

**Treatments, Trends, and Outcomes of Acute Myocardial Infarction and Percutaneous Coronary Intervention**

Matthew T. Roe, John C. Messenger, William S. Weintraub, Christopher P. Cannon, Gregg C. Fonarow, David Dai, Anita Y. Chen, Lloyd W. Klein, Frederick A. Masoudi, Charles McKay, Kathleen Hewitt, Ralph G. Brindis, Eric D. Peterson, and John S. Rumsfeld

*J. Am. Coll. Cardiol.* 2010;56;254-263

doi:10.1016/j.jacc.2010.05.008

**This information is current as of July 29, 2010**

The online version of this article, along with updated information and services, is located on the World Wide Web at:

<http://content.onlinejacc.org/cgi/content/full/56/4/254>

**JACC**

*JOURNAL of the AMERICAN COLLEGE of CARDIOLOGY*



# News from the NCDR



## Treatments, Trends, and Outcomes of Acute Myocardial Infarction and Percutaneous Coronary Intervention

Matthew T. Roe, MD, MHS,\* John C. Messenger, MD,†  
William S. Weintraub, MD,‡ Christopher P. Cannon, MD,§  
Gregg C. Fonarow, MD,|| David Dai, MS,\* Anita Y. Chen, MS,\*  
Lloyd W. Klein, MD,¶ Frederick A. Masoudi, MD, MSPH,†#  
Charles McKay, MD,\*\* Kathleen Hewitt, RN,††  
Ralph G. Brindis, MD, MPH,‡‡ Eric D. Peterson, MD, MPH,\*  
John S. Rumsfeld, MD, PhD†§§

*Durham, North Carolina; Aurora and Denver, Colorado; Newark, Delaware; Boston, Massachusetts; Los Angeles, Torrance, and San Francisco, California; Chicago, Illinois; and Washington, DC*

Coronary artery disease remains a major public health problem in the U.S. as many Americans experience an acute myocardial infarction (MI) and/or undergo percutaneous coronary intervention (PCI) each year. Given the attendant risks of mortality and morbidity, acute MI remains a principal focus of cardiovascular therapeutics. Moreover, 30-day mortality and rehospitalization rates for acute MI are publicly reported in an effort to promote optimal acute MI care, and aspects of MI care delivery are the focus of local,

regional, and national quality initiatives (1–3). PCI remains a central therapy for patients with symptomatic coronary artery disease, particularly among patients with acute MI, and has garnered tremendous attention in the last decade with issues such as the risks and benefits of drug-eluting stents (DES) and adjunctive antithrombotic therapies.

However, there are few representative data describing contemporary patterns of care and outcomes trends for patients with acute MI and/or those undergoing PCI. This is of particular importance because the process of updating clinical practice guidelines and quality metrics for acute MI and PCI has accelerated (4). Updates or revisions to the American College of Cardiology (ACC)/American Heart Association (AHA) practice guidelines for PCI, ST-segment elevation myocardial infarction (STEMI), and unstable angina (UA)/non-ST-segment elevation myocardial infarction (NSTEMI) have been published within the last 3 years, building upon prior versions published earlier in the decade (5–7). The ACC and AHA have also published performance measures to direct quality assessment and improvement activities (8). However, data are lacking on current guideline adherence as well as on trends in the

From the \*Duke Clinical Research Institute, Duke University Medical Center, Durham, North Carolina; †University of Colorado–Denver, Aurora, Colorado; ‡Christiana Care Health System, Newark, Delaware; §TIMI Study Group, Brigham and Women’s Hospital, Boston, Massachusetts; ||University of California–Los Angeles Medical Center, Los Angeles, California; ¶Rush-Presbyterian–St. Luke’s Medical Center, Chicago, Illinois; #Denver Health Medical Center, Denver, Colorado; \*\*Harbor-UCLA Medical Center, Torrance, California; ††National Cardiovascular Data Registry, Washington, DC; †††Northern California Kaiser Permanente, San Francisco, California; and the §§Denver Veterans Affairs Medical Center, Denver, Colorado. The NCDR ACTION Registry–GWTG is a program of the American College of Cardiology and the American Heart Association that receives funding from the Merck/Schering-Plough Corporation and Bristol-Myers Squibb/Sanofi Pharmaceutical Partnership. The CathPCI registry does not receive external funding. For complete author disclosures, please see the end of this paper.

Manuscript received November 5, 2009; revised manuscript received May 17, 2010, accepted May 18, 2010.

quality of care and outcomes for the large population of patients in the U.S. with symptomatic coronary artery disease.

Large-scale, national clinical registries provide an important opportunity to evaluate current clinical practice. The American College of Cardiology's National Cardiovascular Data Registry (NCDR) comprises a suite of programs involving >2,400 hospitals in the U.S. ([www.ncdr.com](http://www.ncdr.com)). We analyzed the NCDR Acute Coronary Treatment and Intervention Outcomes Network (ACTION) Registry–Get With The Guidelines (AR-G) and Catheterization PCI (CathPCI) databases to characterize recent trends in treatment and outcomes among patients with acute MI and those undergoing PCI. More specifically, we sought to evaluate patient and hospital characteristics, rates of guideline adherence, procedural details, and in-hospital outcomes related to acute MI and PCI care over the last several years.

## Methods

**Patient populations.** The NCDR AR-G registry is a national, voluntary quality improvement registry program that is a partnership of the ACC and AHA and includes data on the in-hospital treatment of patients with acute MI, both STEMI and NSTEMI (9). The cohort analyzed for AR-G for this study includes all 131,980 STEMI and NSTEMI patients enrolled from approximately 250 participating centers from the inception of AR-G in January 2007 through June 2009.

The NCDR CathPCI registry is a national quality improvement program focused on diagnostic cardiac catheterization and PCI, and is a partnership between the ACC and the Society for Cardiovascular Angiography and Interventions. The CathPCI registry includes in-hospital data on patients undergoing cardiac catheterization and PCI procedures (10). The analytic cohort from CathPCI for this study includes all 1,708,247 patients who underwent PCI in January 2005 through June 2009; there were 436 participating hospitals in quarters 1 and 2, 2005, and 959 hospitals in quarters 1 and 2, 2009.

**Statistical methods.** Comparisons of patient characteristics, treatments, procedural complications, and in-hospital outcomes were performed between the first 6 months and the last 6 months of the respective analysis time periods for the AR-G (quarters 1 to 2, 2007 vs. quarters 1 to 2, 2009) and CathPCI (quarters 1 to 2, 2005 vs. quarters 1 to 2, 2009) registries. In the AR-G registry cohort, the temporal comparisons were stratified by type of MI (STEMI or NSTEMI). In the CathPCI registry cohort, the comparisons were stratified by acute coronary syndrome (ACS [UA, NSTEMI, and STEMI]) and non-ACS (elective PCI) patients. Median values with interquartile ranges (25th, 75th percentiles) were used to describe continuous variables, and percentages were reported for categorical variables. Continuous and ordinal categorical variables were compared using the stratum-

adjusted Wilcoxon rank-sum test, and nominal categorical variables were compared using the stratum-adjusted chi-square test.

For the AR-G registry, composite performance scores and defect-free care scores were determined separately for STEMI and NSTEMI patients, as detailed in the Online Appendix (8,11,12). The p values for the temporal trends of composite performance scores and defect-free care scores were obtained using linear regression with time as an ordinal independent variable.

Temporal changes in clinical outcomes (adjusted in-hospital mortality and unadjusted major bleeding) were analyzed by quarter separately for STEMI and NSTEMI patients for the 2.5-year analysis time period for the AR-G registry cohort. The AR-G in-hospital mortality model was utilized to calculate adjusted mortality rates for the NSTEMI and STEMI populations (13). For the CathPCI registry, temporal changes in adjusted in-hospital mortality and unadjusted periprocedural vascular and bleeding complications were analyzed by quarter separately in the ACS and non-ACS populations for the 4.5-year analysis time period. The CathPCI risk-adjusted in-hospital mortality model was utilized to calculate adjusted in-hospital mortality rates for the ACS and non-ACS populations (14). The p values for the temporal trends of in-hospital outcomes and complications were obtained by modeling time as an ordinal independent variable using the logistic generalized estimating equations method with an exchangeable working correlation matrix to account for within-hospital clustering because patients at the same hospital are more likely to have similar responses relative to patients at other hospitals (i.e., within-center correlation for responses) (15).

A p value of <0.05 was considered statistically significant for all tests. All analyses were performed using SAS software (version 9.2, SAS Institute, Cary, North Carolina).

## Results

**Patient characteristics.** Among the AR-G registry cohort, there was an increase in the proportion of patients with cardiac risk factors of current smoking, hypertension, and hyperlipidemia (Table 1). Among ACS patients in the CathPCI registry cohort, there was an increase in the

### Abbreviations and Acronyms

**ACC** = American College of Cardiology

**ACS** = acute coronary syndromes

**ACTION** = Acute Coronary Treatment and Intervention Outcomes Network

**AHA** = American Heart Association

**AR-G** = ACTION Registry–Get With The Guidelines

**CathPCI** = catheterization and percutaneous coronary intervention

**DES** = drug-eluting stent

**LMWH** = low-molecular-weight heparin

**NCDR** = National Cardiovascular Data Registry

**NSTEMI** = non–ST-segment elevation myocardial infarction

**PCI** = percutaneous coronary intervention

**UA** = unstable angina

**Table 1** Changes in Acute MI Patient Characteristics From the AR-G Registry

Variables	STEMI			NSTEMI		
	Q1–Q2 2007 (n = 9,390)	Q1–Q2 2009 (n = 11,125)	p Value	Q1–Q2 2007 (n = 15,417)	Q1–Q2 2009 (n = 16,247)	p Value
<b>Demographics</b>						
Age, yrs*	61 (52, 72)	60 (52, 71)	0.24	67 (56, 79)	67 (56, 79)	0.69
Female sex, %	30.3	29.7	0.19	39.3	37.9	0.30
Race/ethnicity, %			0.006†			0.87†
White	84.8	84.8		84.1	83.2	
African-American	7.3	7.9		8.7	9.9	
Hispanic	3.4	3.6		3.4	3.6	
Asian	1.5	1.8		1.5	1.5	
Other	2.6	0.7		1.8	0.7	
<b>Cardiac risk factors, %</b>						
Current smoking	40.8	43.7	0.02	28.8	29.8	0.09
Hypertension	60.2	62.5	0.19	72.1	76.7	<0.0001
Hyperlipidemia	46.7	52.2	0.002	55.5	63.1	<0.0001
Diabetes mellitus	23.0	22.7	0.70	33.7	35.0	0.27
<b>Medical history, %</b>						
Prior MI	19.0	18.8	0.29	27.0	27.9	0.60
Prior HF	5.7	5.4	0.86	16.0	16.9	0.12
Prior PCI	18.3	18.9	0.84	22.3	24.2	0.01
Prior CABG	7.5	7.0	0.39	18.0	18.7	0.38
Prior stroke	5.7	4.7	0.04	9.6	9.7	0.89
Prior PAD	6.0	5.5	0.56	11.3	12.3	0.01
<b>Presentation features</b>						
Symptom onset to presentation, h*‡	1.7 (1.0, 3.7)	1.5 (0.9, 3.1)	0.0001	2.8 (1.3, 7.0)	2.4 (1.2, 6.1)	<0.0001
Signs of HF, %	12.8	10.1	0.0002	22.0	20.6	0.003
eGFR, cc/min*§	72 (57, 87)	73 (58, 89)	0.07	66 (48, 82)	68 (50, 86)	<0.0001

\*Continuous variables displayed as median values with 25th, 75th percentiles. †The p values compare the distribution of race/ethnicity categories. ‡Data missing for time from symptom onset to presentation in 23% of NSTEMI patients and 12% of STEMI patients. §eGFR determined with Modification of Diet in Renal Disease (MDRD) formula; dialysis patients excluded from calculations.

AR-G = Acute Coronary Treatment and Intervention Outcomes Network (ACTION) Registry—Get With The Guidelines; CABG = coronary artery bypass graft surgery; eGFR = estimated glomerular filtration rate; HF = heart failure; MI = myocardial infarction; NSTEMI = non-ST-segment elevation myocardial infarction; PAD = peripheral arterial disease; PCI = percutaneous coronary intervention; Q = quarter; STEMI = ST-segment elevation myocardial infarction.

proportion of patients with cardiac risk factors and signs of heart failure on presentation and a decrease in the proportion of patients with a history of prior MI, prior PCI, or prior coronary artery bypass graft surgery (Table 2). Furthermore, the proportion of ACS patients in the CathPCI registry cohort with UA decreased, whereas the proportions of patients with NSTEMI and STEMI increased (Table 2).

**Treatment and procedural details.** In the AR-G registry, increases in the use of anticoagulants were demonstrated in both STEMI and NSTEMI patients, whereas there were decreases in the use of acute beta-blockers and glycoprotein IIb/IIIa inhibitors (Table 3). Among NSTEMI patients, decreased rates of overdosing of unfractionated heparin, low-molecular-weight heparin (LMWH), and glycoprotein IIb/IIIa inhibitors were observed. Among STEMI patients, the overall proportion of eligible patients who received reperfusion therapy increased, paralleling an increase in the proportion of reperfused patients who underwent primary PCI as well as an increase in the proportion of patients who met quality benchmarks for rapid reperfusion times.

The use of early cardiac catheterization within 48 h and the use of revascularization procedures increased in NSTEMI patients. Increases in the use of discharge statins and clopidogrel, as well as cardiac rehabilitation referral, were observed for both STEMI and NSTEMI patients (Table 3).

In the CathPCI registry cohort, patterns of antithrombotic agent (anticoagulant and antiplatelet medications) use significantly changed among both ACS and non-ACS patients, with increasing use of bivalirudin and decreasing use of unfractionated heparin, glycoprotein IIb/IIIa inhibitors, and LMWH (Table 4). The complexity of PCI procedures appeared to increase, with a larger proportion of patients with type C lesions treated during PCI in both the ACS and non-ACS cohorts at the end of the analysis time period. Significant decreases in the use of DES were demonstrated in both ACS and non-ACS patients, but increases in the use of new DES types (everolimus and zotarolimus) were also observed.

**Composite measures.** The acute MI composite performance scores in the AR-G registry were high, but increased from 90% to 94% among STEMI patients and from 90% to 92% among NSTEMI patients (Fig. 1A). The defect-free composite care scores were lower, but significant improvements in these scores were demonstrated in both STEMI (50% to 69%) and NSTEMI patients (58% to 66%) (Fig. 1B).

**In-hospital/procedural outcomes.** Among patients in the AR-G registry, risk-adjusted in-hospital mortality rates decreased from 6.2% to 5.5% among STEMI patients and decreased from 4.3% to 3.9% among NSTEMI patients during the study period (Fig. 2A). Unadjusted major bleeding rates did not significantly

**Table 2** Changes in PCI Patient Characteristics From the CathPCI Registry

Variables	ACS			Non-ACS		
	Q1–Q2 2005 (n = 92,534)	Q1–Q2 2009 (n = 144,989)	p Value	Q1–Q2 2005 (n = 50,532)	Q1–Q2 2009 (n = 79,892)	p Value
<b>Demographics</b>						
Age, yrs*	63 (54, 73)	63 (54, 73)	<0.0001	66 (57, 74)	67 (58, 75)	<0.0001
Female sex, %	34.1	33.0	<0.0001	33.3	33.0	0.16
Race, %			<0.0001†			<0.0001†
White	87.2	80.9		87.0	79.4	
African-American	5.6	7.4		5.4	7.2	
Hispanic	2.3	3.8		2.2	4.0	
Asian	1.1	1.6		1.2	1.8	
Native American	0.3	0.4		0.2	0.3	
Other	3.3	5.8		3.8	7.2	
<b>Cardiac risk factors, %</b>						
Current smoking	30.7	30.8	0.65	19.1	18.8	0.30
Hypertension	72.9	76.5	<0.0001	78.3	83.5	<0.0001
Hyperlipidemia	70.6	73.4	<0.0001	76.7	81.0	<0.0001
Diabetes mellitus	30.2	32.0	<0.0001	34.0	37.0	<0.0001
<b>Medical history, %</b>						
Prior MI	26.9	23.0	<0.0001	28.3	23.5	<0.0001
Prior HF	9.8	9.5	0.008	11.4	11.8	0.04
Prior PCI	29.3	26.0	<0.0001	34.5	30.3	<0.0001
Prior CABG	18.2	15.9	<0.0001	20.4	18.9	<0.0001
Prior CVD	11.2	10.8	0.001	11.8	12.2	0.06
Prior PVD	11.0	10.4	<0.0001	13.2	13.6	0.06
<b>Presentation features</b>						
Type of ACS, %			<0.0001			
Unstable angina	54.5	47.1		N/A	N/A	
NSTEMI	24.2	27.7		N/A	N/A	
STEMI	21.3	25.2		N/A	N/A	
Symptom onset to presentation ≤6 h, %						
Among NSTEMI	30.0	38.4	<0.0001	N/A	N/A	
Among STEMI	69.7	78.2	<0.0001	N/A	N/A	
Signs of HF, %	9.4	10.7	<0.0001	8.2	10.0	<0.0001
Cardiogenic shock, %	2.9	3.5	<0.0001	0.5	0.7	<0.0001
eGFR, cc/min*‡	73 (58, 88)	74 (59, 75)	<0.0001	72 (58, 87)	73 (58, 88)	<0.0001

\*Continuous variables displayed as median values with 25th, 75th percentiles. †The p values compare the distribution of race categories. ‡The eGFR is determined with Modification of Diet in Renal Disease (MDRD) formula.

ACS = acute coronary syndromes; CathPCI = Catheterization PCI; CVD = cerebrovascular disease; N/A = not applicable; PVD = peripheral vascular disease; other abbreviations as in Table 1.

change, remaining between 11.3% and 11.0% for STEMI patients and between 10.2% and 9.0% for NSTEMI patients (Fig. 2B).

In the CathPCI registry, there were decreases in unadjusted composite vascular complications (Fig. 3A) and composite bleeding complications (Fig. 3B) among ACS and non-ACS patients. Risk-adjusted in-hospital mortality did not change substantially among ACS patients (2.2% to 2.0%) and non-ACS patients (0.5% to 0.5%) during the study period (Fig. 3C).

## Discussion

The goal of this report was to evaluate contemporary clinical practice, as well as recent trends in treatments and outcomes, among acute MI and PCI patients. Analyzing data from 2 large-scale national registry programs of the NCDR, the most notable findings were improvements in the provision and timeliness of reperfusion therapy for STEMI patients and in the use of guideline-recommended medications for both STEMI and NSTEMI, and a decrease in PCI-related procedural and vascular complications despite

an increase in procedural complexity. The results are generally encouraging with regard to key processes in the care of acute MI and PCI patients and the translation of evidence into practice, yet also highlight areas of need for quality improvement, opportunities to improve patient outcomes, and targets for additional research.

Some of the most encouraging findings of this study were the significant increases in the timeliness of acute MI patient presentation after symptom onset, in the proportion of eligible STEMI patients receiving reperfusion therapy, and in the timeliness of reperfusion therapy for STEMI. These findings may, in part, reflect the impact of local, regional, and/or national quality improvement initiatives that have gained an increasing foothold in the U.S. in recent years. Such initiatives have focused on patient education and awareness of acute MI symptoms in the community, reducing door-to-balloon times for primary PCI and improving systems of care for acute MI patients (1–3).

Building upon improvements in treatment for acute MI patients from earlier analyses, we have demonstrated further

**Table 3** Changes in Treatments and Procedure Use in Acute MI Patients From the AR-G Registry

	STEMI			NSTEMI		
	Q1–Q2 2007 (n = 9,390)	Q1–Q2 2009 (n = 11,125)	p Value	Q1–Q2 2007 (n = 15,417)	Q1–Q2 2009 (n = 16,247)	p Value
<b>Acute medications, %*</b>						
Aspirin ≤24 h	98.0	98.3	0.04	96.6	96.6	0.14
Clopidogrel ≤24 h	83.5	87.1	<0.0001	57.8	56.6	0.15
GP IIb/IIIa inhibitors ≤24 h	72.4	68.1	<0.0001	44.2	37.3	<0.0001
Any anticoagulant during hospitalization	93.6	95.6	<0.0001	90.6	92.0	0.02
Unfractionated heparin	78.2	81.0	0.32	55.1	60.1	<0.0001
LMWH	17.1	15.3	0.01	42.2	40.3	<0.0001
Bivalirudin	10.1	19.6	<0.0001	10.1	15.6	<0.0001
Beta-blockers ≤24 h	95.3	93.5	0.0003	92.9	89.2	<0.0001
<b>Medication overdosing, %†</b>						
Unfractionated heparin	N/A	N/A		27.2	21.0	<0.0001
LMWH	N/A	N/A		18.0	15.1	0.003
GP IIb/IIIa inhibitors	9.5	9.8	0.50	10.7	8.8	0.004
<b>Reperfusion therapies, %</b>						
Overall reperfusion use‡	90.8	93.8	0.0005	N/A	N/A	
Primary PCI	75.3	83.0	<0.0001	N/A	N/A	
Fibrinolytics	17.3	12.5	<0.0001	N/A	N/A	
Contraindication to reperfusion	17.0	13.1	<0.0001	N/A	N/A	
<b>Reperfusion timing‡</b>						
Direct arrival D2B ≤90 min	64.5	88.0	<0.0001	N/A	N/A	
Transfer in D2B ≤90 min	7.6	18.7	<0.0001	N/A	N/A	
Door to needle ≤30 min	50.5	65.6	0.48	N/A	N/A	
<b>Cardiac procedures, %</b>						
Catheterization	85.4	93.0	<0.0001	71.6	76.2	<0.0001
Catheterization ≤48 h	82.4	90.9	<0.0001	59.3	62.5	<0.0001
PCI	75.9	81.5	0.003	41.4	43.6	0.09
CABG	7.1	7.0	0.13	10.2	11.5	0.09
<b>Discharge medications, %*</b>						
Aspirin	98.5	98.4	0.18	96.7	96.8	0.40
Clopidogrel	90.4	91.9	0.0002	72.8	74.2	0.0006
Statin	90.6	94.5	<0.0001	84.7	88.3	<0.0001
Beta-blocker	97.0	97.3	0.13	95.3	95.1	0.38
ACEI or ARB	77.5	77.9	0.99	70.9	69.7	0.06
<b>Discharge interventions, %</b>						
Smoking cessation counseling§	96.6	97.3	0.11	94.3	96.7	<0.0001
Cardiac rehabilitation	76.7	83.5	<0.0001	68.2	74.5	<0.0001

\*Medication use determined only among patients without a recorded contraindication to each medication class. For discharge medications, patients transferred out to another hospital, those who died, those who were discharged on comfort measures or to a hospice setting, and those discharged against medical advice were excluded from the calculations. †Medication overdosing was determined as follows: glycoprotein (GP) IIb/IIIa inhibitors: if full dose of tirofiban or eptifibatid given for STEMI or NSTEMI patients on dialysis or those with creatinine clearance <30 cc/min (tirofiban) or <50 cc/min (eptifibatid); unfractionated heparin (UFH): if either the initial bolus is >70 U/kg or the initial infusion is >15 U/kg/h (only for NSTEMI patients); low-molecular-weight heparin (LMWH)–enoxaparin: if the initial dose is >1.05 mg/kg or if total dose given in the first 24 h is >10 mg over the 1 mg/kg dosing recommendation when creatinine clearance <30 cc/min or over the 2 mg/kg dosing recommendation when creatinine clearance ≥30 cc/min (only for NSTEMI patients). ‡Reperfusion therapy use determined only among patients without a recorded contraindication to reperfusion therapy or a non-systems reason for delay in reperfusion. Door-to-needle times displayed only for non-transfer-in patients without a documented reperfusion contraindication who received fibrinolytic therapy at the hospital participating in AR-G (286 patients in Q1 to Q2, 2007, and 147 patients in Q1 to Q2, 2009). §Smoking cessation counseling determined only for current/recent smokers.  
 ACEI = angiotensin-converting enzyme inhibitor; ARB = angiotensin-receptor blocker; D2B = door to balloon; other abbreviations as in Table 1.

improvements in the rates of guidelines- and performance measure-recommended medication adherence over a relatively short period of time at the end of the last decade, with very high rates of utilization of aspirin, clopidogrel, statins, beta-blockers, angiotensin-converting enzyme inhibitors, or angiotensin-receptor blockers, as well as increased rates of smoking cessation counseling and referral for cardiac rehabilitation among eligible patients (5–8,16). Furthermore, significant reductions in the rate of overdosing of anti-thrombotic agents were demonstrated among NSTEMI patients—a finding that highlights a new area of focus in the acute MI performance measures (8,17). The improvements in care demonstrated among NCDR-participating hospitals highlight the potential benefit of voluntary participation in clinical registries as regular data feedback and focused site

performance improvement activities have been shown to result in greater improvements in guidelines adherence compared with pay-for-performance incentive programs (18). The AR-G registry participants, for example, receive quarterly feedback reports that profile and benchmark composite performance scores and defect-free care scores, medication overdosing, and other metrics of guidelines adherence for acute MI patients, whereas CathPCI participants receive quarterly reports focused upon procedural medications, details, and complications. However, the results from this report also reinforce the need for ongoing quality improvement efforts as there are still gaps in the provision of guideline-recommended medications among eligible acute MI patients, and further reductions in procedural complications can still be realized.

**Table 4** Changes in Treatments, Procedural Details, and In-Hospital Outcomes in PCI Patients From the CathPCI registry

Variables	ACS			Non-ACS		
	Q1–Q2 2005 (n = 92,534)	Q1–Q2 2009 (n = 144,989)	p Value	Q1–Q2 2005 (n = 50,532)	Q1–Q2 2009 (n = 79,892)	p Value
<b>Procedural medications, %</b>						
GP IIb/IIIa inhibitors	57.3	44.5	<0.0001	38.5	21.5	<0.0001
Unfractionated heparin	63.9	58.7	<0.0001	49.9	38.2	<0.0001
LMWH	23.1	19.1	<0.0001	7.5	7.1	0.01
Bivalirudin	27.1	43.4	<0.0001	37.8	57.3	<0.0001
<b>Lesion information, %*</b>						
Previously treated lesion	7.5	7.3	0.04	8.2	7.5	<0.0001
Bypass graft lesion	7.7	6.4	<0.0001	6.9	5.9	<0.0001
High-risk type C lesion	43.3	46.9	<0.0001	33.7	38.7	<0.0001
Lesion length ≥25 mm	20.4	21.3	<0.0001	17.9	18.5	0.003
Bifurcation lesion	11.4	12.3	<0.0001	11.2	12.1	<0.0001
<b>Procedural details, %</b>						
Radial artery access	1.2	2.0	<0.0001	1.6	2.3	<0.0001
Multivessel PCI	13.9	12.9	<0.0001	15.5	15.3	0.18
Stents used during PCI†			<0.0001			<0.0001
DES	83.6	65.5		85.7	73.0	
BMS	9.6	27.3		7.6	20.4	
Angioplasty only	6.8	7.2		6.7	6.6	
Type of DES used‡						
Paclitaxel	57.3	21.2	<0.0001	58.0	20.9	<0.0001
Sirolimus	42.7	13.7		42.0	13.7	
Everolimus	N/A	54.8		N/A	54.8	
Zotarolimus	N/A	10.3		N/A	10.6	
<b>Procedural complications and results, %§</b>						
No reflow phenomenon	1.4	1.3	0.04	0.5	0.6	0.39
Dissection	2.4	2.1	<0.0001	2.2	2.0	0.004
Acute closure	0.7	0.7	0.19	0.5	0.5	0.88
Perforation	0.3	0.3	0.32	0.3	0.3	0.38
Procedural success	93.0	94.3	<0.0001	94.0	94.8	0.01
<b>Vascular complications, %</b>						
Access site occlusion	0.07	0.03	0.0001	0.03	0.02	0.22
Peripheral embolization	0.08	0.04	0.0002	0.02	0.02	0.89
Access vessel dissection	0.20	0.17	0.04	0.24	0.19	0.07
Pseudoaneurysm	0.42	0.46	0.11	0.38	0.38	0.84
Arteriovenous fistula	0.07	0.05	0.11	0.08	0.05	0.02
<b>Bleeding complications, %</b>						
Access site bleeding	1.20	0.78	<0.0001	0.67	0.49	<0.0001
Retroperitoneal bleeding	0.33	0.42	<0.0001	0.25	0.17	0.002
Gastrointestinal bleeding	0.54	0.67	<0.0001	0.27	0.15	<0.0001
Genitourinary bleeding	0.20	0.13	<0.0001	0.07	0.05	0.10
Other bleeding location	0.60	0.97	<0.0001	0.27	0.27	0.88
<b>In-hospital outcomes, %</b>						
Transfusion after PCI	5.1	4.7	<0.0001	2.6	2.3	0.0005
Stroke	0.3	0.3	0.33	0.1	0.1	0.20
Emergency bypass surgery	0.4	0.4	0.45	0.2	0.2	0.15

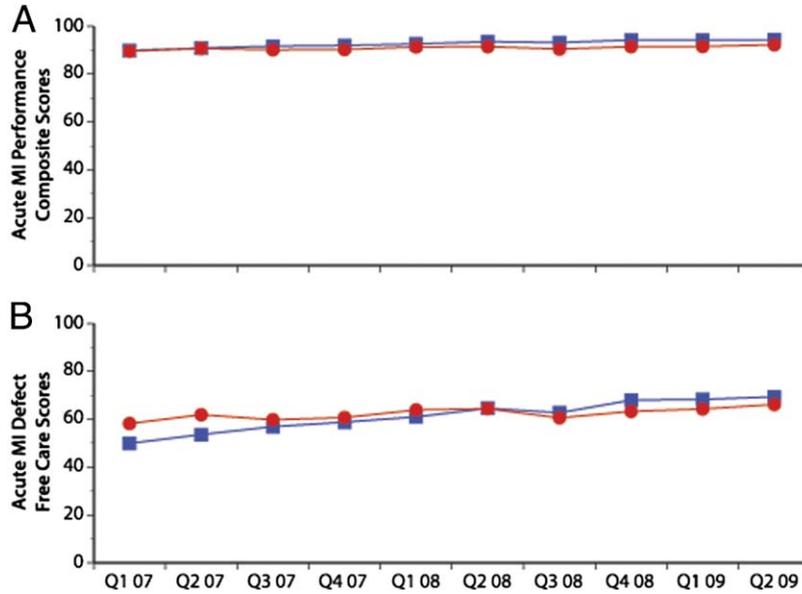
\*Details for highest-risk lesion treated during the index PCI procedure. †If any drug-eluting stent (DES) used during PCI, then classified as DES; p value compares the distribution of stent types used during PCI. ‡Among patients who received a DES. §Procedural complications determined for the highest-risk lesion treated. ||Procedural success defined as successful dilation of all lesions treated during the index PCI procedure. BMS = bare-metal stent(s); other abbreviations as in Tables 1, 2, and 3.

While providing a benchmark for the future evaluation of care processes and outcomes associated with acute MI and PCI procedures, the results from this report highlight several unique temporal changes in care among patients undergoing PCI. First, periprocedural antithrombotic treatment strategies during PCI have significantly changed over the last several years, with decreased use of glycoprotein IIb/IIIa inhibitors and increased use of bivalirudin. This fairly rapid shift in clinical practice is concordant with the most recent guideline updates for management of acute MI and patients undergoing PCI, which reflect new data from

clinical trials evaluating anticoagulation strategies aimed at reducing bleeding (5–7,19,20). Second, while we verified results from other publications by demonstrating declining rates of DES utilization in patients undergoing PCI for both ACS and non-ACS from 2005 to 2009, we have shown the unique finding of recent widespread incorporation of new DES technologies among patients receiving a DES in the CathPCI registry (21). Finally, the complexity of PCI procedures appears to have increased with time, but temporal reductions in vascular and bleeding complications were also demonstrated, so additional studies are needed to

**Figure 1** Quarterly Changes in Composite Quality Scores Among Patients With Acute MI in the AR-G Registry From 2007 to 2009

(A) Performance measure composite scores for ST-segment elevation myocardial infarction (STEMI [trend p value < 0.0001]) and non-ST-segment elevation myocardial infarction (NSTEMI [trend p value = 0.0002]). (B) Defect-free composite performance measure scores for STEMI (trend p value < 0.0001) and NSTEMI (trend p value = 0.0008). Details regarding composite score calculations are reported in the Online Appendix. **Blue lines** = STEMI; **red lines** = NSTEMI. AR-G = Acute Coronary Treatment and Intervention Outcomes Network (ACTION) Registry—Get With The Guidelines; MI = myocardial infarction.



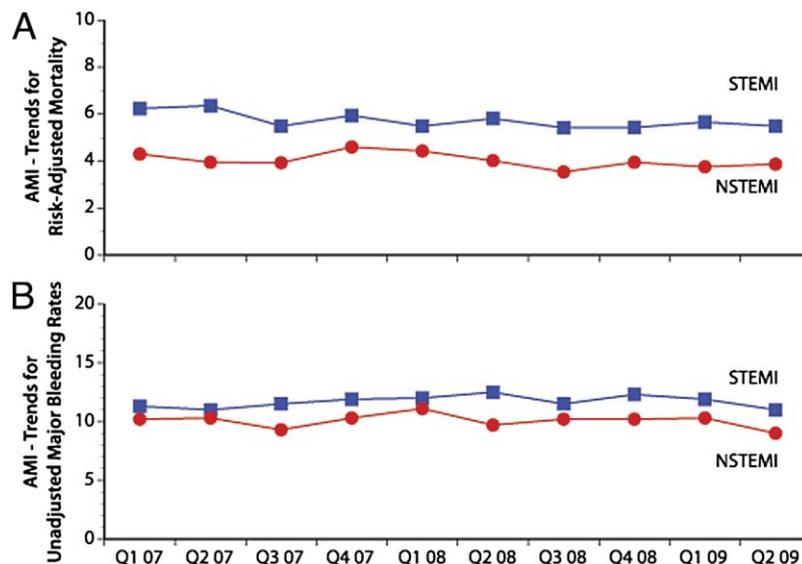
understand how data feedback from the CathPCI registry and changes in procedural techniques and management have influenced the results and safety of PCI.

Mortality risk-adjustment models recently have been derived and validated for both the AR-G and CathPCI

registries based on contemporary patient and procedural data reported in this paper, are currently being used to report risk-adjusted mortality in quarterly site feedback reports for hospitals participating in the AR-G and/or CathPCI registries, and will be published separately (13,14).

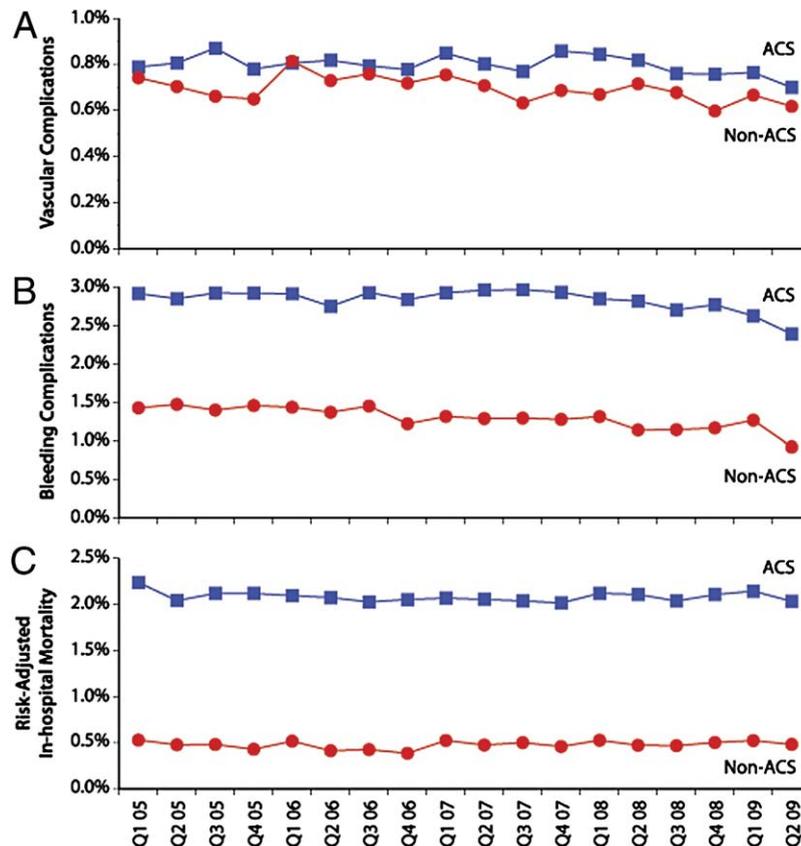
**Figure 2** Quarterly Changes in Risk-Adjusted In-Hospital Mortality and Unadjusted Major Bleeding Among Patients With Acute MI in the AR-G Registry From 2007 to 2009

(A) Risk-adjusted in-hospital mortality for STEMI (trend p value = 0.026) and NSTEMI (trend p value = 0.025). (B) Unadjusted in-hospital major bleeding for STEMI (trend p value = 0.81) and NSTEMI (trend p value = 0.25). Major bleeding defined as including any of the following: absolute drop from baseline to nadir hemoglobin values of  $\geq 4$  g/dl, intracranial hemorrhage, retroperitoneal hemorrhage, red blood cell transfusion (if baseline hemoglobin  $\geq 9$  g/dl), or witnessed bleeding event and red blood cell transfusion (if baseline hemoglobin < 9 g/dl) (9). Patients undergoing coronary artery bypass grafting were censored from the major bleeding calculations starting at the time of coronary artery bypass grafting (i.e., pre-coronary artery bypass grafting bleeding events were captured in the major bleeding calculations). **Blue lines** = STEMI; **red lines** = NSTEMI. AMI = acute myocardial infarction; other abbreviations as in Figure 1.



**Figure 3** Quarterly Changes in Unadjusted Vascular Complications, Unadjusted Procedural Complications, and Risk-Adjusted In-Hospital Mortality Stratified by ACS and Non-ACS Patients Undergoing PCI in the CathPCI Registry From 2005 to 2009

(A) Unadjusted composite vascular complications include all vascular complications listed in Table 4. Trend p values = 0.0007 for acute coronary syndrome (ACS) and 0.001 for non-ACS patients. (B) Unadjusted composite bleeding complications include all bleeding complications/locations listed in Table 4. Trend p values = 0.09 for ACS and <0.0001 for non-ACS patients. (C) Risk-adjusted in-hospital mortality. Trend p values = 0.60 for ACS and = 0.94 for non-ACS patients. **Blue lines** = ACS; **red lines** = non-ACS. CathPCI = Catheterization percutaneous coronary intervention.



Thus, further studies from these databases will be positioned to evaluate temporal trends in risk-adjusted mortality among acute MI and PCI patients in this new decade and will complement prior analyses that demonstrated sustained reductions in risk-adjusted mortality among acute MI patient across prior decades (22). Additionally, site-specific feedback on adjusted mortality in the AR-G and CathPCI registries will complement current risk-adjusted mortality feedback from claims data for hospitals seeking to optimize their care of acute MI and PCI patients. Finally, the NCDR risk-adjustment models will inform and facilitate comparative effectiveness research efforts such as the recently awarded Grand Opportunities grant, which will fund the combined ACC and Society of Thoracic Surgeons effort designed to evaluate the impact of percutaneous versus surgical revascularization procedure.

The results of this report should be interpreted in the context of several considerations. First, the data presented were intended to provide a fairly general representation of current practice and recent trends; as such, these data are largely descriptive without adjustment for case mix, so

conclusions based on observed associations should be made with caution. Second, participation in the AR-G and CathPCI registries is largely voluntary, so the results may not be generalizable to all U.S. hospitals because “high performing” centers may preferentially participate, and non-PCI hospitals are not represented in the CathPCI registry and are under-represented in the AR-G registry. However, both registries have broad geographic participation, and are the largest clinical registries for acute MI and PCI in the U.S. Nonetheless, hospital participation varied in the CathPCI registry from 436 participating hospitals in quarters 1 and 2, 2005, compared with 959 hospitals in quarters 1 and 2, 2009, whereas a relatively stable group of 250 hospitals participated in the AR-G program during the analysis time period. This finding may partly explain the significant differences in patient characteristics such as race and prior revascularization from the beginning to the end of the analysis period for the CathPCI registry. These differences in patient characteristics may have influenced the treatment, procedural, and outcome results presented in this analysis. Finally, only in-hospital outcomes and treatments are pro-

filed in AR-G and CathPCI so longer-term outcomes could not be assessed.

## Conclusions

The contemporary profile of care patterns for patients with acute MI and those undergoing PCI indicates that patient and procedural characteristics have changed over a relatively short time, while significant improvements in the receipt and timeliness of reperfusion therapy for STEMI, in the overdosing of antithrombotic therapies, in the safety and results of PCI procedures, and in composite measures of acute MI care were also demonstrated. These results serve as a benchmark for the ongoing evolution of strategies designed to promote evidence-based and safe care for acute MI and PCI, and also highlight the importance of accurately profiling differences in patient and procedural characteristics to provide comparable feedback on clinical outcomes to hospitals across the U.S.

## Author Disclosures

Dr. Roe has received research funding from Eli Lilly, Bristol-Myers Squibb, Sanofi-Aventis, and Merck/Schering-Plough; and consulting fees/honoraria from GlaxoSmithKline, Novartis, Eli Lilly, Bristol-Myers Squibb, Sanofi-Aventis, Merck/Schering-Plough, and AstraZeneca. Dr. Messenger is a Principal Investigator for the Resolute substudy, Medtronic Co. Dr. Cannon has received research grants/support from Accumetrics, AstraZeneca, GlaxoSmithKline, Intekrin Therapeutics, Merck, and Takeda; is on the advisory board of Bristol-Myers Squibb/Sanofi, Novartis, and Alnylam; and is a clinical advisor with equity in Automedics Medical Systems. Dr. Fonarow has received honoraria from Merck and Bristol-Myers Squibb/Sanofi. Dr. Klein is on the Speakers' Bureau of Pfizer, Lilly, and Daiichi-Sankyo. Dr. Masoudi has contracts with the ACCF and the Oklahoma Foundation for Medical Quality. Dr. McKay is an ACC-NCDR Senior Medical Officer. Dr. Peterson has received research support from Bristol-Myers Squibb/Sanofi, Merck/Schering-Plough, Lilly, and Johnson & Johnson. Dr. Rumsfeld is the Chief Science Officer for the NCDR.

**Reprint requests and correspondence:** Dr. Matthew T. Roe, Duke Clinical Research Institute, 2400 Pratt Street, Room 7035, Durham, North Carolina 27705. E-mail: [matthew.roe@duke.edu](mailto:matthew.roe@duke.edu).

## REFERENCES

1. Nissen SE, Brush JE Jr., Krumholz HM. President's page. GAP-D2B: an alliance for quality. *J Am Coll Cardiol* 2006;48:1911–2.
2. Jacobs AK, Antman EM, Faxon DP, Gregory T, Solis P. Development of systems of care for ST-elevation myocardial infarction patients: executive summary. *Circulation* 2007;116:217–30.

3. Jollis JG, Roettig ML, Aluko AO, et al. Implementation of a statewide system for coronary reperfusion for ST-segment elevation myocardial infarction. *JAMA* 2007;298:2371–80.
4. Califf RM, Peterson ED, Gibbons RJ, et al. Integrating quality into the cycle of therapeutic development. *J Am Coll Cardiol* 2002;40:1895–901.
5. King SB III, Smith SC Jr., Hirshfeld JW Jr., et al. 2007 focused update of the ACC/AHA/SCAI 2005 guideline update for percutaneous coronary intervention. *J Am Coll Cardiol* 2008;51:172–209.
6. Antman EM, Hand M, Armstrong PW, et al. 2007 Focused update of the ACC/AHA 2004 guidelines for the management of patients with ST-elevation myocardial infarction. *J Am Coll Cardiol* 2008;51:210–47.
7. Anderson JL, Adams CD, Antman EM, et al. ACC/AHA 2007 guidelines for the management of patients with unstable angina/non-ST-elevation myocardial infarction. *J Am Coll Cardiol* 2007;50:e1–157.
8. Krumholz HM, Anderson JL, Bachelder BL, et al. ACC/AHA 2008 performance measures for adults with ST-elevation and non-ST-elevation myocardial infarction. *J Am Coll Cardiol* 2008;52:2046–99.
9. Peterson ED, Roe MT, Rumsfeld JS, et al. A call to ACTION (Acute Coronary Treatment and Intervention Outcomes Network): a national effort to promote timely clinical feedback and support continuous quality improvement for acute myocardial infarction. *Circ Cardiovasc Qual Outcomes* 2009;2:491–9.
10. Brindis RG, Fitzgerald S, Anderson HV, Shaw RE, Weintraub WS, Williams JF. The American College of Cardiology–National Cardiovascular Data Registry (ACC-NCDRTM): building a national clinical data repository. *J Am Coll Cardiol* 2001;37:2240–5.
11. Peterson ED, Roe MT, Mulgund J, et al. Association between hospital process performance and outcomes among patients with acute coronary syndromes. *JAMA* 2006;295:1912–20.
12. Mehta RH, Roe MT, Chen AY, et al. Recent trends in the care of patients with non-ST-segment elevation acute coronary syndromes: insights from the CRUSADE initiative. *Arch Intern Med* 2006;166:2027–34.
13. Roe MT, Chen AY, DeLong ER, et al. Predictors of in-hospital mortality in a contemporary acute myocardial infarction population. *J Am Coll Cardiol* 2010;55:Suppl A:A100.
14. Peterson ED, Dai D, DeLong ER, et al. Contemporary mortality risk prediction for percutaneous coronary intervention. Results from 558,398 procedures in the National Cardiovascular Data Registry. *J Am Coll Cardiol* 2010;55:1923–32.
15. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. *Biometrika* 1986;73:13–22.
16. Peterson ED, Shah BR, Parsons L, et al. Trends for quality of care for patients with acute myocardial infarction in the National Registry of Myocardial Infarction from 1990 to 2006. *Am Heart J* 2008;156:1045–55.
17. Alexander KP, Chen AY, Roe MT, et al. Excess dosing of antiplatelet and antithrombin agents in the treatment of non-ST-segment elevation acute coronary syndromes. *JAMA* 2005;294:3108–16.
18. Glickman SW, Ou FS, DeLong ER, et al. Pay for performance, quality of care, and outcomes in acute myocardial infarction. *JAMA* 2007;297:2373–80.
19. Lincoff AM, Bittl JA, Harrington RA, et al. Bivalirudin and provisional glycoprotein IIb/IIIa blockade compared with heparin and planned glycoprotein IIb/IIIa blockade during percutaneous coronary intervention: REPLACE-2 randomized trial. *JAMA* 2003;289:853–63.
20. Stone GW, McLaurin BT, Cox DA, et al. Bivalirudin for patients with acute coronary syndromes. *N Engl J Med* 2006;355:2203–16.
21. Roe MT, Chen AY, Cannon CP, et al. Temporal changes in the use of drug-eluting stents for patients with non-ST-segment elevation myocardial infarction undergoing percutaneous coronary intervention from 2006 to 2008. *Circ Cardiovasc Qual Outcomes* 2009;2:414–20.
22. Krumholz HM, Wang Y, Chen J, et al. Reduction in acute myocardial infarction mortality in the United States—risk-standardized mortality rates from 1996–2006. *JAMA* 2009;302:767–73.

**Key Words:** acute myocardial infarction ■ percutaneous coronary intervention ■ NCDR.

 APPENDIX

For the calculation of acute MI performance measure composite scores and defect-free care composite scores, please see the online version of this article.

### Changes in Acute MI Treatment From 2007 to 2009

Increased reperfusion therapy use for eligible STEMI patients, from 90.8% to 93.8%.

Increased STEMI door-to-balloon times  $\leq 90$  min for primary PCI, from 64.5% to 88.0%.

Decreased overdosing of unfractionated heparin (27.2% to 21.0%), low-molecular-weight heparin (18.0% to 15.1%), and glycoprotein IIb/IIIa inhibitors (10.7% to 8.8%) among NSTEMI patients.

Improved acute MI composite performance measure scores (89.9% to 94.4%) and defect-free care composite performance measure scores (49.9% to 69.4%) among STEMI patients.

Improved acute MI composite performance measure scores (89.6% to 92.3%) and defect-free care composite performance measure scores (58.2% to 66.2%) among NSTEMI patients.

Abbreviations as in Tables 1 and 2.

### Changes in PCI Treatments and Procedural Details From 2005 to 2009

For ACS patients, decreased use of periprocedural glycoprotein IIb/IIIa inhibitors (57.3% to 44.4%) and increased use of bivalirudin (27.1% to 43.4%).

For non-ACS patients, decreased use of periprocedural glycoprotein IIb/IIIa inhibitors (38.5% to 21.5%) and increased use of bivalirudin (37.8% to 57.3%).

Higher procedural complexity, with an increased proportion of ACS (43.3% to 46.9%) and non-ACS patients (33.7% to 38.7%) with type C lesions treated during PCI.

Decreased use of drug-eluting stents in both ACS (83.6% to 66.5%) and non-ACS patients (85.7% to 73%).

Decreased use of sirolimus and paclitaxel stents (100% to 34.9%) with introduction of new stent types (everolimus and zotarolimus) among patients receiving a drug-eluting stent.

Abbreviations as in Tables 1 and 2.

### Changes in Acute MI Outcomes From 2007 to 2009

Significant decreases in risk-adjusted in-hospital mortality among STEMI patients (6.2% to 5.5%) and NSTEMI patients (4.3% to 3.9%).

No change in unadjusted in-hospital major bleeding among STEMI (11.3% to 11.0%) and NSTEMI (10.2% to 9.0%) patients.

Abbreviations as in Table 1.

## Treatments, Trends, and Outcomes of Acute Myocardial Infarction and Percutaneous Coronary Intervention

Matthew T. Roe, John C. Messenger, William S. Weintraub, Christopher P. Cannon, Gregg C. Fonarow, David Dai, Anita Y. Chen, Lloyd W. Klein, Frederick A. Masoudi, Charles McKay, Kathleen Hewitt, Ralph G. Brindis, Eric D. Peterson, and John S. Rumsfeld

*J. Am. Coll. Cardiol.* 2010;56;254-263

doi:10.1016/j.jacc.2010.05.008

**This information is current as of July 29, 2010**

<b>Updated Information &amp; Services</b>	including high-resolution figures, can be found at: <a href="http://content.onlinejacc.org/cgi/content/full/56/4/254">http://content.onlinejacc.org/cgi/content/full/56/4/254</a>
<b>Supplementary Material</b>	Supplementary material can be found at: <a href="http://content.onlinejacc.org/cgi/content/full/56/4/254/DC1">http://content.onlinejacc.org/cgi/content/full/56/4/254/DC1</a>
<b>References</b>	This article cites 22 articles, 20 of which you can access for free at: <a href="http://content.onlinejacc.org/cgi/content/full/56/4/254#BIBL">http://content.onlinejacc.org/cgi/content/full/56/4/254#BIBL</a>
<b>Rights &amp; Permissions</b>	Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at: <a href="http://content.onlinejacc.org/misc/permissions.dtl">http://content.onlinejacc.org/misc/permissions.dtl</a>
<b>Reprints</b>	Information about ordering reprints can be found online: <a href="http://content.onlinejacc.org/misc/reprints.dtl">http://content.onlinejacc.org/misc/reprints.dtl</a>