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CLINICAL RESEARCH

Increasing Percutaneous Coronary Interventions for ST-Segment Elevation Myocardial Infarction in the United States

Progress and Opportunity

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ABSTRACT

OBJECTIVES The aim of this study was to quantify changes in percutaneous coronary intervention (PCI) and mortality rates for ST-segment elevation myocardial infarction (STEMI), and the proportion of hospitals providing STEMI-related PCI in the United States.

BACKGROUND Health care systems have recently emphasized rapid access to PCI for STEMI, but the effects of these efforts in a broad population are unknown.

METHODS We used the Nationwide Inpatient Sample, a discharge database representative of all short-term, nonfederal hospitals in the United States. STEMI discharges were included based on primary discharge diagnosis. We calculated the adjusted odds ratio (OR) of PCI and in-hospital death over time and the changing proportion of hospitals providing STEMI-related PCI.

RESULTS From 2003 to 2011, STEMI accounted for 380,254 hospital discharges. The rate of PCI increased from 53.6% to 80.0% with an adjusted OR of 4.16 (95% confidence interval [CI]: 3.71 to 4.66) in 2011 compared with 2003. The proportion of hospitals providing STEMI-related PCI increased from 25.1% in 2003 to 33.7% in 2011. In-hospital death rates ranged from 7.2% to 9.5%, with the lowest rate in 2009. The OR of death decreased from 2003 to 2011 (adjusted OR: 0.79 in 2011 compared with 2003; 95% CI: 0.74 to 0.84). After accounting for PCI, the OR of in-hospital death did not change between 2003 and 2011 (adjusted OR: 1.01 in 2011 compared with 2003; 95% CI: 0.95 to 1.07).

CONCLUSIONS PCI rates and hospitals providing STEMI-related PCI increased from 2003 to 2011, whereas in-hospital death rates decreased. PCI was an important mediator of decreasing mortality in this nationally representative sample. (J Am Coll Cardiol Intv 2015;8:139–46) © 2015 by the American College of Cardiology Foundation.

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ABBREVIATIONS AND ACRONYMS

ACTION Registry–GWTG = Acute Coronary Treatment and Intervention Outcomes Network Registry–Get With the Guidelines

CABG = coronary artery bypass grafting

CI = confidence interval

D2B = Door-to-Balloon

ICD-9 = International Classification of Diseases-Ninth Revision

IQR = interquartile range

NCDR = National Cardiovascular Disease Registry

NIS = Nationwide Inpatient Sample

OR = odds ratio

PCI = percutaneous coronary intervention

STEMI = ST-segment elevation myocardial infarction

ST-segment elevation myocardial infarction (STEMI) is the most severe form of myocardial infarction and is associated with significant morbidity and mortality. Fortunately, percutaneous coronary intervention (PCI) offers an evidence-based, lifesaving treatment option (1). In recent years, professional societies have developed programs, such as the American College of Cardiology Door-to-Balloon (D2B) Initiative and the American Heart Association Mission: Lifeline, to promote timely access to PCI for all STEMI patients. In addition, the recent American Heart Association/American College of Cardiology guidelines add a specific focus on health care delivery and recommend regional systems of STEMI care to facilitate rapid access to PCI (2).

These system-based efforts are intended to mitigate the morbidity and mortality of STEMI in the U.S. population by disseminating evidence-based treatment, namely PCI, on a broader scale. Studies from the National Cardiovascular Disease Registry (NCDR) (3) indicate that PCI rates for STEMI are increasing. The NCDR, however, reflects a narrow range of self-selected hospitals that may not accurately represent the diverse nation. To overcome these limitations, we used the Nationwide Inpatient Sample (NIS), which includes a nationally representative sample of hospitals and patients, to quantify in-hospital treatment patterns and outcomes and describe the changing landscape of PCI availability for STEMI in the United States. Because the PCI health care delivery initiatives were not tested in a randomized fashion, understanding the effects in an observational fashion is necessary. In the process, we demonstrate that comprehensive assessment of common conditions and health outcomes is possible using publicly available data and relatively simple methods.

METHODS

The NIS, part of the Healthcare Utilization Project from the Agency for Healthcare Research and Quality, is the largest available all-payer hospital discharge database. Each year includes ~8 million discharges from 1,000 hospitals; variables include demographic factors, diagnostic and procedural codes, disposition, and hospital characteristics (4,5). Hospitals are selected based on 5 strata (region, bed size, hospital control, teaching status, urban vs. rural) to approximate a 20% sample of all nonfederal, short-term U.S. hospitals, using the American Hospital Association survey as reference (6). All discharges from selected hospitals are included in the dataset; in other words, the sampling unit is the hospital. The same hospitals are not necessarily selected for inclusion each year; rather hospitals are selected to create a representative snapshot of U.S. hospitals for each year, and the sampling strategy was consistent throughout the study period. It is not possible to determine whether separate discharges represent the same patient because the NIS is a discharge, not patient, database.

Adult STEMI discharges from January 1, 2003, to December 31, 2011 were included based on primary International Classification of Diseases-Ninth Revision (ICD-9) diagnostic code (7–9). ICD-9–based identification of acute myocardial infarction hospitalizations has been validated in several cohorts (7,8,10,11). The specificity exceeds 90%, and the positive predictive values range from 73% to 81%; the predictive value of ICD-9 codes for STEMI has been stable over time (7,10). The source of admission was not a criterion for inclusion or exclusion, so discharges transferred in from other facilities (including emergency departments) were included.

We estimated PCI and in-hospital death rates over time. Continuous variables were compared using analysis of variance, and categorical variables were compared using the chi-square test. PCI use was determined from ICD-9 procedural codes (12). Discharges to other acute care facilities or missing disposition were excluded for outcomes analyses because treatment patterns and mortality could not be determined in these cases. We used logistic regression with generalized estimating equations (to account for clustering within hospitals) to calculate the odds ratio (OR) of PCI and death according to year, with adjustment for age, sex, race/ethnicity, primary payer, comorbid conditions, and hospital characteristics. Comorbid conditions were identified from diagnosis codes using the risk adjustment model developed by the Agency for Healthcare Research and Quality (13,14); this methodology has been used in

management, analysis, and interpretation of the data; and preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication. Dr. Shah is a stockholder in Gilead Sciences. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose.

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several other investigations, including studies examining outcomes in acute myocardial infarction (15). Hospital characteristics included geographic region, teaching status, number of beds, coronary artery bypass grafting (CABG) capability, and STEMI-related PCI volume. Hospitals were defined as CABG capable if 2 or more discharges in a given year included a procedure code for CABG. We included PCI in the mortality model to account for the effect of PCI use on death.

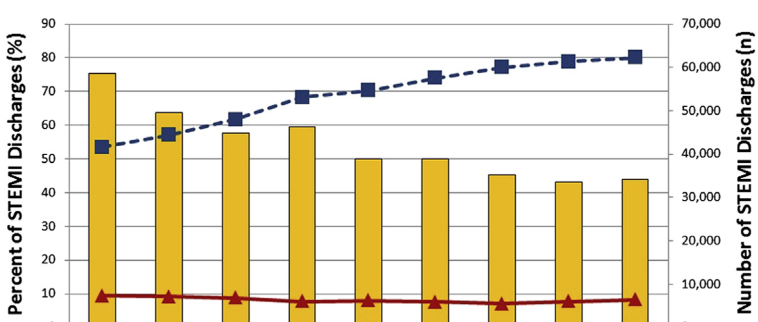
We examined trends in STEMI-related PCI availability by calculating the number of hospitals providing STEMI-related PCI according to year. First, we classified hospitals into STEMI-related PCI volume groups, according to the recently published "Clinical Competence Statement on Coronary Artery Interventional Procedures" (16). STEMI-PCI discharges, defined by the presence of a primary diagnostic code for STEMI and any procedural code for PCI, were summed to generate a STEMI-PCI caseload per hospital per year. Hospitals were classified as zero volume if the annual number of STEMI-related PCI discharges was 0, low if the sum was >0 and <36, and high volume if the sum was >36. We then calculated the proportion of hospitals with zero-, low-, and high-volume caseloads for each year of the study; the denominator was the number of nonfederal, acute care hospitals in the NIS for each year. In addition, we calculated the median (interquartile range [IQR]) number of STEMI-related PCIs per hospital per year for all nonzero-volume hospitals; these were compared nonparametrically across time using median scores. Finally, we assessed the proportion of STEMI discharged patients treated at zero-, low-, and high-volume centers according to year.

Analyses were performed using Stata software version 12 (StataCorp, College Station, Texas), and a 2-sided p value <0.05 was considered statistically significant.

RESULTS

From 2003 to 2011, we identified 380,254 STEMI discharges in the NIS, with fewer discharges in each year of the study (Figure 1). Total discharges to other acute care facilities accounted for 9.23% (N = 35,103) of STEMI hospitalizations, decreasing from 13.8% to 4.8% over the study period. After excluding these transfers and discharges with missing disposition (n = 305), 344,846 discharges remained for outcome analyses. Discharged patients from later years were younger and more likely to be male, diabetic, hypertensive, and uninsured (Table 1). Including all years, 67.8% (n = 233,684) of hospital discharges included PCI and 8.1% of patients (n = 28,020) died in-hospital.

The PCI treatment rate increased during the study period from 53.6% in 2003 to 80.0% in 2011 (Figure 1). After adjustment, the OR of PCI was more than 4 times higher in 2011 compared with 2003 (OR: 4.16 in 2011 vs. 2003, 95% CI: 3.71 to 4.66) (Figure 2A). Concomitant with the increasing PCI rate, an



	2003	2004	2005	2006	2007	2008	2009	2010	2011
STEMI Discharges (n)	58,644	49,515	44,840	46,238	39,014	38,910	35,292	33,619	34,182
PCI (%)	53.57	57.13	61.69	68.32	70.23	74.03	77.12	78.84	79.99
In-Hospital Death (%)	9.49	9.22	8.77	7.76	8.06	7.61	7.17	7.74	8.25

Year

STEMI Discharges (n) PCI (%) In-Hospital Death (%)

FIGURE 1 Number of STEMI Discharges and Rates of PCI and In-Hospital Death in the United States, 2003 to 2011

PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.

TABLE 1 Characteristics of STEMI Discharges According to 3-Year Intervals

Variable	2003, 2004, 2005 (n = 152,999)	2006, 2007, 2008 (n = 124,162)	2009, 2010, 2011 (n = 103,093)
Demographic factors			
Age, yrs	64.55 ± 14.35	63.57 ± 14.32	62.97 (13.91)
Age, yrs	64 (54–76)	62 (53–75)	62 (53–73)
Female	54,389 (35.55)	41,479 (33.41)	32,584 (31.61)
Primary payer			
Medicare	73,521 (48.05)	54,579 (43.96)	43,232 (41.93)
Private	55,923 (36.55)	47,475 (38.24)	38,261 (37.11)
Medicaid	8,131 (5.31)	6,675 (5.38)	7,123 (6.91)
Other, including self-pay	15,198 (9.93)	15,194 (12.24)	14,185 (13.76)
Race/ethnicity			
White	86,894 (56.79)	73,357 (59.08)	68,525 (66.47)
Black	7,551 (4.94)	6,685 (5.38)	6,951 (6.74)
Hispanic	8,023 (5.24)	6,514 (5.25)	6,587 (6.39)
Asian/Pacific Islander	2,186 (1.43)	2,006 (1.62)	2,132 (2.07)
Other	2,607 (1.70)	3,839 (3.09)	4,104 (3.98)
Missing	44,738 (29.24)	31,761 (25.58)	14,794 (14.35)
Comorbid conditions			
Chronic pulmonary disease	23,894 (15.62)	19,471 (15.68)	15,054 (14.60)
Depression	5,335 (3.49)	5,573 (4.49)	5,434 (5.27)
Diabetes	36,325 (23.74)	31,431 (25.31)	27,983 (27.14)
Hypertension	77,451 (50.62)	70,767 (57.00)	63,749 (61.84)
Hypothyroidism	8,661 (5.66)	8,071 (6.50)	7,474 (7.25)
Liver disease	960 (0.63)	956 (0.77)	967 (0.94)
Hospital characteristics			
CABG capable	114,321 (74.72)	100,071 (80.60)	85,637 (83.07)
No. of beds			
Small	13,183 (8.62)	12,104 (9.75)	8,440 (8.19)
Medium	36,037 (23.55)	28,519 (22.97)	20,749 (20.13)
Large	103,762 (67.82)	83,438 (67.20)	72,236 (70.07)
Missing	17 (0.01)	101 (0.08)	1,668 (1.62)
Rural hospital	16,312 (10.66)	11,434 (9.21)	8,435 (8.18)
Hospital region			
Northeast	28,414 (18.57)	20,411 (16.44)	18,700 (18.14)
Midwest	3,382 (2.21)	29,100 (23.44)	24,369 (23.64)
South	62,280 (40.71)	51,256 (41.28)	39,315 (38.14)
West	28,423 (18.58)	23,395 (18.84)	20,709 (20.09)
Teaching hospital	69,528 (45.44)	60,134 (48.43)	51,297 (49.76)
PCI volume			
0	29,024 (18.97)	12,530 (10.09)	5,053 (4.90)
1–36 STEMI-related PCIs/yr	9,927 (6.49)	7,764 (6.25)	7,254 (7.04)
>36 STEMI-related PCIs/yr	114,048 (74.54)	103,868 (83.66)	90,786 (88.06)

Values are mean ± SD, median (interquartile range), or n (%). Note: Numbers do not always equal 100% due to missing data.

CABG = coronary artery bypass grafting; PCI = percutaneous coronary intervention; STEMI = ST-segment elevation myocardial infarction.

increasing proportion of U.S. hospitals provided PCI for STEMI during the study period. In 2003, 25.1% of hospitals provided PCI for STEMI compared with 33.7% in 2011 (**Figure 3**). The number of high-volume PCI centers, ≥36 STEMI-related PCIs/year, increased from 19.8% to 23.6% (**Figure 3**). In addition, increasing proportions of STEMI discharges were from high-volume centers over time, 73.8% in 2003 compared with 88.2% in 2011 (**Figure 3**).

Although more hospitals provided STEMI-related PCIs and more patients were treated at high-volume centers, the case volume of STEMI-related PCIs per hospital decreased. In 2003 (including only non-zero-volume hospitals), the median number of STEMI-related PCIs per hospital was 84 (IQR: 46 to 133) compared with 63 (IQR: 30 to 100) in 2011 ($p = 0.04$).

In-hospital death rates for STEMI ranged from 7.2% to 9.5% during the study period. The unadjusted death rate was highest in 2003, and the lowest was in 2009 (**Figure 1**). After adjustment for demographic factors, comorbid conditions, and hospital characteristics, the OR of death decreased through 2010 and was similar in the final 2 years of the study (OR: 0.79 in 2011 vs. 2003; 95% CI: 0.74 to 0.84) (**Figure 2B**). PCI attenuated the effect of year on death; after inclusion of PCI in the model, the ORs of death were similar in all years of the study (**Figure 2C**).

DISCUSSION

Our study of STEMI in the United States, which included a broad spectrum of payers, ages, and hospitals, demonstrates 3 important observations: PCI reperfusion rates for STEMI increased significantly between 2003 and 2011, in-hospital mortality rates decreased and PCI was a mediator of this decrease, and the proportion of hospitals providing PCI for STEMI increased.

First, these findings suggest that initiatives emphasizing access to PCI have been successful; the odds of undergoing PCI during STEMI hospitalization increased more than 4-fold in less than a decade. Similar trends are present in smaller, more selective U.S. cohorts and other countries. The NCDR Acute Coronary Treatment and Intervention Outcomes Network Registry-Get With The Guidelines (ACTION Registry-GWTG), for example, reported PCI rates of 75% and 85% in 2007 and 2009, respectively, compared with 70% and 80%, respectively, in our sample (3). By 2011, the NCDR rate was 87.9% (17) compared with our 80.0% rate. This difference may be explained by greater interhospital variability because smaller rural hospitals are less likely to be included in the NCDR. In France, the PCI rate increased from 61.5% to 86.7% over 10 years (18).

The proportion of U.S. hospitals providing STEMI-related PCI increased between 2003 and 2011, whereas the total number of STEMI discharges decreased. This finding parallels the finding of a recent report using the American Hospital Association survey that demonstrated an increasing number of PCI-capable hospitals in the United States (19).

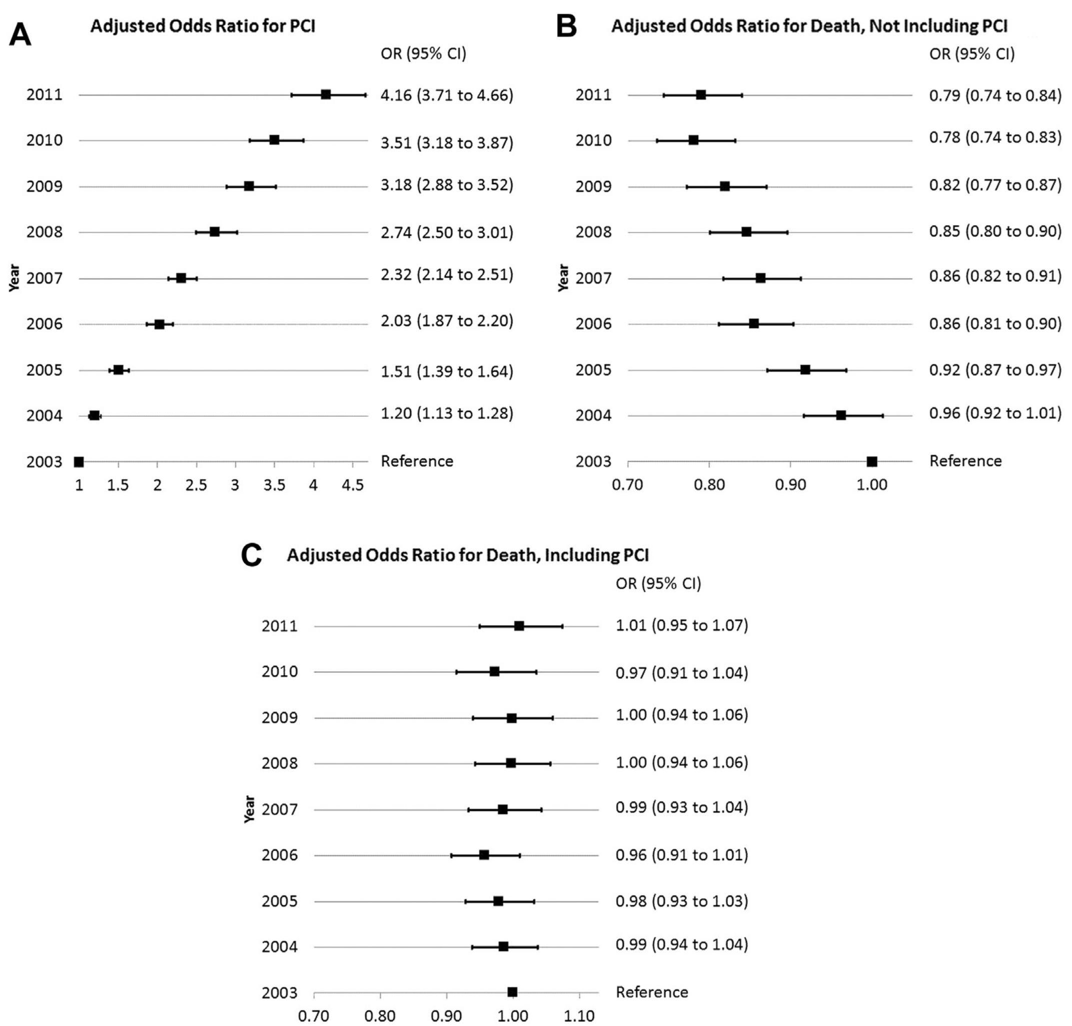


FIGURE 2 Adjusted ORs of PCI and Death According to Year

(A) PCI model includes year, age, sex, race/ethnicity, payer, comorbid conditions as defined by the Agency for Healthcare Research and Quality model for risk adjustment, number of hospital beds, rural hospital, region, hospital teaching status, ST-segment elevation myocardial infarction-PCI volume category, coronary artery bypass grafting capability. **(B)** Adjusted ORs of death according to year, excluding PCI. Mortality model includes all variables in the PCI model. **(C)** Adjusted ORs of death according to year, including PCI. Mortality model includes all variables in the PCI model plus PCI. CI = confidence interval; OR = odds ratio; PCI = percutaneous coronary intervention.

Although the expanding hospital supply may have contributed to higher PCI rates for STEMI, increased capability resulted in a lower case volume per hospital. This pattern will amplify if the total number of STEMI hospitalizations continues to decrease and the number of PCI-capable hospitals continues to increase. Health care delivery systems and regulatory agencies need to focus on optimized expansion of PCI capabilities to balance demand, access, and caseload to maintain proficiency (20).

Concomitant with PCI changes, in-hospital mortality for STEMI decreased between 2003 and 2011. The adjusted OR of death decreased more than 25% between 2003 and 2010 and then stabilized through 2011. Death rates reported in this nationally representative sample, however, are higher than rates reported in the ACTION Registry-GWTG (3,17). One possible explanation is that higher performing hospitals preferentially participate in the registry, and those hospitals select which cases are entered into

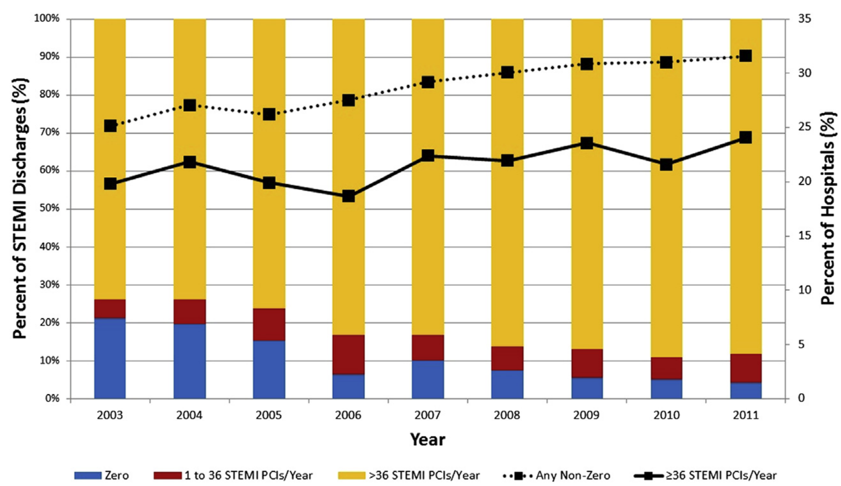


FIGURE 3 **Number of STEMI Discharges From Hospitals According to Case Volume and Proportion of Hospitals Providing STEMI-Related PCI**

Colored bars and **left-hand axis** indicate the proportion of discharges from zero- (no STEMI-related PCIs), low-, and high- (more than 36 STEMI-related PCIs/year) volume centers according to year. By 2011, discharges were clustered into high-volume centers, and few patients were discharged from zero-volume centers. **Black lines** and **right-hand axis** indicate the proportion of hospitals providing STEMI-related PCI. By 2011, the proportion of hospitals STEMI-related PCI increased. Abbreviations as in Figure 1.

the registry, thus favorably biasing the outcomes by "cherry picking." This possibility is exemplified by the fact that our data include 43,663 STEMI discharges (11.6%) from facilities that provided no STEMI-related PCIs; such patients are unlikely to be included in registries.

Death rates stabilized in the final 2 years of the study, and after accounting for PCI, in-hospital mortality did not change between 2003 and 2011. Similarly, the ACTION Registry-GWTG reported a decrease in adjusted in-hospital mortality from 2007 to 2009, from 6.2% to 5.5% (3). A more recent publication reports a 5.9% in-hospital death rate for STEMI in 2011 (17), so the NCDR investigators also may report a similar stall in their next trend analysis. In addition, a report from Worcester, Massachusetts, showed no change in in-hospital mortality through 2005 (21), and a report from Kaiser Permanente of Northern California showed no change in the 30-day mortality rate after STEMI through 2008 (7). These findings, in combination with our results, suggest that we need to devise new initiatives to continue improved STEMI in-hospital outcomes.

Finally, this investigation was completed with publicly available data and demonstrates the feasibility comprehensive surveillance of common conditions. We captured important trend data to inform decision making related to STEMI care in the United States using relatively simple methods. The American Recovery and Reinvestment Act of 2009 created financial incentives to adopt meaningful use of electronic health records, and several professional societies now promote standardized data collection via electronic health records (22,23). As a result, the availability and quality of electronic data will improve such that future investigations will overcome current limitations, including case identification and risk adjustment. These advances should create opportunities for public cardiovascular health surveillance in an effort to improve the health of the country (24).

STUDY LIMITATIONS. The NIS is an administrative database that allows inclusion of a large number of hospitals and patients in the United States at the cost of clinical detail. First, we could not estimate the number of discharged patients who underwent thrombolysis or were reperfusion ineligible using ICD-9 procedure codes; these cases may account for a proportion of discharged patients who did not undergo a PCI, particularly in the early years of the study. We relied on ICD-9 codes among patients who survived to hospitalization for case identification. Although this method has been validated for acute myocardial infarction in different cohorts, our data include hospitals not typically represented in registries and clinical trials; coding practices may vary according to hospital.

The NIS lacks clinical detail; registries such as ACTION Registry-GWTG provide more detail to account for the effects of medications and other important determinants of STEMI outcomes. A recent publication, however, suggests that faster D2B times among patients who undergo a PCI do not improve STEMI outcomes (25); this clinical detail, therefore, may not have altered our results. We could not precisely define comorbid conditions for comprehensive risk adjustment, so it is possible that STEMI patients were sicker over time.

CONCLUSIONS

STEMI-related PCI use increased significantly from 2003 to 2011 in the United States, and more hospitals provided this service over time. These changes occurred during an era of systemwide efforts to expand PCI treatment to all STEMI patients, including the American College of Cardiology D2B Initiative and the American Heart Association Mission: Lifeline. Our findings are encouraging and suggest that wide-scale health service improvements can have a positive impact.

However, these favorable mortality trends have plateaued in recent years. Continued refinement of in-hospital care, such as D2B time, has diminishing returns for improved outcomes (25). The focus must now shift to other health service initiatives to improve STEMI outcomes, including optimizing prehospital care (26). In addition, future studies should focus on identifying sources of variation in STEMI outcomes, such as patient-level variation (e.g., low socioeconomic status and comorbid conditions) and hospital-level variation (e.g., rural and lower volume centers). These types of investigations will help to identify areas for targeted delivery strategies and help get valuable treatment to the patients who need it most.

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