Is Emergency Department Closure Resulting in Increased Distance to the Nearest Emergency Department Associated With Increased Inpatient Mortality?

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Study objective: We seek to determine whether patients living in areas affected by emergency department (ED) closure, with subsequent increased distance to the nearest ED, have a higher risk of inpatient death from time-sensitive conditions.

Methods: Using the California Office of Statewide Health and Planning Development database, we performed a nonconcurrent cohort study of hospital admissions in California between 1999 and 2009 for patients admitted for acute myocardial infarction, stroke, sepsis and asthma or chronic obstructive pulmonary disease. We used generalized linear mixed-effects models comparing adjusted inpatient mortality for patients experiencing increased distance to the nearest ED versus no change in distance.

Results: Of 785,385 patient admissions, 67,577 (8.6%) experienced an increase in distance to ED care because of an ED closure. The median change for patients experiencing an increase in distance to the nearest ED was only 0.8 miles, with a range of 0.1 to 33.4 miles. Patients with an increase did not have a significantly higher mortality (adjusted odds ratio 1.04; 95% confidence interval 0.99 to 1.09). In subgroups, we also observed no statistically significant differences in adjusted mortality among patients with acute myocardial infarction, stroke, asthma or chronic obstructive pulmonary disease, and sepsis. We did not observe any significant variations in mortality for time-sensitive conditions in sensitivity analyses that incorporated a lag effect of time after change in distance, allowance for a larger affected population, or removal of ST-segment elevation myocardial infarction from the acute myocardial infarction subgroup.

Conclusion: In this large population-based sample, less than 10% of the patients experienced an increase in distance to the nearest ED, and of that group, the majority had less than a 1-mile increase. These small increased distances to the nearest ED were not associated with higher inpatient mortality among time-sensitive conditions. [Ann Emerg Med. 2012;60:707-715.]

Please see page 708 for the Editor's Capsule Summary of this article.

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INTRODUCTION

Background

In 2006, the Institute of Medicine reported that "the emergency care system of the future should be highly regionalized, coordinated, and accountable."[1] Although purposeful and nationwide regionalization has yet to materialize into health policy,[2] current changes in emergency department (ED) distribution provide an opportunity to study the natural experiment of ED closures and the subsequent effects on patients to inform regionalization initiatives or other health policies aiming to restructure health care delivery systems.[3]

During the last 2 decades, the annual number of ED visits nationwide increased from 94.9 million to 116.8 million (23%) amidst a concurrent decrease in the number of EDs from 4,114 to 3,925 (4.6%).[4] The trend in California is even more striking, where there has been a 12% reduction in available EDs and a 27% increase in total patient visits per ED.[5-9] Increased ED demand in a setting of progressive ED closures—which disproportionately occur in underserved areas[10]—has stirred significant public and media concern.[11]

Editor's Capsule Summary

What is already known on this topic

As hospitals close, access to an emergency department (ED) is altered for many patients because of greater travel distances.

What question this study addressed

Do hospital and ED closures increase distance from an ED and affect inpatient mortality?

What this study adds to our knowledge

Using a 10-year California database and evaluating select time-sensitive conditions, 8.6% of patients had an increased ED travel distance, most less than a mile, but without a change in mortality.

How this is relevant to clinical practice

ED closures in California increased travel distances but did not change mortality. This may not be true in all geographic regions.

Importance

ED closure is important because it may increase the distance and time it takes for patients to access critical medical care. Increased geographic distance affects people's willingness to seek care.[12,13] One study of hospital closure in Los Angeles demonstrated that even a 1-mile increase in hospital proximity is associated with a 6.5% increase in the death rate from acute myocardial infarction and an 11% to 20% increase from unintentional injuries.[14] However, this study was done with aggregated outcomes rather than patient-level outcomes. Another study in Los Angeles found that hospital closure caused a transient increase in crowding and ambulance diversions for surrounding EDs,[15] which have both been related to adverse patient outcomes.[16,17]

Goals of This Investigation

There is limited literature evaluating the effect of ED closure on clinically relevant patient health outcomes and little known about the extent to which people are affected by closures. Defining such effects may provide policymakers with a clearer picture of the effect of closure as they propose changes in acute care systems, especially given the federal emphasis on regionalization.[1] In this study, we sought to first quantify the proportion of patients who, during an 11-year period, experienced an increase in distance to their nearest ED and the extent to which they were affected. Our main goal was to determine whether patients who experienced increases in distance to their nearest ED also experienced increased inpatient mortality. Specifically, we hypothesized that these increases in distance would be associated with poorer outcomes for 4 time-sensitive medical conditions: acute myocardial infarction, stroke, sepsis, and asthma or chronic obstructive pulmonary disease. We sought to evaluate whether patients with these prespecified time-sensitive conditions had a higher risk of inpatient mortality when evaluated as an overall cohort together, as well as separately, in analyses stratified by condition.

MATERIALS AND METHODS

Study Design and Setting

Using data from nonfederal hospitals in California, we performed a nonconcurrent cohort study of all admissions for conditions that have been previously identified as time-sensitive[18-22]: acute myocardial infarction, stroke, sepsis, and asthma or chronic obstructive pulmonary disease, according to the Clinical Classifications Software from the Agency for Healthcare Quality and Research.[23]

We used nonpublic patient-level data for admitted adult patients from January 1, 1999, to December 31, 2009, from the California Office of Statewide Health and Planning Development Patient Discharge Data, including age, sex, race/ethnicity, insurance, visit date, source of admission, *International Classification of Diseases, Ninth Revision* (*ICD-9*) codes of primary and secondary diagnoses, and hospital disposition (including inhospital death). We did not analyze patients who were discharged from the ED and were not admitted.

We also obtained use data from the state to document which hospitals had ED closures by year from 1999 to 2009 and merged corresponding annual hospital-level characteristics from the hospital financial and use reports.[24] Discrepancies or missing data were confirmed directly, as described previously.[25] We also obtained case mix of each hospital to adjust for case severity.

We identified the longitude and latitude coordinates of each patient zip code with Mailer's software.[26] The Figure and Appendix E1, Figure E1 (available online at http://www.annemergmed.com) demonstrate our data set linkage and patient selection flowchart, respectively. This study was approved by the University of California San Francisco Committee on Human Research.

Selection of Participants

To determine the patients affected by ED closures, we geocoded the location of each patient's home zip code to the nearest ED and calculated the straight-line distance between the population centroid of the 2 zip codes for each year.[27] We then calculated the change in distance between adjacent years for each zip code. This allowed us to stratify patients into those who experienced an increase in distance to the nearest ED and those who did not.

To capture the patient population more precisely, we limited the study to include only patients who were admitted from the ED by excluding direct or elective admissions from the community because they bypass the ED (and therefore would not be affected by ED closure). Additionally, we included only those patients who actually were admitted to their nearest

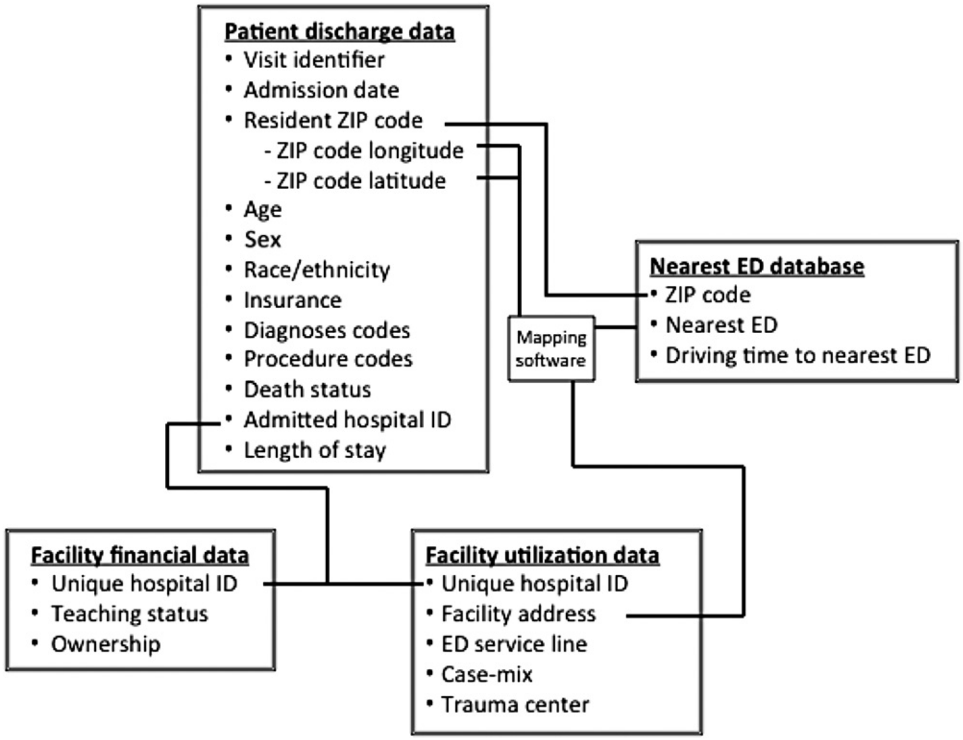

Figure. Schematic of data linkage.

hospital rather than analyzing a more theoretical cohort of patients who potentially could have experienced change according to geocoding of zip code calculations alone. This allowed us to exclude patient preferences for certain EDs. For example, patients with a specific health plan (eg, Kaiser, Veterans Administration) may prefer going to their designated hospital even if it is not the closest ED. We did not completely exclude all patients from these health plans, however, because our model still captured such patients if the preferred destination was the closest or overridden (eg, deemed unsafe because of critical condition) by out-of-hospital providers. We also excluded patients whose mailing zip codes were more than 100 miles away from their admitted hospital, as done in another study,[28] because they were likely admitted to hospitals while away from home (eg, vacation) or not residing at the location they provided to the hospital.

The treatment group included all patients living in zip codes that experienced an increase in driving distance to their nearest ED in the year they visited the ED, compared with the base year, 1999. The control group consisted of all patients living in zip codes that did not experience an increase in driving distance in the year they visited the ED, compared to the base year, 1999.

The primary outcome variable in our model is composite inpatient mortality for all of the time-sensitive conditions studied. The secondary outcomes are the inpatient mortality for each condition studied. The mortality outcomes were obtained from the patient-level files.

We adjusted for age, race or ethnicity, sex, and insurance status (Medicare, Medicaid, private, indigent, and other). We also controlled for standard Elixhauser comorbidities[29] to adjust for differences in baseline mortality risks, as well as case mix of each hospital to control for hospital-level differences in patient acuity.

Primary Data Analysis

We applied a generalized linear mixed-effects model framework to estimate a patient's likelihood for inpatient mortality as a function of the distance to the nearest ED. We performed hierarchic modeling to account for patient-level effects and hospital-level clustering. We analyzed the general cohort of patients with all 4 time-sensitive conditions and also performed stratified analyses to determine whether there were isolated effects in any of the specific conditions. We specified 2 models a priori of the relationship between difference in distance and mortality: model 1, which compared mortality if a patient had no change or a decrease in distance compared to an increase in distance, and model 2, which compared inpatient mortality among those experiencing a decrease, no change, and increase in distance.

Because mortality could potentially change over time because of, for example, the development of new treatments, we also added year as a linear variable to control for secular trends. Additionally, because closures are usually implemented gradually, allowing for community awareness and change in ED-seeking behavior, we incorporated a lag effect for the year

Table 1. Characteristics of study patients according to whether they experienced an increase in distance to the nearest ED (n=785,385).

Change in Distance	Decrease and No Change (%)	Increase (%)
Number of patients*	717,808 (91.4)	67,577 (8.6)
Subgroup conditions*		
AMI	149,273 (92.0)	12,979 (8.0)
Stroke	174,989 (91.6)	16,116 (8.4)
Sepsis	178,209 (90.3)	19,148 (9.7)
Asthma or COPD	215,337 (91.8)	19,334 (8.2)
Sex		
Male	329,912 (46.0)	31,011 (45.9)
Female	387,881 (54.0)	36,565 (54.1)
Unknown	15 (0)	1 (0)
Age category, y		
18–44	52,489 (7.3)	5,410 (8.0)
45–64	182,758 (25.5)	19,231 (28.5)
65–74	149,845 (20.9)	13,848 (20.5)
75–84	201,438 (28.1)	17,533 (26.0)
>85	131,278 (18.3)	11,555 (17.1)
Race/ethnicity		
Non-Hispanic white	477,645 (66.5)	40,033 (59.2)
Non-Hispanic black	54,105 (7.5)	9,553 (14.1)
Hispanic	109,163 (15.2)	11,949 (17.7)
Other (Asian, Pacific Islander, Native American)	64,530 (9.0)	5,330 (7.9)
Unknown	12,365 (1.7)	712 (1.1)
Insurance		
Medicare	468,755 (65.3)	42,907 (63.5)
Medi-Cal (Medicaid)	90,400 (12.6)	10,009 (14.8)
Private	115,881 (16.1)	10,179 (15.1)
Uninsured/self-pay	33,653 (4.7)	3,777 (5.6)
Other	8,914 (1.2)	697 (1.0)
Unknown	205 (0)	8 (0)
Elixhauser comorbidities†		
Hypertension	418,781 (58.3)	42,508 (62.9)
Diabetes	169,252 (23.6)	17,382 (25.7)
Fluid and electrolyte disorder	203,746 (28.4)	21,393 (31.7)
Mortality	75,075 (10.5)	7,459 (11.0)
Case mix index mean (SD)	1.12 (0.19)	1.19 (0.18)

AMI, Acute myocardial infarction; *COPD*, chronic obstructive pulmonary disease.
*These are row percentages; the remainder of the table shows column percentages.
†Only the most common 3 Elixhauser comorbidities are listed.

Table 2. Distance changes experienced by patients, 1999 to 2009, overall and stratified by disease condition.

Description	Median Distance Change (Miles)	Interquartile Range (IQR)	Range
All			
Decrease	–6.6	−20.2 to −0.5	−77.7 to −0.1
Increase	0.8	0.2 to 1.4	0.1 to 33.4
AMI			
Decrease	−0.8	−11.6 to −0.3	−77.7 to −0.1
Increase	0.8	0.2 to 1.4	0.1 to 13.2
Stroke			
Decrease	−6.7	−20.2 to −0.7	−77.7 to −0.1
Increase	0.8	0.2 to 1.4	0.1 to 33.4
Sepsis			
Decrease	−1.8	−20.2 to −0.5	−77.7 to −0.1
Increase	0.8	0.2 to 1.4	0.1 to 33.4
Asthma or COPD			
Decrease	−7.6	−20.2 to −0.7	−77.7 to −0.1
Increase	0.8	0.2 to 1.4	0.1 to 17.9

*All patients experiencing "no change" were zero.

the ED closed. Patients were categorized as unaffected if admitted in the first half of the year of closure and affected if hospitalized in the latter half. All analyses were performed with SAS (version 9.2; SAS Institute, Inc., Cary, NC).

RESULTS

We studied a total of 785,385 patients during this period (Table 1), of which 67,577 (8.6%) individuals experienced an increase in distance to their nearest ED. The increase in distance experienced by patients ranged from as little as 0.1 to as great as 33.4 miles, with a median of 0.8 miles. As shown in Table 2, the medians were identical when analyzed by disease condition. Patients experiencing a decrease had a greater distance change than those experiencing an increase; overall, patients who had a decrease in distance to the nearest ED were, on average, 13.8 miles closer than before, with a median of 6.6 miles and a range of 0.1 to 77.7 miles.

Patients who faced increased distances to the nearest ED were more likely to be black or Hispanic, more likely to be uninsured or be insured by Medicaid, and less likely to be privately insured. They were more likely to experience hypertension, diabetes, fluid and electrolyte disorders, renal failure, and mental health disease.

The adjusted mortality of the entire cohort of patients experiencing an increased distance to the nearest ED was not significantly higher than that of those who did not (adjusted odds ratio [OR] 1.04; 95% confidence interval [CI] 0.99 to 1.09) (Table 3).

Given that patients experiencing a decrease in distance had a much greater change in distance than those experiencing an increase, we wanted to test whether the potential benefit of experiencing a decrease in distance was diluting the effect of patients experiencing an increase in distance. As shown in Table 4, adjusted analysis in the 3 subgroups of patients (those experiencing a decrease in distance, no change in distance, and an increase in distance) also showed no significant difference in those with an increased distance (OR 1.04; 95% CI 0.99 to 1.09). Patients with a decrease in distance similarly did not experience a benefit, as defined by a decrease in the adjusted risk of inpatient mortality (OR 1.01; 95% CI 0.92 to 1.12).

We present our stratified results from model 1 comparing mortality of patients in all subgroups who experienced an increase in distance compared with those who did not experience a change or had a decrease (Table 3). Of 162,252 patients with acute myocardial infarction, 8.0% (n=12,979)

Table 3. Multivariate model comparing inhospital mortality of patients experiencing an increased distance to their nearest ED compared with those having no increase in distance.*

	Patients Experiencing Increased Distance to Nearest ED (n=785,385)	
	Sample Size (%)	**OR (95% CI)**
All time-sensitive conditions		
Decrease/no change in distance to nearest ED	717,808 (92.0)	Reference
Increase in distance to nearest ED	67,577 (8.6)	1.04 (0.99 to 1.09)
AMI (n=162,252)		
Decrease/no change in distance to nearest ED	149,273 (92.0)	Reference
Increase in distance to nearest ED	12,979 (8.0)	1.09 (0.94 to 1.25)
Stroke (n=191,105)		
Decrease/no change in distance to nearest ED	174,989 (91.6)	Reference
Increase in distance to nearest ED	16,116 (8.4)	1.02 (0.95 to 1.10)
Sepsis (n=197,357)		
Decrease/no change in distance to nearest ED	178,209 (90.3)	Reference
Increase in distance to nearest ED	19,148 (9.7)	1.04 (0.97 to 1.11)
Asthma/COPD (n=234,671)		
Decrease/no change in distance to nearest ED	215,337 (91.8)	Reference
Increase in distance to nearest ED	19,334 (8.2)	1.08 (0.94 to 1.24)

*Models adjusted for age, race/ethnicity, sex, insurance, case-mix index, and Elixhauser comorbidities (congestive heart failure, paralysis, neurologic disorders, chronic lung disease, diabetes, renal failure, liver disease, metastatic cancer, solid tumor, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, chronic blood loss anemia, deficiency anemia, peripheral vascular disease, alcohol abuse, and depression), year, and zip code level clustering.

Table 4. Multivariate model comparing inhospital mortality of patients experiencing a decrease, no change, and increase in distance to their nearest ED.*

	Patients Experiencing Increased and Decreased Change to Nearest ED (n=785,385)	
	Sample Size (%)	**OR (95% CI)**
All time-sensitive conditions		
Decrease in distance to nearest ED	23,981 (3.1)	1.01 (0.92–1.12)
No change in distance to nearest ED	693,827 (88.3)	Reference
Increase in distance to nearest ED	67,577 (8.6)	1.04 (0.99–1.09)
AMI		
Decrease in distance to nearest ED	4,580 (2.8)	1.09 (0.94–1.25)
No change in distance to nearest ED	144,693 (89.2)	Reference
Increase in distance to nearest ED	12,979 (8.0)	1.04 (0.96–1.13)
Stroke		
Decrease in distance to nearest ED	5,710 (3.0)	1.15 (1.00–1.31)
No change in distance to nearest ED	169,279 (88.6)	Reference
Increase in distance to nearest ED	16,116 (8.4)	1.03 (0.96–1.10)
Sepsis		
Decrease in distance to nearest ED	5,442 (2.8)	1.07 (0.94–1.21)
No change in distance to nearest ED	172,767 (87.5)	Reference
Increase in distance to nearest ED	19,148 (9.7)	1.04 (0.97–1.11)
Asthma/COPD		
Decrease in distance to nearest ED	8,249 (3.5)	1.02 (0.80–1.29)
No change in distance to nearest ED	207,088 (88.3)	Reference
Increase in distance to nearest ED	19,334 (8.2)	1.08 (0.94–1.24)

*Models adjusted for age, race/ethnicity, sex, insurance, case-mix index, and Elixhauser comorbidities (congestive heart failure, paralysis, neurologic disorders, chronic lung disease, diabetes, renal failure, liver disease, metastatic cancer, solid tumor, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, chronic blood loss anemia, deficiency anemia, peripheral vascular disease, alcohol abuse, and depression), year, and zip code level clustering.

experienced a closure and subsequent increase in distance to the nearest ED compared with 92.0% (n=149,273) who did not. There was no statistically significant difference in inpatient mortality when these 2 groups were compared (OR 1.09; 95% CI 0.94 to 1.25). Of 191,105 stroke patients, 8.4% (n=16,116) faced an increase in distance compared with 91.6% (n=174,989) who did not. Again, there was no difference in inpatient mortality (OR 1.02; 95% CI 0.95 to 1.10) between these groups. When data from the 197,357 sepsis patients were analyzed, 9.7% (n=19,148) experienced an increase in distance, and again there was no statistically increased odds (OR 1.04; 95% CI 0.97 to 1.11) of inpatient mortality compared with the 90.3% (n=178,209) who did not. For the 234,671 asthma or chronic obstructive pulmonary disease patients, those experiencing an increase in distance to the nearest ED (8.2%; n=19,334) similarly had no significant odds of inpatient mortality (OR 1.08; 95% CI 0.94 to 1.24) of inpatient death compared with the referent group (91.8%; n=215,337).

The model 2 in Table 4 shows the results of a 3-category analysis, when patients experiencing an increase in distance and decrease in distance were separately compared with the referent group of those with no change. For acute myocardial infarction patients, a very small group experienced a decrease in driving distance to the nearest ED (2.8%; n=4,580) compared with the no change group (89.2%; n=144,693) and the increase group (8.0%; n=12,979). No significant differences in inhospital mortality were found when these groups were compared. These results were similar again for all patients experiencing an increase in distance to the nearest ED with the other 3 conditions.

Patients with stroke experiencing a decrease in distance to the nearest ED just met the criteria for 95% statistical significance. For these patients, 3.0% (n=5,710) had a decrease in distance to the nearest ED, with a barely perceptible increase in inpatient mortality (OR 1.15; 95% CI 1.00 to 1.31) compared with the referent group of no change (88.6%; n=169,279).

Sensitivity Analyses

We performed numerous sensitivity analyses to investigate whether certain assumptions would result in different findings, specifically in regard to (1) lag time related to potential differential effects, depending on when changes in distance occurred; (2) the inclusion criteria for patients who were assumed to be affected by changes in distance; and (3) the assumption that all acute myocardial infarction patients experienced similar effects from distance changes, especially those with ST-segment elevation myocardial infarction.

First, to test for the idea that EDs and hospitals likely recover from nearby closures, adjusting staffing and resources to meet increased demand, we carried out subset analyses including only patients who experienced change within 2 years of closure. These analyses were not different from our main results.

Second, our main model excludes patients who were not admitted at their nearest ED, which allows for the most conservative estimate of the effect on mortality. We performed an additional sensitivity analysis that includes all of these potential patients living in a zip code that experienced an increase to the nearest ED. These results showed no change from our main model. The results for the stratified analyses for the remaining conditions remained insignificant.

Third, there is a real possibility that patients with ST-segment elevation myocardial infarction could have been rerouted (and therefore traveled longer distances) intentionally because of regionalization networks that, in California, began first in 2003 (Marin County) and subsequently in several counties in Southern California, including Los Angeles, San Diego, Ventura, and Orange Counties. Although inception of a formalized network did not always mean that the infrastructure was fully established to implement direct transport to the nearest hospital with cardiac catheterization capability (eg, not all ambulances had trained paramedics or even ECG machines on board), it is possible that these patients could have benefited from being transported farther distances if they received a higher level of care. Therefore, we removed patients with ST-segment elevation myocardial infarction from our acute myocardial infarction group and reanalyzed our results in the overall cohort modeled with all conditions, as well as stratified by disease condition. We found no difference in our results.

LIMITATIONS

Our study has several notable limitations. First, our primary outcome was inhospital mortality, which, although having strong face validity, remains a crude indicator of adverse outcomes related to delays in emergency care, relative to endpoints such as survival to longer periods or clinical outcome measures such as angina, ejection fraction, or functional status. It is possible that small changes in distance and time are more likely to affect morbidity than mortality, but this effect remains unmeasured by our study. In addition, compared with other more frequent clinical outcomes, mortality may have lower statistical power. This being said, and even though death remained a rare event, the number of deaths in our cohort was quite large.

Second, our data do not contain information about the proportion of our cohort that arrived by ambulance or whether they could have received intervention before arrival. It is possible that there are systematic differences in method of transport between groups who experienced an increase in distance compared with the control group, or even at baseline, because people living farther from an ED could be more likely to activate emergency medical services (EMS) than others. However, the literature suggests that greater distance from EDs in some areas (notably rural areas) have a lower likelihood of EMS use.[30,31] Even if patients with increased distance to an ED were more likely to use EMS, it would affect the results only if such patients were more ill or had more comorbidities. Given the lack of information in this area, it is unclear whether this would positively or negatively bias our results, yet remains a potential limitation. Similarly, it is possible that patients most affected by ED closure die before they reach the ED. Such patients would not be included in our study, and this immortal time bias could therefore attenuate our results.

Third, our data for increases in driving time are very skewed, with the majority of patients experiencing less than a 10-minute increase. Detecting mortality differences if patients do not experience a significant increase could be limited. Additionally, any significant measurement error in the geocoding of distances could attenuate the effect. We do not believe there are systematic biases in our measurement of driving time for communities experiencing increases in driving time; however, theoretically, if shorter increases in distance are underestimated when driving times are calculated, compared with longer increases in distance, our findings would be conservative and therefore not show an effect.

Fourth, although we measured increased distance to the nearest ED, factors such as ED crowding, waiting times, diversion, or even traffic patterns and road construction could alter driving distances or time to ED care. Moreover, changes over time in the care of each of the conditions studied (eg, the sepsis campaign) are likely not addressed equally at each hospital in the same time frame, but adoption of such changes is nearly impossible to measure across all hospitals for all our conditions and is a limitation of the study. Although our model did cluster on the hospital to account for some intrahospital differences, systematic differences—such as overall early adoption of aggressive treatments to decrease mortality for the time-sensitive conditions we studied—in hospitals in which patients experienced no change in their distance to the nearest ED compared with hospitals where patients did experience an increased distance could contribute to our negative findings.

Fifth, although our retrospective cohort approach has advantages for this type of analysis and our use of *ICD-9* codes is a common approach in health care research, we had limited control over the accuracy of the data and variation in coding of conditions. We cannot completely exclude the possibility of unknown but important population differences between the treatment and control groups. However, as noted in our previous work, the Office of Statewide Health and Planning Development database is very detailed, with high response rates, and we do not expect bias in the results as long as the errors do not systematically differ by the characteristics examined.[25]

Sixth, our findings are limited to the context of California, which is somewhat more urban than the nation, producing more closures of EDs in areas with concentrated populations. As a result, our findings may not apply to different settings, such as rural areas with lesser concentration of health care resources.

DISCUSSION

In this study of California EDs, closures that produced longer distances to emergency care were not associated with higher odds for inpatient mortality across a range of time-sensitive conditions. Our results are contrary to our initial hypothesis that mortality would worsen when the distance to emergency care increases. Despite strong evidence for early treatment of many acute conditions, these findings raise several interesting possible explanations.

First, only a small percentage—less than 2%—of patients experienced an increase in distance. Of those who did, the increases in distance were minimal, with a mean of 1.4 miles or median of 0.8 miles. Although rural closures have occurred in California, the majority of ED closures have been in urban areas with other existing services that could mitigate potential negative consequences of closures. Studying closures in other settings, particularly more rural settings, could provide an important contribution to the literature about whether closures in different contexts have differential effects.

Second, because we studied time-dependent conditions, time waiting to be treated by a clinician would potentially be less affected than less urgent conditions. In most EDs, ambulance transports are triaged before walk-in patients. Therefore, the minimal increase in travel time incurred by an increase in distance could have been negligible for patients with these time-sensitive conditions who would be triaged first. It is possible that a similar analysis in patients with non–time-sensitive conditions could have different findings.

On the other hand, it is also possible that time waiting to be treated, which is generally longer than transport times, could overwhelm any increases in distance to the nearest ED. Transport times would especially be shorter for patients who activate EMS. As mentioned in the limitations, our data do not contain information about method of transport to the ED. The literature states that approximately 50% of acute myocardial infarction patients arrive to the ED by self-transport[32] despite the benefits of EMS activation.[33] Similarly, patients with stroke often delay seeking care or activating EMS because they doubt the seriousness of symptoms.[34] In urban areas, even without EMS activation, however, transport times are generally shorter than the waiting time to consult a physician, which could partially explain a negative effect of increased distance on outcome.

Third, it is possible that ED closure takes place because the ED is underperforming in terms of volume or quality of care provided. For example, hospitals that close are more likely to be small (<100 beds), be less efficient, be financially distressed, operate at excess capacity, and offer fewer specialty services, all of which may negatively affect patient care.[14,35-39] Similarly, EDs that close have fewer monthly ambulance transports, ED treatment stations, and annual ED visits.[9,15] Because greater volume often results in better outcomes,[40,41] closures may disproportionately occur in underperforming EDs. As a result, mortality may not be increased because although patients must travel farther to their nearest hospital, they may be benefiting from improved quality of care. This, too, would be a vital area of inquiry and may be condition specific. For example, after a well-publicized closure of the Martin Luther King–Drew trauma center that had been faulted for providing poor quality care to patients, trauma patients who were diverted to a nearby hospital did not experience an increase in mortality.[42]

An important point about our findings relates to our ability to interpret a non–statistically significant result as essentially no effect. Given that the CIs of the adjusted ORs in our combined and stratified cohorts were all very narrow—eg, for our main model, the 95% CI was 0.99 to 1.10 (Table 3)—this limits the size of possible difference to be quite small. On the other end, the 95% CI for the greater than 5-mile increase for the asthma or chronic obstructive pulmonary disease patients was 0.62 to 1.61 (Table 5), which allows for effect sizes in the more important range.

These findings are crucial in the current discussion of regionalization of health care services, particularly emergency care. They suggest that in certain contexts in which other services may exist, it is possible that closures do not have a detrimental effect on patient outcomes, at least when measured by inhospital mortality.

Our study contributes to the understanding of ED closures within a particular context that should be interpreted in light of what is known about hospital consolidations or closures.[43] In certain scenarios, hospital closures have the potential to provide cost savings and improve efficiency of the remaining hospitals.[35,44,45] Patients may use outpatient resources more effectively after hospital downsizing or closure.[46] Alternatively, consolidations or mergers of hospitals that reduce one ED might provide other services that decrease overall mortality in the hospital.[47] For instance, investment in resources such as a 24-hour catheterization laboratory or a fully staffed ICU may lead to no change in mortality, negating the effects of ED closure. Finally, regionalization of services resulting from hospital closure may increase the specialty or disease-specific volume of care at another facility, which may improve outcomes of certain

Table 5. Multivariate model comparing inhospital mortality of patients experiencing stepwise increasing distances to their nearest ED compared with those having no change or a decrease.*

	Patients Experiencing Increased and Decreased Change to Nearest ED (n=785,385)	
	Sample Size (%)	OR (95% CI)
All time-sensitive conditions		
Decrease/no change	717,808 (91.4)	Reference
Increase of <2 miles	55,846 (7.1)	1.04 (0.99–1.10)
Increase of 2–5 miles	7,469 (1.0)	1.03 (0.91–1.16)
Increase of >5 miles	4,262 (0.5)	1.09 (0.95–1.26)
AMI		
Decrease/no change	149,273 (92.0)	Reference
Increase of <2 miles	10,538 (6.5)	1.06 (0.97–1.15)
Increase of 2–5 miles	1,503 (0.9)	0.94 (0.71–1.25)
Increase of >5 miles	938 (0.6)	1.01 (0.82–1.24)
Stroke		
Decrease/no change	174,989 (91.6)	Reference
Increase of <2 miles	13,370 (7.0)	1.00 (0.93–1.09)
Increase of 2–5 miles	1,752 (0.9)	1.03 (0.86–1.25)
Increase of >5 miles	994 (0.5)	1.22 (1.02–1.47)
Sepsis		
Decrease/no change	178,209 (90.3)	Ref
Increase of <2 miles	16,320 (8.3)	1.05 (0.97–1.13)
Increase of 2–5 miles	1,802 (0.9)	0.98 (0.82–1.17)
Increase of >5 miles	1,026 (0.5)	0.93 (0.78–1.11)
Asthma/COPD		
Decrease/no change	215,337 (91.8)	Ref
Increase of <2 miles	15,618 (6.7)	1.09 (0.94–1.26)
Increase of 2–5 miles	2,412 (1.0)	1.04 (0.62–1.72)
Increase of >5 miles	1,304 (0.6)	1.00 (0.62–1.61)

*Models adjusted for age, race/ethnicity, sex, insurance, case-mix index, and Elixhauser comorbidities (congestive heart failure, paralysis, neurologic disorders, chronic lung disease, diabetes, renal failure, liver disease, metastatic cancer, solid tumor, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, chronic blood loss anemia, deficiency anemia, peripheral vascular disease, alcohol abuse, and depression), year, and zip code level clustering.

conditions, such as acute myocardial infarction.[45] Although the exclusion of ST-segment elevation myocardial infarction patients in our study did not result in positive results, our study did not directly evaluate the result of regionalization efforts.

Although distances increased for only a small percentage of the community, that percentage was characteristically more vulnerable, including minority groups, the uninsured or those insured by Medicaid, and those with comorbidities. Increased distance may serve as a surrogate marker of actual difficulty in getting to an ED, and although these groups did not experience a notable difference in mortality, there is a disparity that may appear in other process-driven measures.

In summary, California residents who faced an increase in distance to the nearest ED because of ED closure did not have higher inpatient mortality from acute myocardial infarction, stroke, sepsis, or asthma or chronic obstructive pulmonary disease. Our findings add an important nuance to the complex decisions involved when hospital and health system administrators consider whether to close an ED. Although public concern about closures' effects on access to emergency care will likely remain a valid issue, our data suggest that closures during this period in California resulted in only minimal increases in distance for a minority of patients and that, at least when measured by inpatient mortality, closures did not result in poorer outcomes for these patients with time-sensitive conditions.

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APPENDIX E1.

Table E1. *ICD-9* codes used for patient conditions from the Clinical Classifications Software (AHRQ).

AMI	410.0, 410.00, 410.01, 410.02, 410.1, 410.10, 410.11, 410.12, 410.2, 410.20, 410.21, 410.22, 410.3, 410.30, 410.31, 410.32, 410.4, 410.40, 410.41, 410.42, 410.5, 410.50, 410.51, 410.52, 410.6, 410.60, 410.61, 410.62, 410.7, 410.70, 410.71, 410.72, 410.8, 410.80, 410.81, 410.82, 410.9, 410.90, 410.91, 410.92
Stroke	430, 431, 432.0, 432.1, 432.9, 433.01, 433.11, 433.21, 433.31, 433.81, 433.91, 434.0, 434.00, 434.01, 434.1, 434.10, 434.11, 434.9, 434.90, 434.91, 436
Asthma/COPD	493.00, 493.01, 493.02, 493.10, 493.11, 493.12, 493.20, 493.21, 493.22, 493.81, 493.82, 493.90, 493.91, 493.92, 490, 491.0, 491.1, 491.2, 491.20, 491.21, 491.22, 491.8, 491.9, 492.0, 492.8, 494.0, 494, 494.1, 496
Sepsis	003.1, 020.2, 022.3, 036.2, 038.0, 038.1, 038.10, 038.11, 038.19, 038.2, 038.3, 038.40, 038.41, 038.42, 038.43, 038.44, 038.49, 038.8, 038.9, 054.5, 449, 790.7

Table E2. Multivariate model comparing inhospital mortality of patients experiencing an increased driving time to their nearest ED compared with those having a decrease or no change.*

	Patients Experiencing Increased Driving Distance to Nearest ED (n=785,385)	
	Sample Size (%)	**OR (95% CI)**
All time-sensitive conditions		
Decrease/no change	717,808 (92.0)	Reference
Increase	67,577 (8.6)	1.04 (0.99–1.09)
AMI (n=162,252)		
Decrease/no change in driving time to nearest ED	149,273 (92.0)	Reference
Increase in driving time to nearest ED	12,979 (8.0)	1.09 (0.94–1.25)
Stroke (n=191,105)		
Decrease/no change in driving time to nearest ED	174,989 (91.6)	Reference
Increase in driving time to nearest ED	16,116 (8.4)	1.02 (0.95–1.10)
Sepsis (n=197,357)		
Decrease/no change in driving time to nearest ED	178,209 (90.3)	Reference
Increase in driving time to nearest ED	19,148 (9.7)	1.04 (0.97–1.11)
Asthma/COPD (n=234,671)		
Decrease/no change in driving time to nearest ED	215,337 (91.8)	Reference
Increase in driving time to nearest ED	19,334 (8.2)	1.08 (0.94–1.24)

*Models adjusted for age, race/ethnicity, sex, insurance, case-mix index, and Elixhauser comorbidities (congestive heart failure, paralysis, neurologic disorders, chronic lung disease, diabetes, renal failure, liver disease, metastatic cancer, solid tumor, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, chronic blood loss anemia, deficiency anemia, peripheral vascular disease, alcohol abuse, and depression), year, and zip code level clustering.

Table E3. Multivariate model comparing inhospital mortality of patients experiencing a decrease, no change, and increase in driving time to their nearest ED.*

	Patients Experiencing Increased and Decreased Change to Nearest ED (n=785,385)	
	Sample Size (%)	**OR (95% CI)**
All time-sensitive conditions		
Decrease	23,981 (3.1)	1.01 (0.92–1.12)
No change	693,827 (88.3)	Reference
Increase	67,577 (8.6)	1.04 (0.99–1.09)
AMI		
Decrease in driving time to nearest ED	4,580 (2.8)	1.09 (0.94–1.25)
No change in driving time to nearest ED	144,693 (89.2)	Reference
Increase in driving time to nearest ED	12,979 (8.0)	1.04 (0.96–1.13)
Stroke		
Decrease in driving time to nearest ED	5,710 (3.0)	1.15 (1.00–1.31)
No change in driving time to nearest ED	169,279 (88.6)	Reference
Increase in driving time to nearest ED	16,116 (8.4)	1.03 (0.96–1.10)
Sepsis		
Decrease in driving time to nearest ED	5,442 (2.8)	1.07 (0.94–1.21)
No change in driving time to nearest ED	172,767 (87.5)	Reference
Increase in driving time to nearest ED	19,148 (9.7)	1.04 (0.97–1.11)
Asthma/COPD		
Decrease in driving time to nearest ED	8,249 (3.5)	1.02 (0.80–1.29)
No change in driving time to nearest ED	207,088 (88.3)	Reference
Increase in driving time to nearest ED	19,334 (8.2)	1.08 (0.94–1.24)

*Models adjusted for age, race/ethnicity, sex, insurance, case-mix index, and Elixhauser comorbidities (congestive heart failure, paralysis, neurologic disorders, chronic lung disease, diabetes, renal failure, liver disease, metastatic cancer, solid tumor, coagulopathy, obesity, weight loss, fluid and electrolyte disorders, chronic blood loss anemia, deficiency anemia, peripheral vascular disease, alcohol abuse, and depression), year, and zip code level clustering.

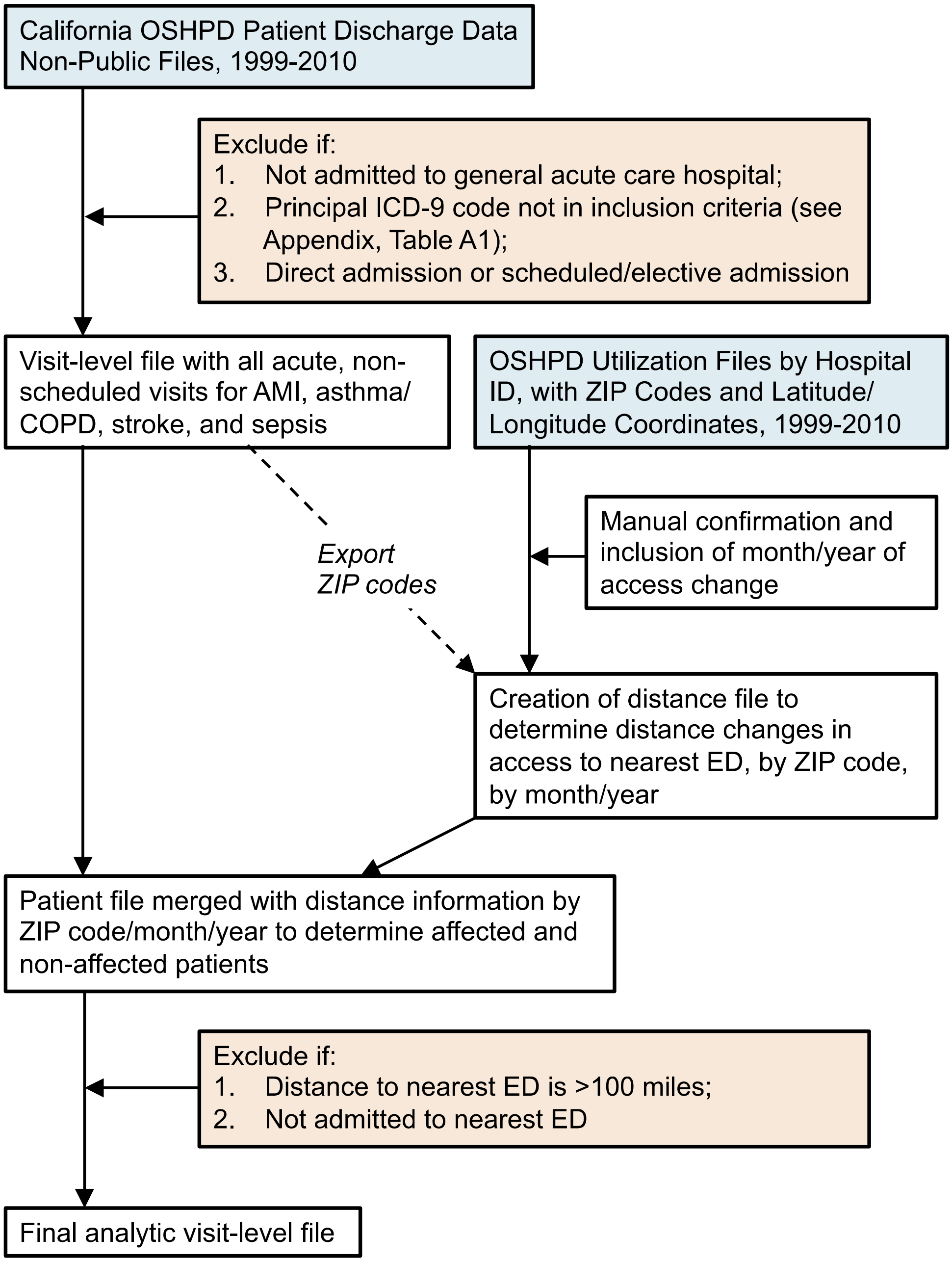

Figure E1. Patient selection flowchart.

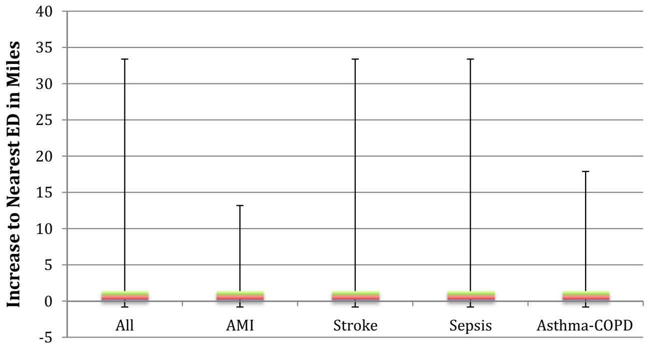

Figure E2. Increase of distance to nearest ED across study conditions.