygenator. Tranexamic acid (2 g) was added to prime solution. Myocardial protection was achieved using antegrade and optional retrograde cold blood cardioplegia. Intraoperative heparin monitoring was by standard activated clotting time (ACT, Medtronic Inc, Minneapolis, MN). Additional heparin boluses (5000 U) were given if the ACT

values were less than 400 seconds. Protamine sulphate was administered to reverse heparin.

### Troponin Measurement

Samples for preoperative cTnI measurements were collected the morning of the operation. Cardiac troponin I was measured according to the manufacturer's recommendation by standard immunoassay technique (Cardiac Troponin-I Flex Reagent Cartridge, Dade Behring, Newark, NJ). Postoperative cTnI measurements were performed at 6, 12, 24, and 36 hours and then daily until postoperative day 6.

### Follow-Up

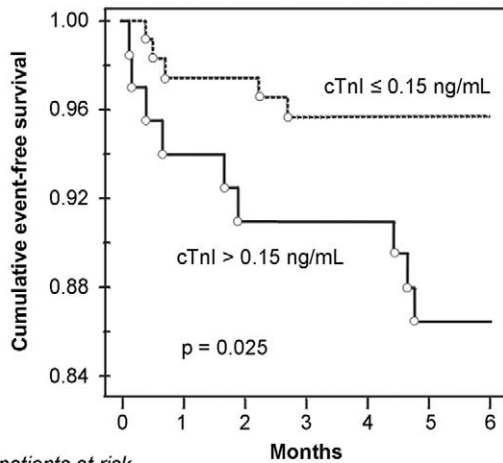
After discharge home, follow-up was accomplished by periodic evaluation of patients at our institution or by telephone contact with the patients' general practitioner.

Table 2. Intraoperative Variables and Postoperative Outcomes Based on Preoperative Cardiac Troponin I Values

Variable <sup>a</sup>	Pre-op cTnI, ng/mL		p Value
	≤0.15	>0.15	
<b>Intraoperative</b>			
Grafts, No.	2.95 ± 1.06	2.85 ± 1.06	0.64
Arterial grafts, No.	1.01 ± 0.32	1.06 ± 0.37	0.65
Operation time, h	4.76 ± 1.03	4.93 ± 1.1	0.60
IABP use	2 (2)	8 (12)	0.005
CPB time, min	95 ± 50	96 ± 47	0.95
Cross-clamp time, min	50 ± 27	49 ± 25	0.96
Blood products transfusion, U	0.33 ± 0.84	0.13 ± 0.52	0.57
<b>Postoperative outcomes</b>			
Intensive care unit stay, h	39 ± 13	43 ± 19	0.07
Overall stay, d	9.8 ± 9.2	11.8 ± 10.9	0.19
Mechanical ventilation > 4 h	8 (7)	11 (16)	0.04
Inotropes use	15 (13)	10 (14)	0.69
IABP use <sup>b</sup>	2 (2)	8 (12)	0.003
Total blood loss, mL	771 ± 261	808 ± 309	0.52
Blood products transfusion, U	1.64 ± 3.25	2.00 ± 2.76	0.57
Acute renal failure	11 (9)	4 (6)	0.58
LCOS	15 (13)	15 (22)	0.09
Atrial fibrillation	27 (23)	25 (37)	0.039
Sepsis	2 (2)	1 (1)	1.00
cTnI peak, ng/mL	7.01 ± 9.63	24.49 ± 48.02	<0.001
In-hospital mortality	5 (4)	6 (9)	0.20
Major post-op complications <sup>c</sup>	21 (18)	21 (31)	0.037
6-month mortality	5 (4)	9 (13)	0.024

<sup>a</sup> Continuous variables are expressed as the mean ± standard deviation; categorical variables as number (%). <sup>b</sup> IABP insertion after CPB weaning. <sup>c</sup> LCOS, IABP necessity, mechanical ventilation > 72 hours, acute renal failure, in-hospital mortality.

cTnI = cardiac troponin I; CPB = cardiopulmonary bypass; IABP = intraaortic balloon pump; LCOS = low cardiac output syndrome.



Number of patients at risk	0	1	2	3	4	5	6
cTnI ≤ 0.15 ng/mL	117	114	114	112	112	112	112
cTnI > 0.15 ng/mL	67	63	61	61	61	58	58

Fig 1. Kaplan-Meier curves are shown for patients with a preoperative cardiac troponin I (cTnI) ≤ 0.15 ng/mL (dashed line) and cTnI > 0.15 ng/mL (solid line).

ners. Follow-up was stopped at 6 months and was 100% complete.

### Statistical Analysis

Data are shown as mean values ± standard deviation. The continuous variables were compared using analysis of variance or *t* test for independent samples. The non-parametric Mann-Whitney *U* test was used when appropriate. Categorical data were tested with the  $\chi^2$  test or the Fisher exact test, where appropriate. cTnI was evaluated as continuous and as a dichotomous variable (>0.15 vs ≤0.15 ng/mL). Multivariate logistic regression model

was applied including variables with a significance level of less than 0.20 at univariate analysis. Estimated odds ratios (OR) and corresponding 95% confidence intervals (CI) and probability values are reported. The OR for a continuous variable refers to the risk ratio per unit of the analyzed variable unless specified otherwise. Survival curves at 6 months between the cTnI ≤ 0.15 ng/mL group and the cTnI > 0.15 ng/mL group were based on Kaplan-Meier analyses and were compared by means of the log-rank test. The analyses were made using Statistica 6.1 software (StatSoft Inc, Tulsa, OK), and values of *p* < 0.05 were considered statistically significant.

### Results

Table 1 reports the preoperative characteristics and demographics of the patients in our study group. Preoperative use of continuous intravenous nitrate and heparin was significantly higher in the cTnI > 0.15 ng/mL group. This influenced the preoperative risk stratification by both the logistic and additive European System for Cardiac Operative Risk Evaluation (EuroSCORE). Intraoperative variables and postoperative outcomes according to preoperative cTnI values are reported in Table 2.

The CABG operations were performed similarly in both groups, and no material differences in intraoperative variables were noted. The cTnI > 0.15 ng/mL group experienced longer mechanical ventilation time, more IABP use, and a higher incidence of atrial fibrillation. Intensive care unit length of stay, overall hospital length of stay, and low cardiac output syndrome were higher in cTnI > 0.15 ng/mL patients, without statistically significant differences. Mechanical ventilation was significantly longer in cTnI > 0.15 ng/mL patients. In-hospital mortality was 4% in the cTnI ≤ 0.15 ng/mL group and 9% in

Table 3. Logistic Regression Analysis for Major Postoperative Complications

Factor	Yes	No	Univariate		Multivariate	
	(n = 42)	(n = 142)	OR (95% CI)	<i>p</i> Value	OR (95% CI)	<i>p</i> Value
Males, No. (%)	29 (69)	110 (77)	0.65 (0.30–1.40)	0.27	...	...
Age, mean ± SD, y	68 ± 8	64 ± 9	1.05 (1.01–1.10)	0.016	1.03 (0.98–1.09)	0.182
BMI, mean ± SD, kg/m <sup>2</sup>	26 ± 4	27 ± 4	0.90 (0.81–1.00)	0.044	0.90 (0.80–1.01)	0.077
Hypertension, %	71	68	1.16 (0.54–2.49)	0.70	...	...
Diabetes mellitus, %	45	43	1.1 (0.55–2.20)	0.79	...	...
Hypercholesterolemia, %	76	69	1.44 (0.65–3.20)	0.37	...	...
Smoking history, %	48	56	0.72 (0.36–1.45)	0.36	...	...
COPD, %	21	21	1.02 (0.43–2.38)	0.97	...	...
Unstable angina, %	40	33	1.37 (0.67–2.80)	0.38	...	...
EF, mean ± SD	0.41 ± 0.11	0.46 ± 0.08	0.94 (0.90–0.98)	0.002	0.95 (0.90–0.99)	0.014
CA stenosis > 50%, %	10	10	0.96 (0.30–3.12)	0.95	...	...
PVD, %	17	10	1.83 (0.68–4.91)	0.23	...	...
Renal disease, %	17	2	9.27 (2.26–38.02)	0.002	8.34 (1.55–44.90)	0.013
cTnI, mean ± SD, ng/mL	2.53 ± 5.40	0.79 ± 2.77	1.12 (1.02–1.23)	0.019	1.20 (1.04–1.39)	0.014
cTnI > 0.15 ng/mL, %	50	32	2.81 (1.03–4.22)	0.039	...	...

BMI = body mass index; CA = carotid artery; CI = confidence interval; COPD = chronic obstructive pulmonary disease; cTnI = cardiac troponin I; EF = ejection fraction; OR = odds ratio; PVD = peripheral vascular disease; SD = standard deviation.

Table 4. Logistic Regression Analysis for 6-Month Mortality

Factor			Univariate		Multivariate	
	Yes (n = 14)	No (n = 170)	OR (95% CI)	p Value	OR (95% CI)	p Value
Males, No. (%)	8 (57)	131 (77)	0.40 (0.13–1.22)	0.11	0.39 (0.08–1.88)	0.24
Age, mean ± SD, y	69 ± 8	65 ± 9	1.07 (1.00–1.14)	0.06	1.09 (1.00–1.19)	0.06
BMI, mean ± SD, kg/m <sup>2</sup>	26 ± 5	27 ± 4	0.96 (0.83–1.11)	0.58	...	...
Hypertension, %	79	68	1.71 (0.45–6.43)	0.43	...	...
Diabetes mellitus, %	64	42	2.51 (0.80–7.87)	0.11	2.30 (0.62–8.50)	0.21
Hypercholesterolemia, %	64	71	0.73 (0.23–2.30)	0.59	...	...
Smoking history, %	36	55	0.45 (0.14–1.41)	0.17	0.63 (0.12–3.32)	0.58
COPD, %	21	21	1.02 (0.27–3.81)	0.98	...	...
Unstable angina, %	43	34	1.45 (0.48–4.40)	0.51	...	...
EF, mean ± SD	0.36 ± 0.11	0.45 ± 0.09	0.90 (0.85–0.96)	<0.001	0.87 (0.81–0.94)	<0.001
CA stenosis > 50%, %	14	9	1.60 (0.33–7.89)	0.56	...	...
PVD, %	21	11	2.30 (0.58–9.12)	0.23	...	...
Renal disease, %	7	5	1.38 (0.16–11.89)	0.77	...	...
cTnI, mean ± SD, ng/mL	2.60 ± 6.16	1.07 ± 3.31	1.07 (0.97–1.19)	0.16	...	...
cTnI > 0.15 ng/mL, %	64	34	3.48 (1.11–10.93)	0.032	3.74 (1.04–13.48)	0.043

BMI = body mass index; CA = carotid artery; CI = confidence interval; COPD = chronic obstructive pulmonary disease; cTnI = cardiac troponin I; EF = ejection fraction; OR = odds ratio; PVD = peripheral vascular disease; SD = standard deviation.

cTnI > 0.15 patients, which was not significant. The incidence of major postoperative complications and the 6-month mortality rate were significantly higher in cTnI > 0.15 ng/mL patients (31% and 13%) than in cTnI ≤ 0.15 ng/mL patients (18% and 4%). Figure 1 shows Kaplan-Meier curves for the 6-month mortality rate of the groups with preoperative TnI ≤ 0.15 ng/mL vs cTnI > 0.15 ng/mL. All deaths that occurred during the 6-month follow-up were due to cardiac causes.

Multivariable analyses are reported in Tables 3 and 4. When used as a continuous variable, the preoperative cTnI value was an independent predictor for major postoperative complications (OR, 1.20; 95% CI, 1.04 to 1.39; *p* = 0.014 per unit of cTnI increase). However, it did not predict 6-month mortality. When used as a dichotomous variable, abnormal preoperative cTnI values were associated with increased risk of death at 6 months (OR, 3.74; 95% CI, 1.04 to 13.48; *p* = 0.043 per cTnI > 0.15 ng/mL).

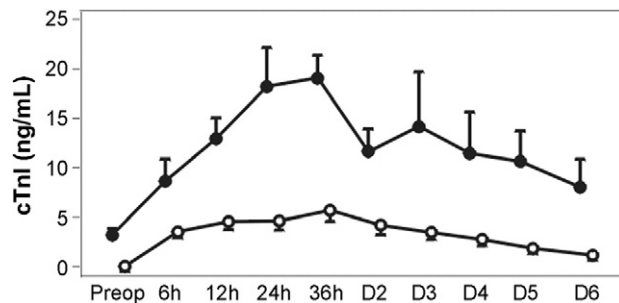


Fig 2. Mean values with the standard error (error bars) are shown for cardiac troponin I (cTnI) in patients with preoperative values cTnI ≤ 0.15 ng/mL (open circle) and cTnI > 0.15 ng/mL (closed circle) through postoperative day 6.

As expected, postoperative cTnI values increased after on-pump CABG in all patients; however, they were significantly higher in the cTnI > 0.15 ng/mL group in the first 36 postoperative hours and in postoperative days 2 to 5 (Fig 2). Postoperative cTnI mean peak values were higher in cTnI > 0.15 group patients (24.5 ± 48.0 vs 7.01 ± 9.63 ng/mL; *p* = 0.0002).

#### Time From AMI

Figure 3 shows cTnI mean values and the 6-month mortality rate in patients who underwent operations within 1, 2, or 3 weeks after AMI. Mean cTnI values were lower in patients with a longer delay from AMI before operation. The 6-month mortality rate was lower in patients operated on during the second week after AMI but the difference was not statistically significant. Considering the cTnI > 0.15 ng/mL patients, no significant difference in the 6-month mortality rate was observed between patients who underwent operations before or after 7 days from AMI (respectively, 15% and 12%; *p* = 0.52).

#### Comment

An increasing number of patients receive coronary angiography in the context of recent AMI. This has led to an increase in candidates for CABG operations as a response to failed angioplasty or because of left main/multivessel disease. Most of these patients do not require an immediate operation but are commonly transferred as a matter of urgency to cardiac surgical wards. Surgeons are therefore faced with the difficult decision of determining the optimal timing of CABG operations for clinically stable patients with a recent AMI.

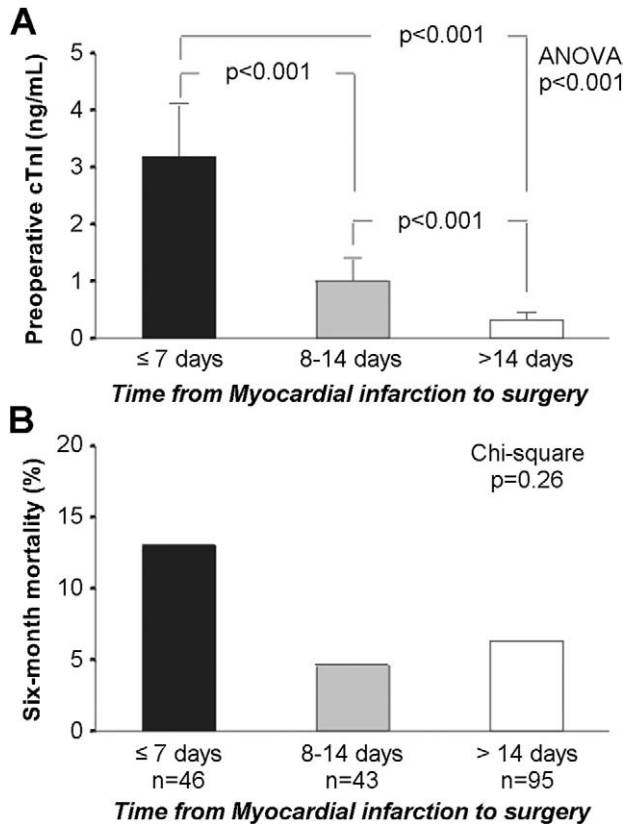


Fig 3. (A) Mean values with the standard error (error bars) are shown for cardiac troponin I (cTnI) and (B) 6-month mortality in patients operated on within week 1, 2, or 3 after acute myocardial infarction. (ANOVA = analysis of variance).

Even with improvements in myocardial protection and anesthetic management, patients with recent AMI still have a high mortality rate after CABG operations. Retrospective examination shows that CABG operations should be postponed, when possible, for 3 or more days after the onset of the AMI. A retrospective multicenter analysis of 44,365 patients who underwent CABG after a transmural or nontransmural AMI revealed that hospital mortality decreased in all patients with increasing waiting time from AMI. Patients with transmural and nontransmural AMI had similar postoperative outcomes, but the mortality rate was higher in patients with a transmural AMI if CABG was performed within 7 days after the AMI [1]. Weiss and colleagues [2] evaluated 40,159 patients hospitalized for AMI who underwent subsequent CABG. Patients were stratified by the timing of CABG in “early” ( $\leq 2$  days from AMI) and “late” ( $\geq 3$  days from AMI) groups. Mortality rates were higher in the early-group patients, suggesting that CABG ought to be deferred for 3 or more days after AMI in nonurgent patients [2].

Preoperative cardiac troponin levels are more accurate than a “time from AMI” evaluation and therefore have been introduced to improve risk stratification of patients undergoing CABG. Thielmann and colleagues [14] used preoperative cTnI values to divide 1405 elective CABG

patients in three groups: group I, cTnI  $< 0.1$  ng/ml; group II, cTnI 0.11 to 1.15 ng/mL; and group III, cTnI  $> 1.5$  ng/mL. The group III patient experienced longer intensive care unit stay and higher incidences of low cardiac output syndrome and in-hospital mortality.

The prognostic value of preoperative cTnI was also evaluated also in 57 patients with ST-elevation AMI and compared with 197 patients with non-ST-elevation AMI. The study concluded that ST elevation patients had a worse clinical outcome and that preoperative cTnI value was an independent determinant of in-hospital mortality and major adverse coronary events both in ST and non-ST-elevation patients [8].

We focused our attention in this study on patients with a recent MI who did not require emergency revascularization because their clinical condition was stable. We demonstrated that preoperative cTnI values were an independent predictor for the incidence of major postoperative complications and cTnI exceeding 0.15 ng/mL was associated with an increased risk of death during 6 months of follow-up. We showed that it takes generally more than 14 days for cTnI to return to normal values; however, cTnI is still elevated in some patients 2 weeks after AMI. This is probably due to the extension of the necrosis that occurred during MI; unfortunately, we were not able to analyze peak post-AMI cTnI values or loss of contractility after MI. However, we found it interesting that the mortality risk was similar in patients with elevated cTnI levels who underwent operations before or after 7 days from AMI, suggesting that preoperative cTnI values may be a more precise prognostic indicator than the interval between AMI and the operation.

Preoperative and intraoperative patient variables, including strong outcome predictors such as age, ejection fraction, cardiopulmonary bypass, and cross-clamp time, were similar in both groups and therefore suggested that the reason why postoperative prognosis is poor in patients with elevated preoperative cTnI values may be due to a higher degree of perioperative myocardial damage. Myocardial damage, evaluated by serial postoperative cTnI measurements, is in fact significantly increased in patients with preoperative cTnI values that are higher than normal levels. Increased postoperative myocardial damage influences not only the immediate postoperative outcome but also 6-month mortality rates. Using magnetic resonance imaging, Steuer and colleagues [15] showed that elevated cTnI, creatine kinase-MB, and troponin T levels after on-pump CABG correspond to the amount of perioperatively infarcted myocardium. The correlation between the release of cardiac enzymes and the loss of vital myocardium could probably explain the increased mortality rate that we observed in the cTnI  $> 0.15$  ng/mL group.

Different surgical strategies or pharmacologic compounds, or both, may reduce perioperative myocardial damage in the general population undergoing CABG; for example, antegrade/retrograde cardioplegia [16], warm blood cardioplegia [17], preoperative IABP [18], and preoperative levosimendan administration [19]. Future research should be focused on identifying the optimal

surgical or pharmacologic approach to limit perioperative myocardial damage in patients undergoing CABG with ongoing laboratory signs of recent AMI.

The principle limitation of our study was its retrospective design and the consequent lack of serial postoperative echocardiographic or magnetic resonance imaging evaluation of left ventricular function to possibly correlate postoperative myocardial function with survival. As already stated, another important limitation was the lack of a cTnI value when AMI was initially diagnosed.

We therefore conclude that, if possible, normalization of cTnI values before CABG operations seems warranted in patients who have sustained a recent AMI, but this should be confirmed by specifically designed studies. If clinical conditions or coronary anatomy require a patient with elevated cTnI values to undergo a CABG operation, then surgeons ought to be aware that these patients are under a higher risk of perioperative myocardial damage and, consequently, a higher risk of postoperative adverse events, including death, within the 6 months after the operation.

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We thank Felicia Kohn Passaro for kindly reviewing the manuscript.

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## INVITED COMMENTARY

As cardiac surgeons, we are quite frequently faced with the situation of performing coronary artery bypass grafting after acute myocardial infarction (AMI). With the advent of primary angioplasty, the patients referred to us for surgical intervention will be those who have been deemed unfit for percutaneous intervention because of unfavorable anatomy of coronary disease for angioplasty, diffuse disease, or poor left ventricular function. The most important clinical decision in these situations is when to perform the operation. Too soon may be too risky, and too late may invite another acute coronary

event. Various studies, as quoted by Paparella and colleagues [1], have tried to inform us about the risk of the operation according to the time elapsed since the AMI.

It is appreciated that authors in this study have tried to investigate whether one can have a guideline based on the measurement of cardiac troponin I (cTnI). In this study, the patients with a cTnI level of less than 0.15 ng/mL had an advantage in terms of less postoperative morbidity and death at 6 months. Assuming that now we put this in practice, would we wait to perform surgical revascularization in patients with AMI until the cTnI falls