Patterns of Cardiac Marker Surveillance After Elective Percutaneous Coronary Intervention and Implications for the Use of Periprocedural Myocardial Infarction as a Quality Metric: A Report From the National Cardiovascular Data Registry (NCDR)

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Patterns of Cardiac Marker Surveillance After Elective Percutaneous Coronary Intervention and Implications for the Use of Periprocedural Myocardial Infarction as a Quality Metric: A Report From the National Cardiovascular Data Registry (NCDR)

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The Clinical Issue

With recent advances in catheter technology and adjunctive pharmacotherapy, percutaneous coronary intervention (PCI) has achieved high procedural success rates and is a widely used means of myocardial revascularization among patients with coronary artery disease. Outcomes after PCI vary depending on patient selection, angiographic complexity, operator skill, and institutional care practices. Periprocedural myocardial infarction (MI) is detected in up to 30% of patients undergoing PCI, depending on the marker tested, population studied, and threshold for diagnosis based upon the degree of marker elevation (1). In clinical trials of PCI-related therapies, periprocedural MI is commonly adjudicated as an outcome measure and has been shown to be significantly associated with increased long-term mortality (2–5). However, there is no clearly defined threshold at which this increase in risk and definition of "myocardial infarction" converge, nor is there consensus on what treatment should be rendered when elevated markers are detected after a procedure (6). As such, expert panels have varied in their recommendations. Although some recommend routine cardiac marker testing after PCI (1), others recommend measurements driven by evidence of symptomatic ischemia or procedural complications (7,8).

Recent quality improvement initiatives have led to the development of both regional and national databases scrutinizing PCI practice and outcome variations (9–11). Whereas periprocedural MI has been suggested as a metric for assessing the quality of PCI care, in light of the aforementioned differences in opinion regarding the role of periprocedural marker testing, the viability of periprocedural MI as a quality metric should be assessed. Studies to date examining the incidence of periprocedural MI have largely been composed of single-center registries or post hoc clinical trial database analyses in which post-procedure cardiac marker measurements are mandated by study protocol. With the American College of Cardiology National Cardiovascular Database CathPCI Registry (ACC-NCDR), we investigated contemporary patterns of post-PCI cardiac marker testing in a large national database, patient predictors of marker testing, and variability among

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hospitals in the frequency of marker measurement and periprocedural MI detection.

Data From the ACC-NCDR

The ACC-NCDR is a large, ongoing, national registry of diagnostic cardiac catheterization and PCI in the U.S. and, as such, offers a unique opportunity to examine contemporary patterns of post-PCI cardiac marker testing. Patient and hospital characteristics were collected prospectively via a standardized set of data elements and definitions (12).

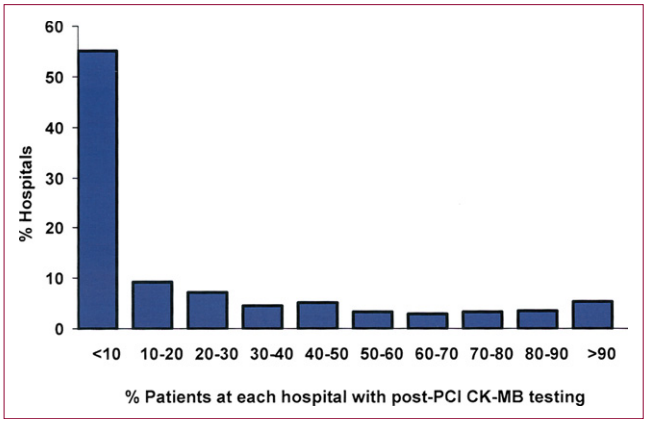
Between January 1, 2004, and March 30, 2007, data from 708,481 consecutive patients undergoing PCI in the U.S. were entered into the ACC-NCDR database. Patients who presented with acute coronary syndrome (n = 458,658) or with pre-procedure creatine kinase (CK)-MB or troponin levels greater than the upper limit of normal (ULN) (n = 36,428) were excluded, owing to the inability to determine whether post-PCI marker testing was performed as a result of the presenting ACS event and likely overlap of positive cardiac markers from the pre- to post-PCI time periods. The final study population consisted of 213,395 patients who underwent elective PCI at 463 hospitals with no reported evidence of myocardial necrosis before the PCI procedure.

Patterns of Cardiac Marker Testing

Across all hospitals, a median of 7% of patients undergoing PCI had post-procedure CK-MB levels measured. As shown in Figure 1, most hospitals did not routinely measure CK-MB levels after elective PCI; 298 of 463 hospitals (64.4%) measured post-procedure CK-MB levels in <20% of patients who underwent PCI. On the other end of the spectrum, 59 of 463 hospitals (12.7%) performed post-procedure marker testing more routinely in ≥70% of patients undergoing PCI. Hospitals that routinely measured post-procedure cardiac markers (defined as those that measured markers in ≥70% of patients undergoing PCI) had higher diagnostic catheterization and PCI volumes/year (Table 1).

Figure 1 Distribution of Hospitals by the Frequency of Post-Procedure Cardiac Marker Testing

CK = creatine kinase; PCI = percutaneous coronary intervention.



Abbreviations and Acronyms

ACC = American College of Cardiology
AHA = American Heart Association
CABG = coronary artery bypass grafting
CK = creatine kinase
MI = myocardial infarction
NCDR = National Cardiovascular Database Registry
PCI = percutaneous coronary intervention
ULN = upper limit of normal

A total of 52,746 patients (24.7% of the total PCI population) had CK-MB assessment after PCI. Among the 181,990 patients treated at 404 hospitals that do not routinely measure post-PCI markers, there were very few differences in baseline demographic or clinical characteristics between patients with and without CK-MB testing (Table 2). However, patients with post-PCI CK-MB measurement had higher-risk angiographic characteristics such as multivessel disease, bifurcation or type C lesions, and lesions requiring the use of debulking devices. Although periprocedural ischemia was not captured in the data collection form, patients with measured markers had longer procedural times and higher rates of procedural complications such as vessel dissection or acute vessel closure (Table 3).

Multivariable logistic regression was used to determine factors independently associated with cardiac marker testing in patients who underwent PCI at hospitals that do not routinely assess post-procedure markers. Among these independent patient and hospital variables (Table 4), the most significant factor associated with testing was the presence of a periprocedural complication.

Association of Marker Testing With Periprocedural MI Detection and Outcomes

Among the 52,746 patients with measured CK-MB levels, 12,728 (24%) had new CK-MB elevations greater than the ULN after procedure. Of these patients, 8,351 (16%) had peak CK-MB levels between 1 and 3 × ULN and 4,377 (8%) had peak CK-MB levels >3 × ULN—a threshold often used to define periprocedural MI in consensus recommendations (6). Among patients with peak CK-MB levels >3 × ULN, only 14.9% had reported periprocedural complications such as acute closure, perforation, or dissection.

Patients undergoing elective PCI at hospitals that routinely measured post-procedure markers had a trend toward lower in-hospital mortality compared with those treated at hospitals that do not perform routine marker testing: odds ratio 0.74, 95% confidence interval 0.53 to 1.02 after adjustment for independent predictors of mortality derived from a validated mortality risk model for patients undergo-

Table 1 Hospital Characteristics

	Hospitals With ≥70% Marker Testing (n = 59)	Hospitals With <70% Marker Testing (n = 404)	p Value
Number of inpatient beds*	400 (254, 589)	348 (249, 500)	0.07
Academic hospital (%)†	61.0	54.5	0.34
Diagnostic catheter volume/yr*	2,000 (1,046, 3,300)	1,459 (900, 2,313)	0.02
PCI volume/yr*	785 (296, 1,193)	568 (329, 882)	0.04
Surgical backup (%)	86.4	85.9	0.91
Hospital region (%)			
West	15.3	21.8	0.13
Northeast	20.3	10.4	
Midwest	35.6	37.4	
South	25.4	29.0	
Hospital location (%)			
Urban	50.8	53.2	0.37
Suburban	23.7	28.7	
Rural	25.4	18.1	

*Presented as median (25th, 75th percentile). †Academic affiliation reflects listing in Council of Teaching Hospitals.
PCI = percutaneous coronary intervention.

ing PCI (unpublished model from the ACC-NCDR database, c-index = 0.93, including age, body mass index, diabetes, prior heart failure, prior PCI, prior cerebrovascular or peripheral vascular disease, renal dysfunction, cardiogenic shock, ejection fraction, lesion severity, lesion complexity [ACC/American Heart Association (AHA)/Society of Cardiovascular Angiography and Interventions (SCAI) lesion classification type], and pre-procedure Thrombolysis In Myocardial Infarction [TIMI] flow). Patients treated at hospitals that routinely performed post-procedure CK-MB testing were also more likely to be discharged on guideline-recommended secondary prevention therapies.

As shown in Figure 2, periprocedural MI detection (defined as peak CK-MB levels >3 × ULN) correlated with the frequency of CK-MB measurement ($p < 0.0001$). Hospitals that more routinely measured markers had significantly higher rates of periprocedural MI detection (4.8% vs. 1.6%, $p < 0.0001$). However, the association was reversed when the denominator was limited to only those patients with measured CK-MB levels (n = 52,746). Hospitals that tested less frequently had higher rates of periprocedural MI detection (11.4% vs. 5.4%, $p < 0.0001$).

Table 2 Baseline Patient Characteristics Among 181,990 Patients Treated at 404 Hospitals That Measured Post-PCI CK-MB Levels in <70% of Patients

	Patients With Post-PCI Marker Testing (n = 25,214)	Patients Without Post-PCI Marker Testing (n = 156,776)
Demographic (%)		
Age (yrs)*	66 (57, 74)	66 (57, 74)
Female	32.7	33.3
Caucasian	85.8	87.7
Clinical history (%)		
Hypertension	80.2	79.4
Diabetes mellitus	35.1	34.7
Dyslipidemia	80.0	78.9
Prior MI	28.2	29.9
Prior PCI	40.5	41.5
Prior CABG	19.7	20.0
Prior CHF	11.0	11.0
Peripheral vascular disease	13.8	13.0
Renal insufficiency	5.2	5.3

A total of 31,405 patients from 59 hospitals that routinely measured post-percutaneous coronary intervention (PCI) creatine kinase (CK)-MB levels (in ≥70% of all patients undergoing PCI) were not included in this table. *Presented as median (25th, 75th percentile).
CABG = coronary artery bypass graft surgery; CHF = congestive heart failure, MI = myocardial infarction.

Discussion

This report from the ACC-NCDR shows that post-procedure cardiac markers are assessed in only one-quarter of patients after elective PCI, with wide variations in the pattern of marker surveillance across hospitals in the U.S. Hospitals that routinely performed marker testing had higher rates of periprocedural MI detection despite a trend toward lower mortality and greater adherence to recommended medications that suggest better overall quality of care for PCI patients at these hospitals. Therefore, in the absence of routine cardiac marker surveillance after PCI, the use of periprocedural MI as a quality metric for PCI will be misleading.

Current Patterns of Post-Procedure Cardiac Marker Testing

In the ACC/AHA/SCAI PCI guidelines, post-procedure CK-MB measurement was designated as a class IB recommendation for patients with suspected ischemia during PCI, whereas routine marker measurement for all patients undergoing PCI was given a class IIC recommendation (8,13). This report shows that most clinicians are following guideline recommendations and primarily performing testing in patients with higher-risk lesions or procedural complications. As a result, cardiac markers are assessed infrequently after PCI; yet the frequency of marker measurement corre-

Table 3 Angiographic and Procedural Characteristics Among 181,990 Patients Treated at 404 Hospitals That Measured Post-PCI CK-MB Levels in <70% of Patients

	Patients With Post-PCI Marker Testing (n = 25,214)	Patients Without Post-PCI Marker Testing (n = 156,776)
Disease burden (%)		
Ejection fraction*	59 (50, 61)	57 (50, 60)
Multivessel disease	55.5	52.5
Worst lesion characteristic (%)		
Lesion location		
Left main	2.2	2.0
Proximal LAD	17.7	17.6
Proximal RCA/mid LAD/proximal LCx	39.7	38.7
Other	40.3	41.8
Pre-procedure TIMI flow grade 0 to 1	12.2	13.7
High-risk (type C) lesion†	39.4	35.2
Lesion length ≥20 mm	39.9	37.9
Bifurcation lesion	14.6	12.1
Device used (%)		
Any stent	90.5	91.3
Drug-eluting stent	80.7	82.1
Debulking device‡	5.4	4.8
Procedural characteristics (%)		
Fluoroscopy time (min)*	12.1 (7.4, 20.2)	11.1 (6.9, 18.3)
Contrast volume (ml)*	200 (140, 270)	190 (135, 250)
Lesion success (%)§	95.7	95.1
Any procedural complication (%)‖	4.9	3.1
Dissection	3.9	2.6
Acute vessel closure	1.4	0.6
Perforation	0.5	0.3
No reflow	0.8	0.4

A total of 31,405 patients from 59 hospitals that routinely measured post-PCI CK-MB levels (in ≥70% of all patients undergoing PCI) were not included in this table. *Presented as median (25th, 75th percentile). †Per American College of Cardiology/American Heart Association (ACC/AHA) lesion classification scheme (29): high-risk (type C) lesion defined as length >2 cm, excessive tortuosity of proximal segment, extremely angulated segments >90°, total occlusions >3 months old and/or bridging collaterals, inability to protect major side branches, or degenerated vein grafts with a friable lesion. ‡Debulking device includes any atherectomy, thrombectomy, or extraction catheters or cutting balloons. §Lesion success defined as post-procedure Thrombolysis In Myocardial Infarction (TIMI) flow grade 3 with <25% residual stenosis if lesion stented or <50% residual stenosis if no stent used. ‖Procedural complication defined as any coronary dissection, perforation, no reflow, or acute closure during the procedure.
LAD = left anterior descending coronary artery; LCx = left circumflex artery; RCA = right coronary artery; other abbreviations as in Table 2.

lated directly with the likelihood of periprocedural MI detection. Although clinically apparent procedural complications such as distal embolization, side branch occlusion, or intimal dissection contribute to periprocedural myocardial injury (14–17), the overall incidence of such complications was low and the majority of patients with CK-MB elevation had no reported periprocedural complication. These observations raise the concern that in the absence of complications meeting the threshold for suspected ischemia during PCI that might instigate post-procedure marker testing, hospitals that do not routinely perform marker testing might significantly underestimate the true incidence of periprocedural MI.

Notably, 8,166 patients (4% of the overall population) had troponin-only measurements after PCI. Troponin has become the preferred cardiac biomarker, owing to its high sensitivity and specificity for myocardial damage (6). Among patients undergoing PCI, the magnitude of post-procedural troponin elevation correlates directly with the extent of myocardial injury (6,18). Yet, although troponin is more sensitive than CK-MB in detecting smaller amounts of periprocedural myonecrosis, the prognostic implications of troponin elevation after PCI are less certain (19–22). In a study by Cavallini et al. (20), troponin elevation was detected in 44% of patients undergoing PCI (vs. 16% CK-MB elevation) but, unlike CK-MB, did not predict 2-year mortality (odds ratio 1.2, 95% confidence interval 0.9 to 1.7). Similarly, a study by Miller et al. (23) showed that the rise in troponin post-procedure was not predictive of long-term outcomes. As such, troponin elevations were not incorporated into the definition of periprocedural MI in this report.

Implications of Detecting Periprocedural Myocardial Injury

Routine marker measurement after PCI has been controversial, largely owing to its uncertain utility in the absence of clinically apparent ischemia during PCI, particularly in regard to therapeutic decision-making after PCI when an asymptomatic periprocedural MI is detected. Among patients with uncomplicated PCI, CK-MB elevation has been associated with discrete regions of delayed hyperenhancement within the target vessel perfusion territory on magnetic resonance imaging as well as more diffuse plaque burden and thrombus-rich lesions (24–26). As such, practice guidelines recommend that patients with periprocedural CK-MB elevation >3 × ULN should be treated like a

Table 4 Factors Associated With Post-Procedure Cardiac Marker Testing Among 181,990 Patients Treated at 404 Hospitals That Measured Post-PCI CK-MB Levels in <70% of Patients

Variable	Adjusted Odds Ratio	95% Confidence Interval	Chi-Square	p Value
Patient factors				
Previous MI	0.91	0.88–0.94	36.4	<0.001
Dyslipidemia	1.07	1.04–1.11	15.6	<0.001
Previous CABG	0.94	0.91–0.98	9.4	0.002
Heart failure on admission	1.07	1.02–1.12	6.8	0.009
Angiographic factors				
Procedural complication*	1.56	1.47–1.67	180.3	<0.001
High-risk/type C lesion†	1.17	1.14–1.21	118.8	<0.001
Multivessel disease burden	1.15	1.12–1.19	96.2	<0.001
Bifurcation lesion	1.19	1.14–1.24	76.6	<0.001
Pre-procedure TIMI flow grade 0 to 1	1.07	1.05–1.08	54.3	<0.001
Post-procedure TIMI flow grade 0 to 1	1.16	1.11–1.21	50.0	<0.001
Stent use	0.86	0.82–0.90	37.8	<0.001
Debulking device use‡	1.08	1.01–1.14	5.5	0.02
Hospital factors				
Midwest hospital location	0.73	0.71–0.76	354.3	<0.001
Teaching hospital	0.83	0.80–0.85	155.0	<0.001
Hospital beds (per 100 increase)	1.03	1.03–1.04	76.1	<0.001
Northeast hospital location	1.21	1.15–1.26	67.6	<0.001

A total of 31,405 patients from 59 hospitals that routinely measured post-PCI CK-MB levels (in ≥70% of all patients undergoing PCI) were not included in this table. Other nonsignificant variables included in the model are age, gender, diabetes, dyslipidemia, renal failure, multivessel intervention, lesion location, and hospital region. *Procedural complication defined as any coronary dissection, perforation, no reflow, or acute closure during the procedure. †Per ACC/AHA lesion classification scheme (29): high-risk (type C) lesion defined as length >2 cm, excessive tortuosity of proximal segment, extremely angulated segments >90°, total occlusions >3 months old and/or bridging collaterals, inability to protect major side branches, or degenerated vein grafts with a friable lesion. ‡Debulking device includes any atherectomy, thrombectomy, or extraction catheters or cutting balloons. Abbreviations as in Tables 2 and 3.

standard MI patient with initiation of appropriate secondary prevention measures before discharge (6,8,13). This report showed that patients who underwent routine post-procedure CK-MB testing were more likely to be discharged on aspirin, clopidogrel, beta-blocker drugs, and statin drugs, so routine surveillance of post-PCI cardiac markers seems to correlate with better quality of overall hospital care for patients undergoing PCI.

On an institutional level, routine post-procedure marker measurement could potentially stimulate more rigorous assessment of PCI quality and influence PCI practices (27). Periprocedural MI rates higher than national standards should prompt institutional review of the patient case-mix for PCI procedures, decision-making regarding the choice of percutaneous versus surgical revascularization for individual patients, operator technique, device selection, and the use of adjunctive pharmacotherapies during PCI procedures that affect periprocedural complications.

Should Periprocedural MI Be Used as a Quality Metric?

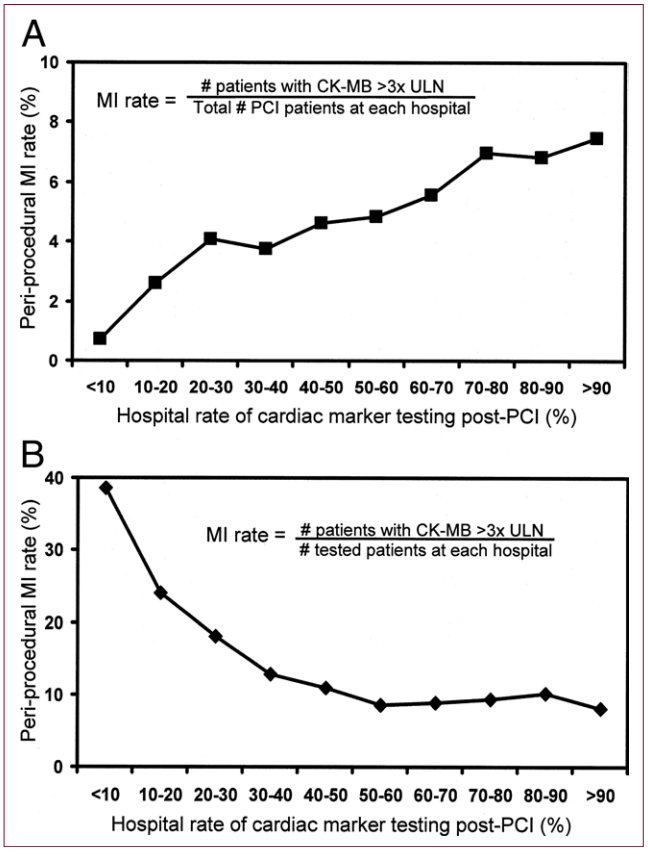
Periprocedural MI, an end point frequently used in clinical trials, has been suggested as a quality metric for PCI care (28). However, on the basis of these results, observational databases, in contrast to clinical trials, cannot provide an accurate assessment of the frequency of periprocedural MI, owing to wide variations in the measurement of post-procedure cardiac markers. Although several states have instituted quality improvement data registries that mandate post-procedural marker assessment (10,11), very few hospitals nationally perform systematic post-PCI marker surveillance. Because most periprocedural MIs are clinically silent, routine marker measurement after PCI is necessary to make adequate comparisons of quality of care and procedural outcomes across hospitals.

Hospitals that routinely measure post-procedure CK-MB levels likely represent those that have a strong interest in quality improvement, as suggested by the trend toward lower adjusted in-hospital mortality and greater use of appropriate discharge medications. However, the principle of "the more you look, the more you find" is demonstrated here. Hospitals that routinely screen for periprocedural MI might in fact be penalized for practicing a "quality process" by demonstrating worse outcomes (higher rates of periprocedural MI) when benchmarked against hospitals that measure post-procedure markers less frequently. Thus, at this time, periprocedural MI cannot be a quality metric for PCI care unless routine post-procedure marker measurement is implemented universally.

Several limitations of the data were present. First, among patients with post-procedural marker measurement, the incidence of periprocedural MI might be underestimated if the patient was discharged before enough time elapsed for post-PCI markers to reach a true peak. Second, detailed information regarding periprocedural ischemic symptoms and electrocardiographic changes was not collected in this registry. Finally, although we adjusted for a broad range of clinical and hospital variables in the mortality analysis, unmeasured confounders might have influenced the results.

Figure 2 Periprocedural MI Rate for 463 Hospitals

Periprocedural myocardial infarction (MI) rate for 463 hospitals when the denominator is **(A)** total number of patients undergoing percutaneous coronary intervention (PCI) at each hospital and **(B)** total number of PCI patients at each hospital with post-procedure creatine kinase (CK)-MB testing. ULN = upper limit of normal.



Conclusions

Although periprocedural MI has been advocated as a quality indicator of PCI care, current data show that the majority of hospitals do not systematically assess cardiac markers after elective PCI; thus, the incidence of periprocedural MI might be significantly underestimated in current clinical practice. Therefore, the use of periprocedural MI as a quality metric for PCI procedures will remain misleading until efforts to standardize marker measurement practices are successful.

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