Association Between Ambulance Diversion and Survival Among Patients With Acute Myocardial Infarction

Yu-Chu Shen, PhD
Renee Y. Hsia, MD, MSc

A recent synthesis study by the Robert Wood Johnson Foundation and a report by the Institute of Medicine describe the state of emergency departments (EDs) in the United States as reaching a breaking point—the ED system experiences increased utilization but decreased capacity. These trends have led to a milieu of problems for patients, such as longer waiting times, decreased capacity, and increased ED access.2,8,9

Ambulance diversion, a practice in which EDs are temporarily closed to ambulance traffic due to overcrowding or lack of available resources, might be especially problematic for patients experiencing time-sensitive conditions, such as acute myocardial infarction (AMI). Ambulance diversion occurs for a variety of reasons, including overcrowding, shortage of ED staff, lack of specialty services (eg, trauma, neurosurgery), staffed inpatient beds, or major equipment failures.2,8 Regardless of the reason for diversion, an ED on diversion effectively creates a temporary decrease in ED access.

Although there are many anecdotal reports or single-hospital case studies suggesting the adverse effects of ambulance diversion and closures on patient care, there is little systematic evidence to show whether diversion is associated with worse patient outcomes.

Objective To analyze whether temporary ED closure on the day a patient experiences AMI, as measured by ambulance diversion hours of the nearest ED, is associated with increased mortality rates among patients with AMI.

Design, Study, and Participants A case-crossover design of 13,860 Medicare patients with AMI from 508 zip codes within 4 California counties (Los Angeles, San Francisco, San Mateo, and Santa Clara) whose admission date was between 2000 and 2005. Data included 100% Medicare claims data that covered admissions between 2000 and 2005, linked with date of death until 2006, and daily ambulance diversion logs from the same 4 counties. Among the hospital universe, 149 EDs were identified as the nearest ED to these patients.

Main Outcome Measures The percentage of patients with AMI who died within 7 days, 30 days, 90 days, 9 months, and 1 year from admission (when their nearest ED was not on diversion and when that same ED was exposed to <6, 6 to <12, and ≥12 hours of diversion out of 24 hours on the day of admission).

Results Between 2000 and 2006, the mean (SD) daily diversion duration was 7.9 (6.1) hours. Based on analysis of 11,625 patients admitted to the ED between 2000 and 2005, and whose nearest ED had at least 3 diversion exposure levels (3541, 3357, 2667, and 2060 patients for no exposure, exposure to <6, 6 to <12, and ≥12 hours of diversion, respectively), there were no statistically significant differences in mortality rates between no diversion and exposure to less than 12 hours of diversion. Exposure to 12 or more hours of diversion was associated with higher 30-day mortality vs no diversion status (unadjusted mortality rate, 392 patients [19%] vs 545 patients [15%]; regression adjusted difference, 3.24 percentage points; 95% CI, 0.60-5.88); higher 90-day mortality (537 patients [26%] vs 762 patients [22%]; 2.89 percentage points; 95% CI, 0.13-5.64); higher 9-month mortality (680 patients [33%] vs 980 patients [28%]; 2.93 percentage points; 95% CI, 0.15-5.71); and higher 1-year mortality (731 patients [35%] vs 1034 patients [29%]; 3.04 percentage points; 95% CI, 0.33-5.75).

Conclusion Among Medicare patients with AMI in 4 populous California counties, exposure to at least 12 hours of diversion by the nearest ED was associated with increased 30-day, 90-day, 9-month, and 1-year mortality.
empirical evidence to demonstrate these claims. A recent ecological study based on data from New York City found that high levels of ED diversion were associated with increased AMI mortality rates. Because this study was not conducted at the individual patient level, however, the authors could not ascertain whether the differences in mortality rates were due to diversion or unobserved individual patient and hospital characteristics. As emphasized by the most prominent health service researchers in emergency medicine, there is a need to document whether decreased access as measured by diversion affects the quality of care or outcomes and, if so, the extent of such effects.

In this study, we use 100% of Medicare claims and daily ambulance diversion logs from local emergency medical services in 4 counties in California to analyze the relationship between ambulance diversion and health outcomes of patients experiencing AMI. Specifically, we address the following research question. Is temporary ED closure on the day a patient experiences AMI, as measured by ambulance diversion hours of the nearest ED, associated with increased mortality rates among patients with AMI?

METHODS

Conceptual Model

An ED on diversion can be considered as a signal that available resources are unable to match demand or a proxy (albeit imperfect) of crowding. Conceptually, diversion could have implications for both patients who are diverted to other hospitals and nondiverted patients within the diverting hospital. For patients who had to be diverted elsewhere, ambulance diversion increases transport time, likely causing delays in receiving treatment and potentially worse prognosis of AMI. Even if the increased transport time is trivial, the patients might end up in a less desirable setting (eg, ED without catheterization capacity if the one ED with catheterization capacity is on diversion). For nondiverted patients in an ED that is on diversion (either because these patients were admitted before the status change, arrived by private vehicles, or were brought in under exception), their outcome could still be affected as they are in an ED during a time when clinicians or resources are limited in such a way to prevent optimal patient care.

Moreover, diversion in one hospital can potentially affect patients in nearby hospitals, as nearby hospitals would receive the diverted patients. This increased patient load could similarly cause treatment delays. Many EDs are on diversion for short periods on a given day and in many instances have multiple episodes of diversion throughout a day. Our patient data contain date of admission, but not the exact time of admission. Although we cannot verify that a patient was diverted or not, the conceptual model described herein hypothesizes that longer exposure to diversion hours would be associated with worse outcome for both the diverted and nondverted patients in the affected area.

Data Sources

The primary data sources for ambulance diversion were the daily diversion logs from 4 California counties (Los Angeles, San Francisco, San Mateo, and Santa Clara). Together, these 4 counties represent 63% of California’s population based on 2000 US Census data. We obtained detailed daily diversion logs for the years 2000–2006 from each county by directly contacting their local emergency medical services agencies and securing permission. The first available date of each county’s data varied (San Mateo started January 2000, San Francisco started March 2000, Los Angeles started June 2001, and Santa Clara started January 2003). All counties have daily logs available until November 2006. We only included patients from the relevant months or year when data for the corresponding county were available.

The local emergency medical services agencies govern and track diversion in all hospitals under each county’s jurisdiction. The daily diversion log is specific to ED and trauma centers, and contains information regarding date and exact time diversion began and ended for every hospital as well as the reason for diversion in each instance (ie, whether the ED diversion is due to ED saturation, if only trauma care is on diversion, lack of a neurosurgeon, equipment downtime). During the study period, there were no policies to selectively divert patients with AMI to percutaneous coronary intervention–equipped hospitals in these 4 counties. For the purpose of our analysis, we excluded diversion that only applied to trauma center or psychiatric EDs and diversion due to lack of a neurosurgeon or computed tomographic scan downtime, because these types of diversion would not affect the admission of patients with AMI. To capture the relevant hospital universe for matching patients to the correct EDs (because hospitals not on diversion would not appear in the diversion logs), we merged the daily diversion logs with California Office of Statewide Health Planning and Development and Medicare Healthcare Cost Report Information System data sets to obtain additional facility data.

Patient data from the 4 California counties, including patients’ mailing zip codes, were obtained from the Medicare Provider Analysis and Review. We linked each patient’s zip code with longitude and latitude coordinates of each zip code using Mailer’s software. We also obtained the longitude and latitude coordinates of the hospital’s physical address or heliport (if one existed). We identified the nearest ED for each patient’s zip code as follows: (1) we calculated the driving time between each patient’s zip code and all EDs, and (2) we designated the ED with the shortest driving time as the nearest ED. In addition, we identified the diversion level of the nearest ED on the day a patient

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experienced AMI by merging the ED diversion data to the patient database on admission date and provider identification. The study was approved by the Naval Postgraduate School Institutional Review Board and, regarding patient informed consent, a waiver was obtained as part of the institutional review board review because we used secondary data for analysis.

**Patient Population**

We identified the AMI population by extracting from 100% Medicare Provider Analysis and Review records that had codes 410.x0 or 410.x1 as the principal diagnoses, number of admissions occurring between 2000 and 2005, and by county of residence as 1 of the 4 counties for which diversion data were available. These patients' Medicare records were linked to death certificates, if deceased, up until the end of March 2006. We applied several exclusion criteria to the patient sample. First, we followed the exclusion criteria of McClellan et al to minimize selection bias, which excluded patients who had a prior AMI admission within the past 12 months, patients who had a length of stay of 1 day (because the patient might have been misclassified as AMI at the initial presentation), and patients without continuous Medicare part A coverage within the past 12 months. We also excluded 24% of the patient population who were not admitted through the ED, because admission through the ED is the relevant population. Furthermore, we excluded 11% of patients whose admitted hospital is more than 100 miles away from their mailing zip codes, because those patients likely do not reside at their mailing address or were admitted to hospitals while being away from home.

**Defining AMI Outcomes**

The dependent variable in the analysis was whether a patient died within x days from his/her ED admission (x = 7 days, 30 days, 90 days, 9 months, and 1 year). For example, the dependent variable that captures 7-day mortality takes on the value 1 if a patient died within 7 days from his/her date of admission and 0 otherwise.

**Statistical Methods**

Our statistical model follows the same principle as the case-crossover design, while controlling for time-dependent variables. We compared the percentage of patients with AMI who died within 7 days, 30 days, 90 days, 9 months, and 1 year when their nearest ED is in normal operation (ie, no exposure to diversion [control group]) and when the same ED is exposed to different levels of diversion (ie, the same ED crosses over to higher exposure of diversion). By using each ED as its own matched control, we can eliminate any inherent differences across EDs, such as possible differences in baseline mortality rates, quality of care, case-mix of the patient population, teaching status, or other unobserved characteristics that might be confounded with mortality rates.

We defined 4 diversion exposure levels as 0 hours (reference group), less than 6 hours, 6 to less than 12 hours, and 12 or more hours. These cut points were determined before we linked the daily diversion data to patient outcomes by dividing the empirical distribution of the daily ambulance diversion hours into quartiles. The cutoffs for the quartiles are 3.0, 6.6, and 11.6 hours. We combined the first 2 quartiles because a priori we did not expect to see an association with patient mortality at lower levels of diversion and wanted to account for only practically meaningful thresholds. We therefore used 6 and 12 hours (instead of 6.6 and 11.6 hours) for easier exposition of the thresholds for the 2 upper quartiles.

The ED fixed effects removes any time-invariant unobserved differences across EDs, and the 3 diversion exposure indicators allow us to compare AMI mortality rates when the same ED is exposed to different levels of diversion. Because each ED serves as its own matched control to compare mortality rates across different levels of diversion, we excluded patients from hospitals in which we observed fewer than 3 levels of exposure.

Although a logistic model is the natural choice for estimating a dichotomous dependent variable for cross-sectional data, it would result in an inconsistent estimator in a panel data setting because we are including a significant number of fixed effects. On the other hand, a linear probability model can provide consistent estimates.25,26 In addition to the key diversion variables, we included fully interacted patient demographic covariates (5-year age groups; sex; white, black, or other race/ethnicity; and counts of comorbidities). Race/ethnicity was obtained from the Medicare denominator file and classified by the Centers for Medicare & Medicaid Services. We also included a list of disease-related risk adjustments following the work by Skinner and Staiger, which uses the same patient data source. Specifically, risk adjustments were made if patients had peripheral vascular disease, chronic pulmonary disease, dementia, chronic renal failure, diabetes, liver disease, or cancer at the time of admission.

We included hospital characteristics of the admitted hospital, including whether the hospital has catheterization capacity, hospital ownership (for-profit, government), and size (measured by log transformed total available beds). In addition, we controlled for year trends (overall mortality rates have decreased steadily over time) and monthly (seasonal) trends within each year. For all models, we estimated heteroskedasticity robust standard errors, which allow for intra-ED correlation among patients who lived closest to the same ED.

All estimations were performed using Stata version 11 (StataCorp, College Station, Texas), and we used
.05 level of significance with 2-sided testing. Our sample size was sufficient, by conventional standard of 80% power, to detect a minimum of 10% differences in mortality rates—the estimated study power for the analysis was more than 90% for all dependent variables.

**RESULTS**

The final sample consisted of 13,860 patients from 508 zip code areas whose admission date was within the relevant period in which ED diversion data were available. Among the hospital universe, 149 EDs were identified as the nearest ED to these patients. The **Figure** shows the mean hours of diversion per day between January 2000 and November 2006 among hospitals that reported positive diversion hours. The mean (SD) daily diversion duration was 7.9 (6.1) hours, but the **Figure** shows a seasonal trend in which the hours of diversion tend to peak in winter.

Merging the diversion information to the patient data, we excluded 2,235 patients whose closest ED was not exposed to at least 3 levels of diversion and we excluded diversion logs from 2006 because the last matched admission date was December 2005. The multivariate analysis consisted of 11,625 patients. Among these patients, 3,541, 3,357, 2,667, and 2,060 patients were admitted for AMI when their closest ED was not exposed to diversion and exposed to less than 6 hours, 6 to less than 12 hours, and 12 or more hours, respectively. **Table 1** shows that 1,034 patients (29%) in the no diversion category died within 1 year of ED admission. The number of patients who died within 1 year of admission in the less than 6 hours, 6 to less than 12 hours, and 12 or more hours diversion categories were 1,028 (31%), 794 (30%), and 731 (35%), respectively.

**Table 1** shows that 1034 patients (29%) in the no diversion category died within 1 year of ED admission. The number of patients who died within 1 year of admission in the less than 6 hours, 6 to less than 12 hours, and 12 or more hours diversion categories were 1028 (31%), 794 (30%), and 731 (35%), respectively.

**Table 2** reports the hospital characteristics of admitted ED. When the closest ED was on diversion, a lower share of patients was admitted to hospitals with a catheterization laboratory (1,611 patients [78%] in ≥12 hours exposure category vs 1,750 [49%] in the no diversion category; and number of patients receiving percutaneous coronary intervention was 489 [24%] in ≥12 hours exposure category vs 1,105 [31%] in the no diversion category).

**Table 2** reports the hospital characteristics of admitted ED. When the closest ED was on diversion, a lower share of patients was admitted to hospitals with a catheterization laboratory (1,611 patients [78%] in ≥12 hours exposure category vs 1,750 [49%] in the no diversion category; and number of patients receiving percutaneous coronary intervention was 489 [24%] in ≥12 hours exposure category vs 1,105 [31%] in the no diversion category).
[17%] vs 259 patients [7%]) and to government hospitals (255 patients [12%] vs 336 patients [9%]). The number of patients who were admitted to their closest ED and the distance between admitted ED and closest EDs were similar across the 4 diversion categories. The similar levels of travel pattern might suggest that distance is a minor factor in describing the relationship between diversion and mortality, and that other mechanisms discussed in the conceptual model section play a bigger role.

TABLE 3 shows the multivariate results, focusing on the diversion variables only (full regression results are shown in eTable 1, available at http://www.jama.com). The first column shows the mean mortality rates in our control group (no diversion on day of admission). The next 3 columns show the regression-adjusted differences in mortality rates between each of the exposure groups and the control group. There were no statistically significant differences in mortality rates between no diversion status and when the exposure to diversion was less than 12 hours. Exposure to 12 or more hours of diversion was associated with higher 30-day mortality compared with no diversion status (unadjusted mortality rate, 680 patients [33%] vs 980 patients [28%]: regression adjusted difference, 3.04 percentage points; 95% CI, 0.33-5.75).

We performed several sensitivity analyses. First, to make sure that our results were not driven by the underlying differences across admitted hospitals, we estimated our model by replacing the nearest ED fixed effects with admitted ED fixed effects. Our results were similar and all conclusions remained the same. Second, our sample did not include patients who died on arrival or in the ED; those patients would have only had outpatient records. We therefore obtained authorization to access 2 years of outpatient records (2000 and 2005), resulting in 63 additional cases. When we added this group to our original sample, our conclusions on the key diversion variables remained the same. Third, we implemented an additional model by including an additional indicator for patients who bypassed their closest ED and interaction terms between the 3 diversion exposure categories and this by-pass indicator. eTable 2 shows that for the same level of diversion exposure, the point estimate of the mortality rate was indeed higher for people who bypassed their closest ED than for those admitted to their closest ED. However, the standard errors are too large to make definitive statements.

COMMENT

Our study to our knowledge is the first multisite, multicounty analysis

Table 1. Descriptive Statistics of Patient Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Nearest ED Was Not Diverted</th>
<th>Nearest ED’s Exposure to Diversion on the Day of Admission</th>
<th>&lt;6 h</th>
<th>6 to &lt;12 h</th>
<th>≥12 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Share of patients who died within</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 d</td>
<td>300 (9)</td>
<td>300 (9)</td>
<td>222 (8)</td>
<td>208 (10)</td>
<td></td>
</tr>
<tr>
<td>30 d</td>
<td>536 (16)</td>
<td>451 (17)</td>
<td>392 (19)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90 d</td>
<td>760 (23)</td>
<td>605 (23)</td>
<td>537 (26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9 mo</td>
<td>978 (29)</td>
<td>751 (28)</td>
<td>680 (33)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 y</td>
<td>1028 (31)</td>
<td>794 (30)</td>
<td>731 (35)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demographics</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Women</td>
<td>1677 (50)</td>
<td>1354 (51)</td>
<td>1065 (52)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black</td>
<td>203 (6)</td>
<td>169 (6)</td>
<td>231 (11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other nonwhite races</td>
<td>662 (19)</td>
<td>522 (20)</td>
<td>414 (20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age distribution, y</td>
<td>432 (12)</td>
<td>342 (15)</td>
<td>294 (14)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>65-69</td>
<td>531 (15)</td>
<td>398 (15)</td>
<td>313 (15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>70-74</td>
<td>656 (19)</td>
<td>520 (19)</td>
<td>403 (20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>75-79</td>
<td>773 (22)</td>
<td>580 (22)</td>
<td>445 (22)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>80-84</td>
<td>670 (19)</td>
<td>445 (17)</td>
<td>344 (17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>≥85</td>
<td>479 (14)</td>
<td>382 (14)</td>
<td>261 (13)</td>
<td></td>
<td></td>
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<tr>
<td>Comorbid conditions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>245 (7)</td>
<td>192 (7)</td>
<td>142 (7)</td>
<td></td>
<td></td>
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<tr>
<td>Chronic pulmonary disease</td>
<td>660 (19)</td>
<td>501 (19)</td>
<td>436 (21)</td>
<td></td>
<td></td>
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<tr>
<td>Dementia</td>
<td>150 (4)</td>
<td>110 (4)</td>
<td>99 (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chronic renal failure</td>
<td>72 (2)</td>
<td>52 (2)</td>
<td>42 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td>874 (25)</td>
<td>726 (27)</td>
<td>572 (28)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver disease</td>
<td>12 (&lt;1)</td>
<td>15 (1)</td>
<td>5 (&lt;1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cancer</td>
<td>224 (6)</td>
<td>141 (5)</td>
<td>107 (5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catheterization</td>
<td>1750 (49)</td>
<td>1239 (46)</td>
<td>860 (42)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Catheterization on day of admission</td>
<td>756 (43)</td>
<td>491 (40)</td>
<td>340 (40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCI</td>
<td>1105 (31)</td>
<td>752 (28)</td>
<td>469 (24)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PCI on day of admission</td>
<td>578 (52)</td>
<td>381 (51)</td>
<td>239 (40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrombolytic therapy</td>
<td>51 (1)</td>
<td>38 (1)</td>
<td>32 (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thrombolytic therapy on day of admission</td>
<td>42 (82)</td>
<td>31 (82)</td>
<td>30 (94)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations: ED, emergency department; PCI, percutaneous coronary intervention.
*Data are presented as No. (%).

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using daily ambulance diversion and patient-level data to evaluate the association between diversion and patient outcomes for patients experiencing AMI. We showed that when the nearest ED is on diversion, a lower proportion of patients is admitted to hospitals with catheterization capacity, and a higher proportion is admitted to for-profit and government hospitals. Under a variety of specifications and sensitivity analyses, we found that lengthy periods of ED diversion are associated with higher mortality rates among patients with a time-sensitive condition such as AMI. Specifically, when a patient’s nearest ED was exposed to diversion for 12 or more hours on the day of admission, the patient experienced a higher death rate by about 3 percentage points than when that same ED was not on diversion. This adverse relationship persisted even when we examined the 1-year mortality rate.

When a hospital’s ED is on diversion, it can affect different types of patients—those patients who were diverted, those patients receiving care or admitted while the ED is on diversion status, and those patients in nearby hospitals receiving the diverted patients. Although we were able to examine patient and hospital interactions at a more precise level than the community-wide ecological analysis, we could not identify individual patients diverted from their ED of choice vs those who were not, or the mode of transportation (those patients who arrived via private vehicles would be admitted). Although our study design was advantageous in that it avoided confounding of patients who were or were not selected to be diverted, our results must be interpreted with caution because we cannot disentangle the precise mechanisms through which diversion affects patient outcomes. Our results should not be interpreted as causal.

Ambulance diversion is common and more likely to occur in urban settings—the National Center for Health Statistics estimated that hospitals divert more than 0.5 million ambulances a year in the United States—an average of 1 ambulance per minute. The estimated association is also not trivial—a 3.24 percentage point increase off a 15% 30-day mortality rate indicates a 21.6% increase in overall mortality rate. Fortunately, we only observed the adverse relationship in hospitals that were on diversion for at least 12 hours on any given day. In our data, such long diversion days occurred in 25% of the daily logs. Notably, such long diversion hours are more likely to occur in winter and in densely populated metropolitan areas—both factors associated with increased ED demand.

These findings point to the need for more targeted interventions to appropriately distribute system-level resources in such a way to decrease crowding and diversion, so that patients with time-sensitive conditions such as AMI are not adversely affected. It is important to emphasize that while demand on emergency care is increasing as evidenced by increasing utilization, supply of emergency care is decreasing. If these issues are not addressed on a larger scale, ED conditions will deteriorate, having significant implications for all.

Our study has several limitations. First, we identified the nearest ED for each patient based on the longitude and latitude information of the patient’s zip code and the hospital’s location. Two patients from the same zip code might have very different distances to the same ED. We believe the problem is minimized for our sample because all 4 counties are in densely populated metropolitan statistical areas.
Second, the patient’s zip code on file is based on mailing zip code, which might not reflect the actual residence. We took the standard approach and applied exclusion criteria, dropping patients whose admitted hospital was more than 100 miles away from their zip code. In addition, approximately 80% to 85% of AMIs have been shown to occur at home.\(^{31,32}\) More importantly, there is no evidence to suggest that out-of-home AMIs (or more specifically, nonresidential zip code AMIs) would systematically differ across patients who experience more diversion than others; therefore, this data limitation should not affect our analyses.

Third, it is possible that some patients’ closest EDs are out of the counties in which we can match diversion logs (e.g., a resident in San Francisco county might be closest to an ED in Alameda county). In our method that follows the case-crossover design, those patients would be excluded from the analysis, because we only included patients whose nearest ED experienced multiple levels of diversion. Fourth, there might be reporting errors in the diversion daily logs. As long as the errors do not systematically differ by diversion duration (ie, there are not more errors for log entries that record longer duration), we do not expect to have a bias in our estimates.

Fifth, the study is limited to elderly populations, which only represent between 50% and 60% of patients with AMI. Therefore, our results should not be generalized to the younger population. Similarly, our results are based on 4 populous counties in California that collectively represent 63% of the state’s population. Although these counties are demographically diverse, the proportion of black individuals is substantially lower and the proportion of other nonwhite minorities is substantially higher than individuals in the United States as a whole. Also, these counties have few rural residents. Therefore, our findings may not be readily generalizable to other parts of the United States, particularly rural areas in which a single hospital is the only option for AMI care. In addition, the exclusion of patients who died before they could generate a hospital admission means our estimated mortality rate differences should be considered a conservative estimate. Suppose we have a hypothetical patient who will die in either case, whether the ED is on diversion or not. In the case-crossover design, this patient does not contribute to the mortality difference if we can observe his/her death at all levels of exposure to diversion (ie, when counting the number of deaths under different exposure levels, the patient contributes 1 death in all cases). However, our data limitation is such that when the patient is diverted and dies en route, he/she does not show up as an observable death when the ED is exposed to diversion; whereas, if the patient survived just long enough to get admitted when an ED is not on diversion, his/her death would be evident in our data. In other words, the patient would contribute as 1 death under no diversion, but no deaths under diversion. The implication of this data limitation means the observed mortality rate is lower than the actual mortality rate when the ED is exposed to diversion, therefore, making our estimated difference in mortality rate between diversion and no diversion a conservative estimate.

**CONCLUSION**

Diversion is a signal of a larger access problem in the health care system, representing resource constraints that are beyond patient factors and related to the hospital and health care system. We show a strong relationship between prolonged ambulance diversion and increased mortality of patients with AMI. Although we cannot disentangle the precise mechanisms through which diversion affects patient outcomes, our results suggest that more integrated health care policies from the prehospital to in-hospital setting should include provisions that minimize instances in which hospitals are on diversion for prolonged periods. Furthermore, restructuring of hospital and larger system-level resources to improve care delivery efficiency may be required to improve outcomes of patients with time-sensitive conditions, such as AMI.

Possible policy options to improve such care could include patient flow initiatives that have been implemented in many counties and states with success.\(^{33}\) Diversion bans have been implemented in various regions,\(^{34,35}\) with the first statewide ban on diversion in Massachusetts in 2009.\(^{36,37}\) Early evaluation of this recent legislation has not revealed any negative outcomes for patients, at least when measured by waiting times.\(^{38}\) To prevent adverse consequences for patients, however, it is critical that such policies are implemented in conjunction with hospital-level changes beyond the ED that improve inpatient capacity and patient flow.\(^{7,39,41}\)

In addition, it would be important for future analyses to disentangle the various mechanisms through which diversion might adversely affect patient care, so that policies targeting the right mechanisms may be adapted for better care that translates into better outcomes for patients in need. It is also crucial to examine the relationship between ambulance diversion and the outcomes of nonelderly patients and patients experiencing other time-sensitive illness such as traumatic injuries.
Amber, analysis, and interpretation of the data, or in the preparation, review, or approval of the manuscript.

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