Mortality Among High-Risk Patients With Acute Myocardial Infarction Admitted to US Teaching-Intensive Hospitals in July

A Retrospective Observational Study

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Background—Studies of whether inpatient mortality in US teaching hospitals rises in July as a result of organizational disruption and relative inexperience of new physicians (July effect) find small and mixed results, perhaps because study populations primarily include low-risk inpatients whose mortality outcomes are unlikely to exhibit a July effect.

Methods and Results—Using the US Nationwide Inpatient sample, we estimated difference-in-difference models of mortality, percutaneous coronary intervention rates, and bleeding complication rates, for high- and low-risk patients with acute myocardial infarction admitted to 98 teaching-intensive and 1353 non–teaching-intensive hospitals during May and July 2002 to 2008. Among patients in the top quartile of predicted acute myocardial infarction mortality (high risk), adjusted mortality was lower in May than July in teaching-intensive hospitals (18.8% in May, 22.7% in July, P<0.01), but similar in non–teaching-intensive hospitals (22.5% in May, 22.8% in July, P=0.70). Among patients in the lowest three quartiles of predicted acute myocardial infarction mortality (low risk), adjusted mortality was similar in May and July in both teaching-intensive hospitals (2.1% in May, 1.9% in July, P=0.45) and non–teaching-intensive hospitals (2.7% in May, 2.8% in July, P=0.21). Differences in percutaneous coronary intervention and bleeding complication rates could not explain the observed July mortality effect among high-risk patients.

Conclusions—High-risk acute myocardial infarction patients experience similar mortality in teaching- and non–teaching-intensive hospitals in July, but lower mortality in teaching-intensive hospitals in May. Low-risk patients experience no such July effect in teaching-intensive hospitals.

Key Words: mortality ■ myocardial infarction

Each summer US teaching hospitals experience a turnover of resident physicians, leading many to investigate whether declines in patient outcomes occur as a result of submission to organizational disruption and relative inexperience of new cohorts of physicians (July effect).1-3 Although substantial variability in results exists across studies of the July effect, most large and high-quality studies find a relatively small but statistically significant increase in mortality at the start of the residency year.4

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An important reason why previous estimated July effects may have been mixed and small in magnitude is that most studies do not examine whether the July effect varies according to the predicted risk of inpatient mortality. Mortality outcomes of patients at low risk of inpatient mortality—either because of few severe comorbid conditions or because the disease necessitating hospitalization is relatively low risk—may be unaffected by resident inexperience in July, whereas mortality among hospitalized patients with high predicted mortality may be most affected by errors or relative inexperience at the start of the residency year.

Although several studies have examined the July effect among patients at high risk of inpatient mortality (eg, patients with femoral neck fractures,4 patients undergoing cardiac surgery,3-4 and trauma patients9-11), these studies have been primarily surgery-oriented in nature and do not include comparisons with patients at lower risk of inpatient mortality.

A second limitation of most previous studies is that they do not adequately distinguish between teaching hospitals that are highly teaching-intensive versus those that are not. Although some studies distinguish teaching hospitals as being minor or major,5 even among major teaching hospitals there may be substantial variation in the number of resident physicians per bed. The July effect is more likely to occur in hospitals that rely heavily on resident physicians for patient care than in hospitals in which residents play a smaller role.
We studied inpatient mortality among a national sample of patients admitted with acute myocardial infarction (AMI) to US hospitals during May and July 2002 to 2008. We studied AMI given its prevalence, range in mortality risk, and the clinical importance of early recognition of complications and implementation of optimal medical therapy and of percutaneous coronary intervention (PCI). We estimated the difference in inpatient mortality between May and July in teaching-intensive and non–teaching-intensive hospitals (July effect) for patients at low and high predicted risk of inpatient mortality after AMI. We hypothesized that a July mortality increase in teaching-intensive hospitals would be greatest for patients already at high risk of inpatient mortality because this group of patients may be most susceptible to errors arising from organizational disruption and the relative inexperience of residents in July. To assess possible mechanisms of a differential July effect between low- and high-risk patients with AMI, we also estimated rates of PCI and rates of complication from bleeding among both groups.

Methods

Data Source

We used the Nationwide Inpatient Sample (NIS) to identify a nationally representative sample of patients admitted to US hospitals with AMI. The NIS approximates a 20-percent stratified random sample of US hospitals. Each hospital discharge includes demographic and clinical data on each patient, including age, sex, race (white, black, Hispanic, other/unknown), month and year of hospital admission, length of stay, primary and secondary diagnoses and procedures, and disposition (eg, inpatient death). Diagnoses are coded according to the International Classification of Diseases, Ninth Revision (ICD-9). Use of the data for this project was approved by the Institutional Review Board at the University of Southern California.

Study Sample

In our baseline analysis, we identified patients admitted with AMI during May and July 2002 to 2008. Patients with AMI were identified according to ICD-9 criteria in the Agency for Healthcare Research and Quality (AHRQ) Inpatient Quality Indicators, version 3.2 (AHRQ, Rockville, MD).12,13 We studied patients admitted during May and July, rather than longer timeframes such as March-to-May and July-to-September, to minimize differences in patient characteristics and outcomes that may occur with seasonal variation.1 In establishing a clean comparison between May and July, we studied patients whose admission date to the hospital was during May 1 to May 31 or July 1 to July 31. In our baseline analysis, we did not study patients admitted during June because some residency programs begin within the month. However, in additional analyses we explored differences in mortality between teaching-intensive and non–teaching-intensive hospitals throughout the academic year.

We studied AMI given its prevalence, range in mortality risk across patients, and the importance for clinical outcomes of early recognition of AMI and its complications and early implementation of optimal medical therapy and PCI in appropriate patients. Identifying a condition with a large range in mortality risk across patients is important to assessing whether the relative inexperience of residents in July disproportionately impacts patients at high rather than low mortality risk. Similarly, relative inexperience of residents may be expected to have its greatest adverse effect for conditions in which early recognition and management of disease is particularly important. We studied all patients with AMI, regardless of whether they were admitted directly to a hospital or transferred from another hospital; our results were unchanged when transfers were excluded.

Definition of Teaching-Intensive Hospitals

Teaching hospitals have traditionally been identified according to the American Hospital Association’s (AHA) Annual Survey, which defines teaching hospitals by an American Medical Association approved residency, membership in the Council of Teaching Hospitals, or a ratio of resident physicians to beds of 20:25.14 Within this definition, however, teaching hospitals vary significantly in the extent to which residents are involved in the care of the hospitals’ patients. For instance, in some teaching hospitals trainees do not perform specific procedures whereas in other hospitals they do, leading some analyses of the July effect to focus on procedures performed by trainees only.7,15 Similarly, teaching hospitals vary significantly in the ratio of resident physicians to hospital beds,1 mitigating the July effect when a substantial number of teaching hospitals have relatively few resident physicians per bed.

To appropriately focus our analysis of the July effect among teaching hospitals in which a substantial amount of patient care is actually delivered by resident physicians, we divided hospitals into the following categories based on previous studies: non-teaching hospitals (zero residents per bed), very minor or minor teaching hospitals (>0.25–0.60 residents per bed), major teaching hospitals (>0.60 residents per bed), and very major teaching hospitals (>0.60 residents per bed).16,17 Based on these categorizations, we defined teaching-intensive hospitals as those that were very major teaching hospitals. Non–teaching-intensive hospitals were defined as all other hospitals. Teaching-intensive or very major teaching hospitals approximately corresponded to the top quartile of teaching hospitals in terms of the ratio of residents per bed. In addition to our baseline analysis which studied the July effect using this binary classification of teaching-intensive and non–teaching-intensive hospitals, we studied how mortality differences between July and May varied across the four more specific hospital categories.

Our final sample of patients admitted with AMI included 14 919 patients admitted to 98 teaching-intensive hospitals (7630 in May; 7289 in July) and 61 298 admitted to 1353 non–teaching-intensive hospitals (31 375 in May; 29 923 in July).

Outcome Variables

Our primary outcome variable was all-cause inpatient mortality. Longer mortality measures such as 30-day mortality could not be evaluated because the NIS does not follow patients after discharge. To evaluate mechanisms for how a July mortality effect among patients with AMI could be mediated, we analyzed rates of PCI and bleeding complications associated with either PCI or anticoagulant therapy. We hypothesized that patients admitted with AMI to teaching-intensive hospitals in July may experience either relatively lower rates of PCI or higher rates of bleeding complications. PCI was identified through procedural codes; bleeding complications were identified through ICD-9 diagnoses codes for hemorrhage associated with a procedure or anticoagulation therapy and procedural codes for blood transfusion.

Risk Stratification of Patients With AMI

To study the July effect among patients at highest predicted risk of inpatient mortality after AMI, we computed mortality after AMI for each individual in our database using a validated risk adjustment tool from the AHRQ.18 The AHRQ risk prediction tool includes risk parameters for patient age, sex, and relevant diagnoses and procedure codes that have been estimated from national AMI discharge data. These risk parameters can be applied to other claims-based discharge data to predict patient-level inpatient mortality after AMI. We applied the AHRQ risk parameters to each patient in our data to obtain patient-level predicted mortality. We did not directly estimate a risk prediction model; rather, the AHRQ tool allows investigators to use administrative data to compute predicted mortality for a patient using AHRQ’s risk coefficients already estimated from national data. A priori and based on prior studies, we defined patients dichotomously to be at high predicted inpatient mortality risk after AMI if their predicted mortality was in the top quartile and at low risk if their predicted mortality was in the bottom three quartiles.19 To ensure that our categorization of high- and low-risk patients was homogeneous across teaching-intensive and non–teaching-intensive hospitals, risk quartiles were defined for the entire population rather than separately for teaching-intensive and non–teaching-intensive hospital populations.
We chose predicted-mortality categories that were broad enough to ensure an adequate sample size for comparison but that also exhibited a substantial difference in predicted mortality. For instance, predicted inpatient mortality after AMI in the top quartile and bottom 3 quartiles of patients in our data was 19.8% (3774 deaths among 19054 patients) and 3.32% (11964 deaths among 57163 patients), respectively. Our results were insensitive to alternative definitions of high risk such as the top tercile, quintile, and decile of predicted inpatient mortality. In addition to defining high-risk patients as the top quartile of inpatient mortality, we also explored whether the estimated July effect varied with more discrete measures of predicted inpatient mortality.

**Baseline Statistical Analysis**

We estimated a difference-in-difference model comparing inpatient mortality among patients admitted with AMI to teaching-intensive versus non–teaching-intensive hospitals in May and July of the same calendar year. In this model, the difference in mortality between May and July in teaching-intensive hospitals is compared with the difference in mortality between May and July in non–teaching-intensive hospitals, the latter difference accounting for any seasonal differences in AMI mortality occurring between the 2 months. Difference-in-difference models have been commonly used to study the July effect.1,3,19-22 We estimated a difference-in-difference multivariable logistic regression model of the following form:

\[
\text{Logit} \left[ \text{Probability} \left( D_i \right) \right] = \beta_0 + \beta_{\text{July}_i} + \beta_{\text{Teach}_i} + \beta_{\text{July}_i \times \text{Teach}_i} + \beta_{\text{Month}_i} + \beta_{\text{Teach}_i \times \text{Month}_i} + \epsilon_i,
\]

where \( D_i \) was a binary indicator variable for inpatient mortality in hospitalization \( i \), July\(_i\) was a July indicator variable, Teach\(_i\), was an indicator variable for teaching-intensive hospitals status, July\(_i \times \text{Teach}_i\), was the July indicator variable interacted with teaching-intensive hospital status (ie, July effect), \( Z_i \) was a vector of covariates including patient age (continuous), sex, race/ethnicity, AHRQ predicted mortality after AMI, and length of stay, and \( \epsilon_i \) was the error term. The model’s standard errors were clustered at the hospital level to allow for correlation in outcomes across patients at a hospital. To study whether the July effect was different for patients at highest predicted risk of inpatient mortality after AMI, we estimated this model separately for patients with high and low predicted inpatient mortality risk (defined as top versus bottom three quartiles of predicted inpatient mortality, respectively). To evaluate mechanisms through which a July mortality effect among patients with AMI could be mediated, we estimated 2 additional logistic models in which the first outcome variable was a binary indicator for whether PCI was performed during hospitalization and the second outcome variable was a binary indicator for whether a bleeding complication occurred during hospitalization. Covariates in each of these models were identical to the baseline model. STATA, version 11 (STATA Corporation, College Station, TX) was used for statistical analyses and the 95% confidence interval (CI) around reported means reflects 0.025 in each tail or \( P \leq 0.05 \).

**Additional Analyses**

In addition to our baseline analyses, we also explored several other questions related to the July effect. First, we studied whether the mortality difference between AMI patients admitted to teaching-intensive and non–teaching-intensive hospitals was greatest in July compared with all other months and declined over time. We hypothesized that mortality differences between teaching-intensive and non–teaching-intensive hospitals would be greatest in July and would decline over time until May, at least among AMI patients with high predicted mortality risk. We analyzed this question by estimating a multivariable logistic regression of the following form:

\[
\text{Logit} \left[ \text{Probability} \left( D_i \right) \right] = \beta_0 + \beta_{\text{July}_i} + \beta_{\text{Teach}_i} + \beta_{\text{July}_i \times \text{Teach}_i} + \beta_{\text{Month}_i} + \beta_{\text{Teach}_i \times \text{Month}_i} + \epsilon_i,
\]

Second, we analyzed whether the estimated July effects for high- and low-risk AMI patients varied according to hospitals of different teaching intensity, rather than comparing very major teaching hospitals (ie, teaching-intensive) with all other hospitals (ie, non–teaching-intensive). Specifically, we estimated a multivariable logistic regression of the following form:

\[
\text{Logit} \left[ \text{Probability} \left( D_i \right) \right] = \beta_0 + \beta_{\text{July}_i} + \beta_{\text{Teach}_i \times \text{Month}_i} + \beta_{\text{July}_i \times \text{Teach}_i \times \text{Month}_i} + \beta_{\text{Z}_i} + \epsilon_i,
\]

where \( D_i \) was a binary indicator variable for inpatient mortality, July\(_i\) was a July indicator variable, Teach\(_i\) was a July indicator variable, and Teach\(_i\) \times Month\(_i\) was a vector of month indicator variables interacted with teaching-intensive hospital status.

Third, we analyzed whether the estimated July effects changed in magnitude over the study period. In 2003, the Accreditation Council for Graduate Medical Education (ACGME) implemented national duty hour regulations which established a maximum 80-hour work week and reduced shift lengths to no longer than 30 consecutive hours, among other provisions.17,18 An increasing trend in adherence to duty hour regulations by residency programs may have mixed impacts on the July effect. Increases in resident oversight may mitigate the July effect over time, whereas in contrast, increased patient hand-offs and decreased continuity of care may make the July effect stronger in recent years. We analyzed whether the July effect varied by year by estimating a multivariable logistic regression of the following form:

\[
\text{Logit} \left[ \text{Probability} \left( D_i \right) \right] = \beta_0 + \beta_{\text{July}_i} + \beta_{\text{Teach}_i} + \beta_{\text{July}_i \times \text{Month}_i} + \beta_{\text{Teach}_i \times \text{Month}_i} + \beta_{\text{Year}_i} + \beta_{\text{July}_i \times \text{Teach}_i \times \text{Year}_i} + \beta_{\text{Z}_i} + \epsilon_i,
\]

where the **July effect** varied with more discrete measures of predicted inpatient mortality.
where \( D \) was a binary indicator variable for inpatient mortality, July, was a July indicator variable, Teach, was an indicator variable for teaching-intensive hospitals status, and July, * Teach, * Year, was the interaction between the July indicator variable, teaching-intensive hospital indicator, and a vector of year indicators (omitted year was 2002). \( Z \) was a vector of covariates including patient age, sex, race/ethnicity, AHRQ predicted mortality after AMI, and length of stay, and \( \epsilon \) was the error term. The model’s standard errors were clustered at the hospital level.

Fourth, we analyzed whether the estimated July effect varied with more discrete measures of predicted inpatient mortality risk, rather than estimating the July effect dichotomously for patients in the top versus bottom 3 quartiles of predicted mortality. We divided patients into 4 categories on the basis of predicted inpatient mortality: those in the bottom 2 quartiles of predicted risk (ie, bottom half), third quartile, 75th and 90th percentile, and top decile. We chose a broader categorization for patients at low predicted inpatient mortality risk (ie, we combined the bottom 2 quartiles) because AHRQ predicted mortality was low in this population (1.7%), necessitating a greater sample size to be able to detect a statistically significant July effect. Similarly, we divided the top quartile into patients with predicted mortality between the 75th and 90th percentile and those in the top decile, because deaths were more prevalent in these groups. We estimated a multivariable logistic regression of the following form:

\[
\text{Logit} \left[ \text{Probability} \left( D_i \right) \right] = \beta_0 + \beta_1 \text{July}_i + \beta_2 \text{Teach}_i + \beta_3 \text{July}_i \ast \text{Teach}_i + \beta_4 \text{Severity}_i + \beta_5 Z_i + \epsilon_i
\]

where \( D_i \) was a binary indicator variable for inpatient mortality, July, was a July indicator variable, Teach, was an indicator variable for teaching-intensive hospitals status, and July, * Teach, * Severity, was the interaction between the July indicator variable, teaching-intensive hospital indicator, and indicators for each of the 4 predicted mortality groups we defined. \( Z_i \) was a vector of covariates including patient age, sex, race/ethnicity, AHRQ predicted mortality after AMI, and length of stay, and \( \epsilon_i \) was the error term. The model’s standard errors were clustered at the hospital level. We reported adjusted inpatient mortality in teaching-intensive and non–teaching-intensive hospitals in May and July, as well as odds ratios, for each of these predicted inpatient mortality groups.

**Results**

**Baseline Analyses**

The mean age of patients was lower in teaching-intensive hospitals compared with non–teaching-intensive hospitals (eg, 66.3y versus 68.8y in May, \( P<0.001 \)) as was the proportion of patients that were female (eg, 38.2% versus 41.1% in May, \( P<0.003 \); Table 1). Unadjusted inpatient mortality was lower among patients in teaching-intensive hospitals (eg, 5.6% versus 8.0% in May, \( P<0.001 \)) as was AHRQ predicted inpatient mortality (eg, 6.9% versus 7.8% in May, \( P<0.001 \)). Rates of PCI were higher in teaching-intensive hospitals.

Unadjusted inpatient mortality was lower in teaching-intensive hospitals in May compared with July (5.6% versus 6.3%, \( P=0.069 \)), whereas it was slightly higher in non–teaching-intensive hospitals in May compared with July (8.0% versus 7.8%, \( P=0.42 \)). The unadjusted difference-in-difference July mortality effect implied by these unadjusted estimates was a 0.8 percentage points mortality increase (\( P=0.04 \), computed as \([6.3\% - 5.6\%] - [7.8\% - 8.0\%]\)). AHRQ predicted mortality was slightly lower in July than May in teaching-intensive hospitals, and lower in non–teaching-intensive hospitals (7.5% versus 7.8%). The difference-in-difference July mortality effect implied by AHRQ predicted estimates was a 0.3 percentage point mortality increase (\( P=0.12 \), computed as \([6.8\% - 6.9\%] - [7.5\% - 7.8\%]\)). Rates of PCI increased between May and July in both teaching-intensive and non–teaching-intensive hospitals.

**Table 1. Characteristics of Patients Admitted With AMI to US Teaching-Intensive and Non–Teaching-Intensive Hospitals, 2002–2008**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Teaching-Intensive Hospitals</th>
<th>Non–Teaching-Intensive Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
<td>July</td>
</tr>
<tr>
<td>No. of hospitals</td>
<td>98</td>
<td>98</td>
</tr>
<tr>
<td>No. of patients with AMI</td>
<td>7073</td>
<td>6810</td>
</tr>
<tr>
<td>Mean patient age, y (SD)</td>
<td>66.3 (14.1)</td>
<td>66.0 (14.2)</td>
</tr>
<tr>
<td>Female, n (%)</td>
<td>2702 (38.2)</td>
<td>2658 (39.0)</td>
</tr>
<tr>
<td>Race, n (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>White</td>
<td>4278 (60.5)</td>
<td>4068 (59.7)</td>
</tr>
<tr>
<td>Black</td>
<td>629 (8.9)</td>
<td>573 (8.4)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>441 (6.2)</td>
<td>450 (6.6)</td>
</tr>
<tr>
<td>Other or unknown</td>
<td>1725 (24.4)</td>
<td>1719 (25.2)</td>
</tr>
<tr>
<td>Mean No. Charlson-Deyo comorbidities (SD)</td>
<td>2.4 (1.5)</td>
<td>2.4 (1.6)</td>
</tr>
<tr>
<td>Deaths, n</td>
<td>398</td>
<td>429</td>
</tr>
<tr>
<td>Mortality rate, % (95% CI)</td>
<td>5.6 (5.1–6.2)</td>
<td>6.3 (5.7–6.9)</td>
</tr>
<tr>
<td>Predicted mortality rate, Mean % (95% CI)</td>
<td>6.9 (6.7–7.1)</td>
<td>6.8 (6.6–7.0)</td>
</tr>
<tr>
<td>No. patients with PCI (%)</td>
<td>3269 (46.2)</td>
<td>3165 (46.5)</td>
</tr>
<tr>
<td>No. patients with bleeding complications (%)</td>
<td>764 (10.8)</td>
<td>758 (11.1)</td>
</tr>
</tbody>
</table>

Teaching-intensive hospitals were defined as teaching hospitals with a ratio of resident physicians to hospital beds of >0.6. Non–teaching-intensive hospitals were defined as all other hospitals. Predicted mortality was based on a validated risk-adjustment tool from the Agency for Health care Research and Quality. AMI indicates acute myocardial infarction; CI, confidence interval; and PCI, percutaneous coronary intervention.
Among patients at highest predicted risk of inpatient mortality after AMI (defined as those in the top quartile of AHRQ predicted risk), actual mortality in teaching-intensive hospitals was substantially lower in May compared with July (285 versus 333 deaths; 20.6% versus 24.8%, \( P=0.01 \); Table 2). In contrast, mortality was similar among high-risk patients between May and July in non–teaching-intensive hospitals (1908 versus 1730 deaths; 22.3% versus 22.3%, \( P=0.98 \)). Among these high-risk patients, the unadjusted July mortality effect was 4.4 percentage points (\( P=0.02 \)). Unadjusted rates of PCI were not statistically different between May and July in teaching-intensive hospitals (275 versus 267 PCIs; 19.9% versus 19.9%, \( P=0.97 \)) and in non–teaching-intensive hospitals (1115 versus 1052 PCIs; 13.0% versus 13.5%, \( P=0.33 \)). The same was true for bleeding complications.

Among patients in the bottom 3 quartiles of AHRQ predicted risk (low risk), actual mortality was similar in May and July in teaching-intensive hospitals (113 versus 96 deaths; 2.0% versus 1.8%, \( P=0.36 \)) and non–teaching-intensive hospitals (639 versus 644 deaths; 2.7% versus 2.8%, \( P=0.48 \)). Among low-risk patients, the unadjusted July mortality effect was −0.3 percentage points (\( P=0.27 \)). PCI rates were not statistically different between May and July in teaching-intensive hospitals (2994 versus 2898 PCIs; 52.6% versus 53.0%, \( P=0.599 \)) and in non–teaching-intensive hospitals (11355 versus 11139 PCIs; 48.6% versus 49.2%, \( P=0.16 \)). The same was true for bleeding complications.

Adjusted mortality among high risk patients was substantially lower in May than July in teaching-intensive hospitals (18.8% in May, 95% CI 16.9% - 20.7%; 22.7% in July, 95% CI 20.6% - 24.8%; \( P=0.006 \)) but similar between these months in non–teaching-intensive hospitals (22.5% in May; 95% CI 21.5% - 23.5%; 22.8% in July, 95% CI 21.8% - 23.8%; \( P=0.70 \); Figure 1). The adjusted difference-in-difference July mortality effect among high risk patients was 3.6 percentage points (\( P=0.017 \)). Adjusted mortality among low risk patients was not statistically significantly different between May and July in teaching-intensive hospitals (2.1% in May, 95% CI 1.6%–2.5%; 1.9% in July, 95% CI 1.5%–2.3%; \( P=0.45 \)) or non–teaching-intensive hospitals (2.7% in May, 95% CI 2.4%–2.9%; 2.8% in July, 95% CI 2.6%–3.1%; \( P=0.21 \); Figure 1). The adjusted difference-in-difference July mortality effect among low risk patients was –0.3 percentage points (\( P=0.237 \)).

Figures 2 and 3 explore whether differences in rates of PCI or bleeding complications explain the greater July mortality effect estimated among high-risk patients with AMI compared with low-risk patients. Adjusted rates of PCI among high-risk patients with AMI were not statistically significantly different between May and July in teaching-intensive hospitals (19.4% in May, 95% CI, 16.0%–22.8%; 19.4% in July, 95% CI, 15.9%–23.0%; \( P=0.98 \)) or non–teaching-intensive hospitals (13.2% in May, 95% CI, 12.1%–14.2%; 13.5% in July, 95% CI, 12.4%–14.6%; \( P=0.53 \); Figure 2). Adjusted PCI rates among low-risk patients were also similar between May and July in both teaching-intensive and non–teaching-intensive hospitals.

Adjusted rates of bleeding complication among high-risk patients were not statistically significantly different between May and July in teaching-intensive hospitals (11.0% in May, 95% CI, 8.9%–13.2%; 11.9% in July, 95% CI, 9.6%–14.1%; \( P=0.52 \)) or non–teaching-intensive hospitals (7.2% in May, 95% CI, 6.5%–7.8%; 7.1% in July, 95% CI, 6.4%–7.9%; \( P=0.92 \); Figure 3). Adjusted rates of complications from

Table 2. Inpatient Mortality, Rates of PCI, and Bleeding Complications Among Patients Admitted With AMI During May and July, According to Teaching-Intensive Hospital Status and Predicted Inpatient Mortality Risk

<table>
<thead>
<tr>
<th>Patients at high predicted inpatient mortality</th>
<th>Teaching-Intensive Hospitals</th>
<th>Non–Teaching-Intensive Hospitals</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. patients</td>
<td>May</td>
<td>July</td>
</tr>
<tr>
<td>1381</td>
<td>1344</td>
<td>8561</td>
</tr>
<tr>
<td>Deaths, n</td>
<td>285</td>
<td>333</td>
</tr>
<tr>
<td>Mortality rate, % (95% CI)</td>
<td>20.6 (18.5–22.9)</td>
<td>24.8 (22.5–27.2)</td>
</tr>
<tr>
<td>Received PCI, n</td>
<td>275</td>
<td>267</td>
</tr>
<tr>
<td>PCI rate, % (95% CI)</td>
<td>19.9 (17.8–22.1)</td>
<td>19.9 (17.8–22.1)</td>
</tr>
<tr>
<td>Bleeding complication, n</td>
<td>170</td>
<td>179</td>
</tr>
<tr>
<td>Bleeding rate, % (95% CI)</td>
<td>12.3 (10.6–14.2)</td>
<td>13.3 (11.5–15.3)</td>
</tr>
<tr>
<td>Patients at low predicted inpatient mortality</td>
<td>May</td>
<td>July</td>
</tr>
<tr>
<td>No. patients</td>
<td>5692</td>
<td>5466</td>
</tr>
<tr>
<td>Deaths, n</td>
<td>113</td>
<td>96</td>
</tr>
<tr>
<td>Mortality rate, % (95% CI)</td>
<td>2.0 (1.6–2.4)</td>
<td>1.8 (1.4–2.1)</td>
</tr>
<tr>
<td>Received PCI, n</td>
<td>2994</td>
<td>2898</td>
</tr>
<tr>
<td>PCI rate, % (95% CI)</td>
<td>52.6 (51.3–53.9)</td>
<td>53.0 (51.7–54.3)</td>
</tr>
<tr>
<td>Bleeding complication, n</td>
<td>594</td>
<td>579</td>
</tr>
<tr>
<td>Bleeding rate, % (95% CI)</td>
<td>10.4 (9.7–11.3)</td>
<td>10.6 (9.8–11.4)</td>
</tr>
</tbody>
</table>

Predicted mortality was based on a validated risk-adjustment tool from the Agency for Health care Research and Quality. Patients at high predicted inpatient mortality were defined as those in the top quartile of predicted mortality. Patients at low predicted inpatient mortality were defined as those in the bottom 3 quartiles of predicted mortality. AMI indicates acute myocardial infarction; CI, confidence interval; and PCI, percutaneous coronary intervention.
bleeding among low-risk patients were similar between May and July in both teaching-intensive and non–teaching-intensive hospitals as well.

**Additional Analyses**

**Differences in Mortality Between Teaching-Intensive and Non–Teaching-Intensive Hospitals According to Month of Hospitalization**

Analysis of mortality differences between teaching-intensive and non–teaching-intensive hospitals over the entire academic year confirmed our baseline results. Among high-risk AMI inpatients, the adjusted mortality difference between teaching-intensive and non–teaching-intensive hospitals was greatest in July and declined over the course of the academic year spanning July to May/June (Table 3). For example, among high-risk AMI patients the adjusted odds ratio of mortality between teaching-intensive and non–teaching-intensive hospitals was at its lowest in the year in May (odds ratio, 0.79) and at its highest in July (1.00), \( P = 0.02 \). From July to May, the adjusted odds ratio of mortality between teaching-intensive and non–teaching-intensive hospitals generally declined in magnitude, for example 0.94 in October, 0.86 in December, and 0.74 in March. Although odds ratios for most of the months, except July and October, were not statistically significantly different from May, they did demonstrate an overall declining trend from July to May. The odds ratio of mortality between teaching-intensive and non–teaching-intensive hospitals in June was higher than the odds ratio in May, but lower than the odds ratio in July, presumably reflecting differences in start dates of new residents across teaching-intensive hospitals. Consistent with our baseline results, the odds ratio of mortality for low-risk AMI patients hospitalized in teaching-intensive versus non–teaching-intensive hospitals did not vary significantly throughout the academic year.

**Association Between July Effect and Hospital Teaching Intensity**

Mortality increases among high-risk AMI patients in July relative to May were primarily concentrated at very major teaching hospitals (those with >0.6 residents per bed and defined in our baseline analyses as teaching intensive) rather than hospitals of lower teaching intensity (Table 4). For example, the odds ratio of mortality in July relative to May was 1.01 in non-teaching-intensive hospitals and 1.00 in teaching-intensive hospitals.
hospitals, 1.10 in very minor or minor teaching hospitals ($P=0.35$ for odds ratio compared with non-teaching hospitals), 0.90 in major teaching hospitals ($P=0.40$ for odds ratio compared with non-teaching), and 1.30 in very major teaching hospitals ($P=0.02$ for odds ratio compared with non-teaching).

**Trends in the July Effect From 2002 to 2008**

The July effect among high risk AMI patients increased in magnitude over the study period, although differences across years were not statistically significantly different at $P<0.05$ (Table I in the online-only Data Supplement). For example, in 2002, adjusted mortality among high-risk AMI patients admitted to teaching-intensive hospitals was 27.7% in May and 26.5% in July (July-May odds ratio 1.08), compared with 26.7% in May and 26.1% in July in non–teaching-intensive hospitals (July-May odds ratio 0.96). In contrast, in 2008, adjusted mortality among high-risk AMI patients admitted to teaching-intensive hospitals was 14.2% in May and 21.6% in July (July–May odds ratio 1.75), compared with 18.2% in May and 17.0% in July in non–teaching-intensive hospitals (July–May odds ratio 0.91). Despite increasing in magnitude over the study period, the July effect odds ratio—which reflects a comparison of the July-May mortality odds ratio in teaching-intensive hospitals compared to the identical ratio in non–teaching-intensive hospitals—was not statistically distinguishable across years given reduced sample sizes in analyses broken down by year.

**July Effect Across Alternative Categories of Predicted Inpatient Mortality Risk**

In addition to estimating the July effect for binary categorizations of high- and low-risk AMI patients, we also analyzed...
whether the July effect varied with more discrete measures of predicted inpatient mortality risk. The July effect in teaching-intensive hospitals was primarily concentrated among patients in the top decile of predicted inpatient mortality risk of patients (Table II in the online-only Data Supplement). The magnitude of the July effect increased with predicted inpatient mortality risk, although differences in the July effect across predicted risk categories were not statistically significantly different from one another with the exception of the top decile of risk.

### Discussion

Using data from a national sample of patients admitted with AMI to US hospitals, we found that adjusted mortality among high-risk AMI patients was similar in teaching- and non–teaching-intensive hospitals in July, but was substantially lower in teaching-intensive hospitals compared with non–teaching-intensive hospitals in May and throughout the rest of the academic year. Importantly, because adjusted mortality among high-risk AMI patients was similar between teaching- and non–teaching-intensive hospitals in July, our findings do not suggest any role of avoidance between teaching- and non–teaching-intensive hospitals in May and throughout the rest of the academic year. Importantly, because adjusted mortality among high-risk AMI patients was similar between teaching- and non–teaching-intensive hospitals in July, our findings do not suggest any role of avoidance of teaching-intensive hospitals in July. Rather, adjusted mortality among high-risk AMI patients is generally lower in teaching-intensive hospitals throughout the year, except for July, consistent with an adverse impact of organizational disruption and physician inexperience in teaching-intensive hospitals in July on outcomes of high-risk AMI patients.

The increase in mortality in July relative to May among high-risk patients admitted to teaching-intensive hospitals was concentrated at the most teaching intensive hospitals: very major teaching hospitals with >0.6 residents per bed. We found no July mortality increase among low-risk patients with AMI admitted to teaching-intensive hospitals. Differences in rates of PCI and complications from bleeding could not explain the observed July mortality increase among high-risk patients with AMI.

Although previous studies have focused on surgical patients and intensive care unit patients in US hospitals as well as emergency admissions to British hospitals—patients at arguably high risk of inpatient mortality—to our knowledge no national studies exist evaluating how the July effect is modified by severity of patient illness. This is important because one reason why July effects estimated in previous studies may have been mixed and small in magnitude is that most studies do not examine patient populations whose mortality outcomes are most likely to be adversely impacted by the relative inexperience of residents in July.

Our findings suggest that patients at high predicted risk of inpatient mortality may not only be most susceptible to adverse events occurring during resident turnover, but that interventions targeting high-risk patients in July may improve mortality substantially. Although our analysis suggests that rates of PCI and complications from bleeding do not explain the July mortality effect among high-risk patients with AMI, we could not explore whether delays in the timing of PCI, errors of medication administration, or other failures to diagnose and expeditiously treat complications of AMI could explain our findings. Our finding that the July mortality effect among patients with AMI is greatest for those already at high risk of inpatient mortality suggests that greater supervisor attention towards these patients may be warranted. This additional oversight may provide a safeguard against errors made attributable to resident or fellow inexperience and organizational disruption. Importantly, because we focused our analysis on patients admitted with AMI during the month of July—as opposed to patients admitted during June who continued their hospitalization into July—our results should not reflect errors arising from pass-off of patients between resident physicians changing over from June to July.

The estimated July effect among high-risk AMI patients admitted to teaching-intensive hospitals also appeared to increase over the study period, though differences were not statistically significantly different across years, perhaps because of low sample sizes in analyses broken down by year. This suggests that while increases in resident oversight would have been expected to diminish the July effect over time, increased patient hand-offs and decreased continuity of care may have more than offset this effect.

Our study also highlighted an interesting risk-treatment paradox in both teaching-intensive and non–teaching-intensive hospitals, whereby AMI patients with lower inpatient predicted mortality risk were more likely to undergo PCI than high-risk patients who, in theory, would be most likely
to benefit from revascularization. This phenomenon has been attributed to a number of explanations, including uncertainty among physicians about the benefits of PCI in higher risk patients who are arguably not reflective of clinical trial populations; risk aversion among physicians; and limited clinical information available in administrative databases, which may make patients who are clinically inappropriate for PCI appear appropriate to researchers analyzing these data.27,28

Our study had several limitations. Despite our difference-in-difference study design, our results may still be confounded by differences in hospital staffing or patient characteristics that occur in teaching-intensive hospitals in July. For instance, we were unable to account for additional resident supervision occurring in teaching-intensive hospitals in July that may mitigate our results. We were also unable to ensure that the care of specific patients in teaching-intensive hospitals was provided by trainees, leading some studies to focus on July effects in procedural outcomes among procedures performed only by trainees.7,15 We were able to partly address this issue, however, by focusing our analysis of teaching hospitals on those that were highly teaching-intensive, an innovation over previous studies. Similarly, physicians recently completing residency or fellowship may begin independent practice in July and may also be responsible for the observed July effect. Although our difference-in-difference study design should account for this possibility if new physicians are equally likely to begin their careers in teaching-intensive and non–teaching-intensive hospitals in July, we cannot exclude the contribution of new attending physicians to the observed July effect.

Our study also relied on administrative diagnoses codes, which may inaccurately reflect patient risk if coding practices vary between teaching and non-teaching hospitals. However, institutional norms that lead to biases in the measurement of illness severity should be similar across months and therefore addressed by our difference-in-difference study design. Our study also focused only on AMI and may not generalize to comparisons of July effects among high- and low-risk patients admitted with other acute conditions. Finally, although we demonstrated that differences in rates of PCI and bleeding complications could not explain the greater July mortality effect among high-risk patients admitted with AMI, we could not identify the specific pathways by which increased mortality in teaching-intensive hospitals in July occurred.

Despite its limitations, our study illustrates that the July mortality effect in teaching-intensive hospitals is most pronounced in high-risk patient populations for whom relative physician inexperience and organizational disruption would be predicted to be most adversely impactful. Recognition of the unique impact of resident turnover on the outcomes of high-risk patients in teaching-intensive hospitals may shape policies to improve mortality outcomes in this vulnerable population.

**Sources of Funding**

Support was provided by the Office of the Director, National Institutes of Health (1DP5OD017897-01, to Dr Jena), by the National Institute on Aging (1R03AG031990-A1, to Dr Romley), and the Leonard Schaeffer Center for Health Policy and Economics at the University of Southern California (to Dr Romley).

**Disclosures**

None.

**References**

23. Philibert I, Friedmann P, Williams WT; ACGME Work Group on Resident Duty Hours. Accreditation Council for Graduate Medical
Each summer US teaching hospitals experience a turnover of resident physicians, raising the possibility that patient outcomes suffer as a result of operational disruption and relative inexperience of new physicians (July effect). Although most studies of the July effect find small if any mortality increases in July, these studies generally do not distinguish between patients of varying predicted inpatient mortality risk. Mortality outcomes of patients at low risk of inpatient mortality may be unaffected by resident inexperience in July, whereas mortality among higher risk patients may be more affected by errors or relative inexperience at the start of the residency year. We studied inpatient mortality among a national sample of patients admitted with acute myocardial infarction to US hospitals during May and July 2002 to 2008. We stratified patients into low- and high-predicted risk of inpatient mortality and studied whether the July effect—defined as the difference in mortality in teaching-intensive hospitals in July relative to May, compared with the difference in mortality in non–teaching-intensive hospitals during these months (control group)—varied according to predicted mortality risk. We found that high-risk acute myocardial infarction patients admitted to teaching-intensive hospitals in July experienced substantial increases in mortality compared to May, whereas low-risk patients did not. Differences in rates of percutaneous coronary intervention or bleeding complications could not explain our findings. Recognition of the unique impact of resident turnover on the outcomes of high-risk patients in teaching-intensive hospitals may shape policies to improve outcomes in this vulnerable population.
Mortality Among High-Risk Patients With Acute Myocardial Infarction Admitted to US Teaching-Intensive Hospitals in July: A Retrospective Observational Study
Anupam B. Jena, Eric C. Sun and John A. Romley

Circulation. 2013;128:2754-2763; originally published online October 23, 2013;
doi: 10.1161/CIRCULATIONAHA.113.004074
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
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**SUPPLEMENTARY TABLE 1** – Adjusted inpatient mortality among high risk AMI patients admitted to teaching-intensive and non-teaching intensive hospitals in May and July, according to year of admission

<table>
<thead>
<tr>
<th>Year</th>
<th>Adjusted mortality in teaching-intensive hospitals</th>
<th>Adjusted mortality in non-teaching-intensive hospitals</th>
<th>July effect odds ratio</th>
<th>p-value relative to 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
<td>July</td>
<td>July-May odds ratio</td>
<td>May</td>
</tr>
<tr>
<td>2002</td>
<td>26.5%</td>
<td>27.7%</td>
<td>1.08</td>
<td>26.7%</td>
</tr>
<tr>
<td>2003</td>
<td>20.8%</td>
<td>24.6%</td>
<td>1.27</td>
<td>25.1%</td>
</tr>
<tr>
<td>2004</td>
<td>22.7%</td>
<td>20.5%</td>
<td>0.87</td>
<td>23.4%</td>
</tr>
<tr>
<td>2005</td>
<td>16.0%</td>
<td>17.4%</td>
<td>1.12</td>
<td>22.5%</td>
</tr>
<tr>
<td>2006</td>
<td>18.0%</td>
<td>26.9%</td>
<td>1.78</td>
<td>20.8%</td>
</tr>
<tr>
<td>2007</td>
<td>14.8%</td>
<td>20.4%</td>
<td>1.53</td>
<td>20.4%</td>
</tr>
<tr>
<td>2008</td>
<td>14.2%</td>
<td>21.6%</td>
<td>1.75</td>
<td>18.2%</td>
</tr>
</tbody>
</table>

Notes: Table presents odds ratio of mortality between July and May for patients admitted to teaching-intensive and non-teaching-intensive hospitals, according to year of hospital admission. The July effect odds ratio reflects the comparison of the July-May mortality odds among teaching-intensive hospitals compared to the July-May mortality odds in non-teaching-intensive hospitals. P-value reflects comparison of July effect odds ratio for patients admitted in a given year, relative to July effects odds ratio for patients admitted in 2002.
**SUPPLEMENTARY TABLE 2** – Adjusted inpatient mortality among patients admitted with AMI to teaching-intensive and non-teaching intensive hospitals in May and July, according to predicted inpatient mortality

<table>
<thead>
<tr>
<th>Percentile of predicted mortality</th>
<th>Adjusted mortality in teaching-intensive hospitals</th>
<th>Adjusted mortality in non-teaching-intensive hospitals</th>
<th>July effect odds ratio</th>
<th>p-value relative to 0-50th percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>May</td>
<td>July</td>
<td>July-May odds ratio</td>
<td>May</td>
</tr>
<tr>
<td>0 – 50th</td>
<td>0.5%</td>
<td>0.4%</td>
<td>0.65</td>
<td>0.7%</td>
</tr>
<tr>
<td>50th – 75th</td>
<td>5.2%</td>
<td>5.0%</td>
<td>0.96</td>
<td>6.7%</td>
</tr>
<tr>
<td>75th – 90th</td>
<td>11.3%</td>
<td>11.9%</td>
<td>1.07</td>
<td>12.4%</td>
</tr>
<tr>
<td>90th – 100th</td>
<td>32.3%</td>
<td>40.1%</td>
<td>1.40</td>
<td>38.4%</td>
</tr>
</tbody>
</table>

Notes: Table presents odds ratio of mortality between July and May for patients admitted to teaching-intensive and non-teaching-intensive hospitals, according to percentile of predicted inpatient mortality. The July effect odds ratio reflects the comparison of the July-May mortality odds among teaching-intensive hospitals compared to the July-May mortality odds in non-teaching-intensive hospitals. P-value reflects comparison of July effect odds ratio for patients in a given percentile of predicted inpatient mortality, relative to July effects odds ratio for patients in the 0-50th percentile of predicted inpatient mortality.