Differences in Patient Survival After Acute Myocardial Infarction by Hospital Capability of Performing Percutaneous Coronary Intervention

Implications for Regionalization

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Background: There are increasing calls for regionalization of acute myocardial infarction (AMI) care in the United States to hospitals with the capacity to perform percutaneous coronary intervention (PCI). Whether regionalization will improve outcomes depends in part on the magnitude of existing differences in outcomes between PCI and non-PCI hospitals within the same health care region.

Methods: A 100% sample of claims from Medicare fee-for-service beneficiaries 65 years or older hospitalized for AMI between January 1, 2004, and December 31, 2006, was used to calculate hospital-level, 30-day risk-standardized mortality rates (RSMRs). The RSMRs between PCI and local non-PCI hospitals were compared within local health care regions defined by hospital referral regions (HRRs).

Results: A total of 523,119 AMI patients was admitted to 1,382 PCI hospitals, and 194,909 AMI patients were admitted to 2,491 non-PCI hospitals in 295 HRRs with at least 1 PCI and 1 non-PCI hospital. Although PCI hospitals had lower RSMRs than non-PCI hospitals (mean, 16.1% vs 16.9%; P = .001), considerable overlap was seen in RSMRs between non-PCI and PCI hospitals within the same HRR. In 80 HRRs, the RSMRs at the best-performing PCI hospital were lower than those at local non-PCI hospitals by 3% or more. Among the remaining HRRs, the RSMRs at the best-performing PCI hospital were lower by 1.5% to 3.0% in 104 HRRs and by greater than 0 to 1.5% in 74 HRRs. In 37 HRRs, the RSMRs at the best-performing PCI hospital were no better or were higher than at local non-PCI hospitals.

Conclusions: The magnitude of benefit from comprehensively regionalizing AMI care to PCI hospitals appears to vary greatly across HRRs. These findings support a tailored regionalization policy that targets areas with the greatest outcome differences between PCI and local non-PCI hospitals.

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mortality rates when treated at PCI hospitals compared with non-PCI hospitals? This is a necessary, but not sufficient, condition for regionalization to improve outcomes. Second, what is the hospital-level variation in risk-adjusted 30-day mortality at PCI and non-PCI hospitals? Ideally, PCI hospitals would have uniformly better outcomes than non-PCI hospitals. Finally, on a region-by-region basis, would mortality decrease if all AMI patients at local non-PCI hospitals had outcomes similar to the best-performing PCI hospital within the same health care region (ie, the most optimistic scenario for comprehensive regionalization)? Each of these analyses has unique implications for assessing the potential benefits of regionalizing AMI care across the United States.

METHODS

PATIENT DATA

The study population consisted of Medicare fee-for-service patients 65 years or older hospitalized with a principal discharge diagnosis of AMI (International Classification of Diseases, Ninth Revision, Clinical Modification\textsuperscript{4} diagnostic codes 410.xx, excluding 410.x2). Three years of hospitalization data were obtained from the 2004-2006 Medicare Provider Analysis and Review (MedPAR) from the Centers for Medicare & Medicaid Services (CMS), including Part A hospital data and Part B outpatient data.

Data from MedPAR contain demographic information, principal discharge and secondary diagnosis codes, and procedure codes for each hospitalization. Patients discharged alive within 1 day and not against medical advice were excluded because these individuals were unlikely to have had an AMI. Additional information on comorbidities was obtained from diagnosis codes for the 12 months preceding the index admission for AMI from Part A hospital data and Part B outpatient facility data. Patient characteristics were classified into categories of comorbidities using the hierarchical condition categories classification system used by the CMS to calculate hospital-specific risk-standardized mortality rates (RSMRs) for AMI.\textsuperscript{10} Dates of death were obtained from Medicare enrollment files.

We excluded patients who did not have 12 months of continuous coverage in Medicare or were hospitalized outside the United States. Health care regions were defined using hospital referral regions (HRRs) from the Dartmouth Atlas of Cardiovascular Health Care,\textsuperscript{11} which empirically constructs health care regions based on referral patterns for major cardiovascular and neurosurgical procedures performed on Medicare beneficiaries. Because the focus of this analysis was to assess the impact of regionalizing AMI care, we also excluded data from patients admitted to 59 hospitals with inadequate information in the American Hospital Association Survey of Hospitals or unresolved zip codes and data from those admitted to 46 hospitals in 11 HRRs without at least 1 PCI hospital and 1 non-PCI hospital. We excluded data from patients admitted to hospitals with fewer than 10 AMI cases treated in the 3-year combined sample given the insufficient data for evaluating hospital performance.

For patients transferred from one acute care hospital to another, hospitalizations were combined into a single episode of care with outcomes attributed to the first hospital (regardless of whether the hospital was of the PCI or non-PCI designation). Comorbidities in claims related to the second hospitalization were not included to avoid the misclassification of complications as preexisting conditions.

HOSPITAL DATA

We classified hospitals as PCI and non-PCI based on their capability of performing primary PCI, which we defined as emergency revascularization during STEMI. We specifically chose to define PCI hospitals based on primary PCI because this is likely to be a distinguishing characteristic of regional centers for AMI care.\textsuperscript{12} To identify PCI hospitals, we used data from the American College of Cardiology National Cardiovascular Registry CathPCI Registry and the Hospital Quality Alliance Door-to-Balloon Time Database between January 1, 2004, and December 31, 2006. In cases where there was inconsistency, we identified billing claims related to any PCI in MedPAR data between January 1, 2004, and December 31, 2006, and then used telephone interviews to directly verify the capability of performing primary PCI. Additional facility characteristics were obtained from the 2004 American Hospital Association Survey of Hospitals, whereas AMI volume was determined by aggregating the number of admissions for AMI between January 1, 2004, and December 31, 2006, in MedPAR data.

STATISTICAL ANALYSIS

We compared baseline characteristics of patients and hospitals on their capability of performing PCI, using \( \chi^2 \) tests for categorical variables and \( t \) tests for continuous variables. The primary outcome measure was death owing to any cause within 30 days after the index hospitalization for AMI.

We initially performed a patient-level analysis of 30-day mortality comparing AMI patients admitted to PCI hospitals with those admitted to non-PCI hospitals. We used multivariable logistic regression to determine the association between admission at PCI hospitals and 30-day mortality, adjusting for patient demographics and comorbidities. Hospital-level random intercepts were included to account for the clustering (non-independence) of patients within hospitals. Covariates used in these analyses were previously published in a risk-adjustment model of 30-day mortality after AMI.\textsuperscript{12} We then performed a hospital-level analysis by calculating 30-day RSMRs specific to each hospital. The RSMRs were determined using the same method used by the CMS for its public reporting efforts for hospital performance in AMI—an administrative risk-adjustment method validated against a medical record–based model\textsuperscript{12} and approved by the National Quality Forum. An RSMR represents the ratio of a particular hospital’s predicted mortality rate to the expected mortality rate of an average hospital that treats patients at similar clinical risk, multiplied by the national mortality rate. The RSMRs were calculated using a hierarchical general linear model that adjusted for patient characteristics, including age, sex, and comorbidities. Although the hierarchical general linear model approach used a shrinkage estimate that considered the available information contained in a given sample size,\textsuperscript{11} hospital volume itself was not used as a variable in the risk-adjustment model. We categorized hospitals into quintiles of the RSMR and examined the distribution of RSMRs for PCI and non-PCI hospitals overall and within quintiles of the RSMR.

Last, we performed a regional-level analysis to approximate how regionalization of AMI care would be expected to affect AMI mortality within each HRR. For this analysis, we examined the difference in 30-day RSMRs between the best-performing PCI hospital and the mean of all local non-PCI hospitals within the same HRR. Comparison of the RSMRs for patients admitted to non-PCI hospitals with those admitted to PCI hospitals with the lowest mortality rate in a particular HRR (ie, the best-performing PCI hospital) represents the most optimistic scenario for regionalization. We report the number of
HRRs where the RSMR difference between the best-performing PCI hospital and the mean of the non-PCI hospitals fell within the following categories: greater than or equal to 3%, 1.5% to 3.0%, and 0% to 1.4% in favor of PCI hospitals and less than 0% (ie, where the best-performing PCI hospital had a mortality rate higher than the local non-PCI hospitals).

We used bootstrapping methods to calculate the 95% internal estimates of the number of HRRs that fell into each of these RSMR difference categories. The cohort of hospitals was sampled with replacement, and the RSMR difference between the best-performing PCI hospital and the mean of all local non-PCI hospitals within an HRR was recalculated; this procedure was repeated for 1600 iterations. The resulting set of RSMR differences between the best-performing PCI hospital and the mean of the non-PCI hospitals was rank ordered for each RSMR difference category. The 95% internal estimate of the number of HRRs for each category of RSMR difference between PCI and non-PCI hospitals was then determined using the bottom 2.5% and top 97.5% of RSMR differences within each category. All analyses were conducted with SAS statistical software, version 9.1.3 (SAS Institute Inc, Cary, North Carolina).

RESULTS

Between January 1, 2004, and December 31, 2006, we identified 718,028 patients hospitalized for AMI at 3873 hospitals who met our study inclusion criteria. Of these, 523,119 (72.8%) AMI patients were admitted to 1382 PCI hospitals and 194,909 (27.2%) AMI patients were admitted to 2491 non-PCI hospitals. The mean (SD) patient age was 79.0 (7.9) years, and 367,343 (31.2%) were women. Because of the large sample size, statistically significant differences were observed for several patient characteristics between PCI and non-PCI hospitals; however, clinically important differences between the 2 groups were few (Table 1). Patients initially admitted to non-PCI hospitals were more likely to be transferred to another acute care facility compared with patients initially admitted to PCI hospitals (31.4% vs 3.3%, P <.001). Patients admitted to PCI hospitals were more likely to have undergone cardiac catheterization, PCI, or coronary artery bypass surgery within 30 days of admission compared with patients admitted to non-PCI hospitals (Table 1).

Differences in facility characteristics between PCI and non-PCI hospitals are summarized in Table 2. On average, PCI hospitals had more beds (339.0 vs 109.5, P <.001) and annual Medicare fee-for-service AMI admissions (125.3 vs 25.1, P <.001). A greater proportion of PCI hospitals were teaching hospitals and not-for-profit or privately owned hospitals compared with non-PCI hospitals.

PATIENT-LEVEL ANALYSIS

Overall, the 30-day mortality rate was significantly lower for AMI patients admitted to PCI hospitals compared with patients admitted to non-PCI hospitals (15.1% vs 20.7%, P <.001; odds ratio [OR], 0.68; 95% confidence interval [CI], 0.66-0.69). After adjusting for age, sex, and comorbidities, this difference in 30-day mortality rate diminished but remained significantly lower for patients admitted to PCI hospitals (OR, 0.89; 95% CI, 0.88-0.91).

HOSPITAL-LEVEL ANALYSIS

On average, PCI hospitals had lower RSMRs compared with non-PCI hospitals (mean RSMR, 16.1% vs 16.9%; P <.001), an absolute difference of 0.8%. However, the RSMRs varied widely within PCI hospitals (SD, 1.8%; range, 10.8%-23.8%) and non-PCI hospitals (SD, 1.4%; range, 12.6%-23.0%), leading to substantial overlap between the 2 hospital groups (Figure 1).

Stratifying all hospitals into RSMR quintiles, we observed a larger number of PCI hospitals in the best-performing quintile. The best-performing quintile (RSMR range, 10.8%-15.5%) included 440 (31.8%) of all PCI hospitals and 335 (13.4%) of all non-PCI hospitals. Hospitals in the best-performing quintile treated 209,990 (40.1%) of all patients at PCI hospitals and 41,870 (21.5%) of all patients at non-PCI hospitals. By contrast, hospitals in the lowest-performing quintile included a comparable proportion of PCI hospitals (259 [18.7%]) and non-PCI hospitals (516 [20.7%]).

REGIONAL-LEVEL ANALYSIS

To examine the impact of comprehensive regionalization of AMI care on outcomes at the regional level, absolute differences in 30-day RSMRs between the best-performing PCI hospital and the mean of the RSMRs of all local non-PCI hospitals within the same HRR were compared. This represents an optimistic scenario for regionalization to change local outcomes. The overall mean difference across all HRRs between the 2 hospital groups was 1.9%, favoring the best-performing PCI hospitals. However, there was a wide range of differences across individual HRRs, varying from a 6.1% lower RSMR favoring the best-performing PCI hospital to a 2.8% lower RSMR favoring the local non-PCI hospitals.

The HRRs were categorized into 4 groups based on the extent of absolute differences between the best-performing PCI hospital and non-PCI hospitals within the same HRR (Table 3). Overall, 80 HRRs had a 3% or greater difference in RSMRs favoring the best-performing PCI hospital, 104 HRRs had a 1.5% to 3% difference, and 74 HRRs had a greater than 0 to 1.5% difference compared with local non-PCI hospitals. However, in 37 HRRs the best-performing PCI hospital had RSMRs that were no better or higher than local non-PCI hospitals; in these 37 HRRs, the difference in favor of non-PCI hospitals was in general small (mean [SD], 1.0% [0.7%]). Results from the bootstrapping analysis suggest that the observed differences between PCI and non-PCI hospitals within HRRs were unlikely to be explained by chance alone, with 95% CIs of 69 to 94 HRRs with a 3% or greater difference in RSMRs favoring the best-performing PCI hospital and 29 to 46 HRRs where the best-performing PCI hospitals had RSMRs that were no better or higher than local non-PCI hospitals (Table 3).

Most HRRs (Figure 2) where differences in RSMRs were 3% or greater and favored the best-performing PCI hospital were concentrated in the Mountain and Midwest regions, although select major urban areas were also identified in the Northeast. No discernable geographic pattern was seen for HRRs where the best-performing PCI hospitals had RSMRs that were no better or higher than local non-PCI hospitals.
We explored the impact of patient transfers on our analysis by examining the correlation of hospital RSMRs that include and exclude transfer patients. Overall, there was a high correlation for RSMRs after including and excluding transfer patients for PCI hospitals (0.95) and non-PCI hospitals (0.92), suggesting that, on average, the impact of transfer patients on a hospital’s RSMR appears limited and that our findings remain robust to the issue of transfers.

Our study illustrates the complexity surrounding decisions to comprehensively regionalize AMI care in the United States. We found that admission to a PCI hospital was associated with a lower 30-day mortality rate compared with admission to a non-PCI hospital. Prior studies that have examined the association between a hospital’s capacity for invasive cardiac procedures and clinical outcomes focused almost exclusively on this type of patient-level analysis. If the benefits of AMI regionalization are judged by results from this perspective alone, our data would support regionalizing AMI care at PCI hospitals. This strategy, however, could be misleading for a number of regions.

To understand why this may be true requires an examination of our hospital-level and regional-level analysis.
Our hospital-level analysis demonstrated overlap in the distribution of RSMRs between PCI and non-PCI hospitals, demonstrating that PCI hospitals do not uniformly have better outcomes than non-PCI hospitals. Our regional-level analysis found that an absolute mortality difference of 3% or greater was present between the best-performing PCI and non-PCI hospitals in 80 of 295 HRRs. In contrast, there were 37 HRRs where the best-performing PCI hospital had a higher RSMR than local non-PCI hospitals. This variation in differences in RSMRs between the 2 groups of hospitals across HRRs reinforces the need to carefully examine outcomes on a region-by-region basis before embarking on strategies to direct all AMI care to PCI hospitals.

Our results do not imply that transfer of high-risk patients to PCI hospitals for invasive cardiac procedures or advanced specialty care is not warranted. Many clinical scenarios exist in which patients are likely to benefit from transfer to these specialized centers. Instead, what these findings highlight is that the presence or absence of PCI alone has a limited ability to stratify hospital performance with respect to 30-day mortality rates. Because the effectiveness of proposals to comprehensively regionalize all AMI care depends on the magnitude of existing differences among hospitals that initiate or receive transfers, it would be valuable to consider differences in hospital-specific outcomes within a region when planning strategies to consolidate AMI care at particular facilities.

The finding that many non-PCI hospitals performed as well or better than even the best-performing PCI hospital in their region suggests that factors other than availability of invasive cardiac procedures likely contribute to hospital performance for AMI care. In an earlier Canadian study, for example, better outcomes at hospitals with invasive cardiac procedures were predominantly explained by teaching status, which itself is a proxy for important processes of care that have yet to be identified. As such, the capacity for PCI may be 1 of many structural and process characteristics of hospital performance to be considered when developing regional systems of care for AMI. Determining the most effective and transferable elements of hospital structure and the processes and treatments that hospitals use to lower AMI mortality rates is challenging and will likely require novel research methods with comprehensive clinical data. One such approach is to combine qualitative and quantitative analysis to identify operational strategies associated with outstanding performance in door-to-balloon times for primary PCI; there is a need to perform similar studies for overall AMI outcomes.

Our study should be interpreted in the context of the following limitations. First, Medicare claims data are unable to reliably distinguish patients with STEMI from those without STEMI. Although this makes our analysis less germane for systems of care that specifically target the emergency transfer of patients with STEMI for primary PCI, it directly informs the larger debate on centralizing care of all patients with acute coronary syndromes, including the much larger group of patients without STEMI.

Second, the number of AMI regionalization programs has likely expanded since the 2004-2006 period of our study. Although the number of regionalization systems has increased over time, not all areas in the country currently have such strategies, and our study provides guidance to policy makers regarding new implementations of regionalization programs. Although an implicit but limited form of AMI regionalization exists in the form of select transfers from non-PCI to PCI hospitals for STEMI care, the goal of our study was to investigate how outcomes would be expected to differ from directing most AMI patients (including those without STEMI) to PCI hospitals within a particular HRR, as advocated by some experts.
Third, we were unable to assess nonfatal outcomes, such as reinfarction and readmission. Similarly, we were unable to assess important dimensions to care that may affect AMI regionalization, such as patient preferences for transfer and quality of life after AMI. However, because the primary motivation for regionalization of AMI care is the reduction of short-term mortality, we believe this issue is of secondary importance.

Fourth, our analysis assumes that redistributing patients across hospitals is feasible and has no adverse consequences. It is possible that logistical issues, such as longer transportation time or delays attributable to reaching capacity limits, may reduce the benefit actually achievable from transferring patients to PCI hospitals. As such, our analysis represents the most optimistic scenario for regionalization, assuming the greatest potential difference between non-PCI and PCI hospital outcomes.

Fifth, we estimated RSMRs based on Medicare fee-for-service data. Thus, our findings may not necessarily be generalizable to younger AMI patients or Medicare patients enrolled in managed care programs.

### Table 3. Difference in 30-Day RSMR Between the PCI Hospital With the Lowest RSMR and the Mean RSMR of All Non-PCI Hospitals Within an HRRa

<table>
<thead>
<tr>
<th>RSMR</th>
<th>≥3%</th>
<th>1.5%-3%</th>
<th>&gt;0%-1.5%</th>
<th>≤0%</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Point difference in RSMR, median, %</td>
<td>3.8</td>
<td>2.4</td>
<td>0.9</td>
<td>-0.9</td>
<td>2.2</td>
</tr>
<tr>
<td>Point difference in RSMR, mean (range)</td>
<td>3.8 (3.0 to 6.1)</td>
<td>2.4 (1.5 to 3.0)</td>
<td>0.9 (0.01 to 1.5)</td>
<td>-1.0 (-2.8 to -0.2)</td>
<td>1.9 (-2.8 to 6.1)</td>
</tr>
<tr>
<td>No. of PCI hospitals, mean (range)</td>
<td>7.3 (1 to 42)</td>
<td>4.9 (1.1 to 25)</td>
<td>3.0 (1 to 10)</td>
<td>1.7 (1 to 4)</td>
<td>4.7 (1 to 42)</td>
</tr>
<tr>
<td>No. of non-PCI hospitals, mean (range)</td>
<td>12.7 (1 to 49)</td>
<td>8.4 (1 to 31)</td>
<td>5.8 (1 to 16)</td>
<td>4.7 (1 to 16)</td>
<td>8.4 (1 to 49)</td>
</tr>
<tr>
<td>No. of HRRs (95% internal estimate)</td>
<td>80 (69 to 94)</td>
<td>104 (88 to 117)</td>
<td>74 (61 to 87)</td>
<td>37 (29 to 46)</td>
<td>295</td>
</tr>
<tr>
<td>No. of patients at PCI hospitals</td>
<td>215149</td>
<td>190910</td>
<td>67394</td>
<td>29666</td>
<td>523119</td>
</tr>
<tr>
<td>No. of patients at non-PCI hospitals</td>
<td>76628</td>
<td>73519</td>
<td>32423</td>
<td>12339</td>
<td>194909</td>
</tr>
</tbody>
</table>

Abbreviations: HRR, hospital referral region; PCI, percutaneous coronary intervention; RSMR, risk-standardized mortality rate.

a Positive RSMR differences indicate that the best-performing PCI hospital had lower RSMRs than the mean of all non-PCI hospitals within the HRR. Negative RSMR differences indicate that the best-performing PCI hospital had higher RSMRs than the mean of all non-PCI hospitals within the HRR.

![Figure 2. Differences in 30-day risk-standardized mortality rates (RSMRs) between the best-performing percutaneous coronary intervention (PCI) hospital and the mean of the non-PCI hospitals by hospital referral region (HRR).](https://example.com/f2.png)

In some cases, data were not available for the HRR (hatched).
Last, because of the statistical approach used to calculate RSMRs, low-volume hospitals typically have RSMRs closer to the mean mortality rate compared with high-volume hospitals. This is because, with limited information, the best estimate of a hospital’s RSMR is the mean mortality rate (ie, small samples contain less information to determine whether the RSMR deviates from the mean). Because non-PCI hospitals typically treat fewer AMI cases than PCI hospitals, non-PCI hospitals would be less able to distinguish themselves as high performers on the basis of RSMR. We attempt to mitigate this concern by limiting our analysis to hospitals with at least 10 AMIs during 3 years.

Our study found that 30-day mortality rates for AMI are lower for PCI hospitals when compared with non-PCI hospitals. However, we also noted considerable overlap in hospital performance between the 2 groups of hospitals. Examining health care regions, we found that regionalizing AMI care to PCI hospitals is likely to reduce mortality in a subset of regions where differences in patient mortality between PCI and non-PCI hospitals are substantial but less likely to do so in many regions where differences were less sizeable. In designing systems for regionalizing AMI care across the United States, policy makers should specifically consider the performances of hospitals within each region to optimize the benefits of this approach.

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