The Impact of Hospital Closures and Hospital and Population Characteristics on Increasing Emergency Department Volume: A Geographic Analysis

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Abstract

Emergency visits are rising nationally, whereas the number of emergency departments is shrinking. However, volume has not increased uniformly at all emergency departments. It is unclear what factors account for this variability in emergency volume growth rates. The objective of this study was to test the association of hospital and population characteristics and the effect of hospital closures with increases in emergency department volume. The study team analyzed emergency department volume at New York State hospitals from 2004 to 2010 using data from cost reports and administrative databases. Multivariate regression was used to evaluate characteristics associated with emergency volume growth. Spatial analytics and distances between hospitals were used in calculating the predicted impact of hospital closures on emergency department use. Among the 192 New York hospitals open from 2004 to 2010, the mean annual increase in emergency department visits was 2.7%, but the range was wide (-5.5% to 11.3%). Emergency volume increased nearly twice as fast at tertiary referral centers (4.8%) and nonurban hospitals (3.7% versus urban at 2.1%) after adjusting for other characteristics. The effect of hospital closures also strongly predicted variation in growth. Emergency volume is increasing faster at specific hospitals: tertiary referral centers, nonurban hospitals, and those near hospital closures. This study provides an understanding of how emergency volume varies among hospitals and predicts the effect of hospital closures in a statewide region. Understanding the impact of these factors on emergency department use is essential to ensure that these populations have access to critical emergency services. (*Population Health Management* 2015;18:459–466)

Introduction

EMERGENCY DEPARTMENTS (EDs) provide care not only for the critically ill, but also for those unable to access care by other means.^{1,2} Emergency visits have risen by 23% in the United States over the last decade.³ Meanwhile, fi-

nancial stress and hospital closures have reduced the number of EDs available to care for these increasing patient volumes.⁴ Significant increases in ED volume create an incredible strain on existing emergency care capacity.^{5,6} These trends have important consequences for patient safety and can lead to poor health outcomes.⁷

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However, ED visits are not increasing at all hospitals at the same rate, and some EDs have reported decreasing volume. It is unclear whether characteristics specific to the hospitals themselves or external factors such as population characteristics and nearby hospital closures account for this variation in ED volume growth rates. Predicting this variability is essential to maintaining appropriate emergency care capacity and ED staffing levels.⁸ This preparedness ensures that EDs are ready to respond to the sharp increases in demand that might occur after the loss of services caused by natural disasters or the bankruptcy of nearby hospitals.^{9,10,11}

After hospital closures occur, ED volume at nearby hospitals increases,¹² but the way in which patients will redistribute to nearby hospitals is not well understood. Geographic distance is known to affect ED utilization,^{13–15} but few studies have quantitatively analyzed how proximity to hospital closures affects ED volume.¹⁶ With technology advances, especially in geographic information systems, it is now possible to model complex systems and study how events such as hospital closures impact the utilization of EDs distributed throughout a wide region.

Given this opportunity, the objective of this study is to use spatial analytics to develop a method to calculate the impact of hospital closures on ED utilization. These measures were then used in addition to hospital and population characteristics to determine which factors are associated with higher ED volume growth. EDs are critical for population health as they provide essential emergency services and account for a significant proportion of inpatient admissions.¹ Therefore, ensuring timely access to ED care requires understanding where the demand for ED care is growing the fastest.

Methods

Study design and setting

For all general acute care hospitals with EDs in New York State, the study team first compared the characteristics of open and closed hospitals at the beginning of the study period in 2004. Then, the team determined the annualized percent change in ED visits from 2004 to 2010 for EDs that remained open during the study period. Any EDs associated with specialty hospitals (ie, stand-alone pediatric, surgical, cancer, rehabilitation, or Veterans hospitals) were excluded. Linear regression was used to evaluate the impact of hospital closures along with hospital and population characteristics to determine the factors associated with ED volume growth.

Data sources

Data on ED volumes were obtained from Institutional Cost Reports (ICRs) and SPARCS Audit Reports provided by the New York State (NYS) Department of Health (DOH). Hospital characteristics also were obtained from the NYS DOH ICRs in addition to the NYS DOH Cardiac Surgery Reporting System,^{17,18} the NYS Trauma Registry,^{19,20} and the Flex Monitoring Team for critical access hospitals.^{21,22} Additionally, population characteristics were obtained at the county level from the Area Health Resource File (AHRF).²³ This study was considered exempt from institutional review board review by the University of Pennsylvania.

Outcome measure

The primary outcome measure was the annualized percent change in ED visits from 2004 to 2010 for each ED. This metric was created by determining the absolute change in ED visits over the 7-year study period and calculating the annualized growth rate. Sixteen hospital systems reported aggregated ED visits to the NYS DOH for multiple EDs owned by the same system. In these cases, the aggregated number of ED visits was decomposed into individual ED locations using data from SPARCS Audit Reports. This disaggregation was performed so that the study analysis would treat separate EDs as distinct facilities even if owned by a single hospital system.

Hospital characteristics

For hospital characteristics, the study team assessed the influence of hospital size, ownership, urban versus nonurban location, and designations as a teaching hospital, tertiary referral center, trauma center, safety net hospital, or critical access hospital on ED volume growth. Hospital size was determined by the number of acute care beds. Ownership was designated as private nonprofit, private for-profit, or public. Identifying hospitals as urban versus nonurban was based on matching hospital addresses to regions defined as Urbanized Areas based on Census data in 2000 and 2010. Teaching status was self-reported by each of the hospitals in the NYS DOH ICRs.

Hospital referral regions have been previously described as having at least 1 hospital providing open heart surgery and a hospital providing neurosurgical services.²⁴ Therefore, the study team used the provision of both open heart surgery and neurosurgical services as the definition of a tertiary referral center. Trauma centers included both regional and area trauma centers certified by the NYS Trauma Program.¹⁹ Safety net hospitals were defined by the criteria for low-income utilization rates and Medicaid utilization rates published by the National Association of Public Hospitals and Health Systems.²⁵ Critical access hospitals were defined as those tracked by the Flex Monitoring Team that monitors these hospitals.²²

Population characteristics

County-level information was obtained from the AHRF to evaluate population characteristics associated with each hospital.²³ Population growth was included and calculated as a percent change of population estimates from 2004 to 2010. Other population characteristics included were: the proportion of elderly population, proportion of minority (nonwhite or Hispanic) population, household median income, proportion of population lacking health insurance, the density of outpatient physicians as measured by the number of nonfederal, office-based medical doctors per 1000 population, and designation of the entire county as a primary care shortage area.

In addition to these population characteristics, the level of hospital competition at the county level was assessed using Herfindhal indexes. These indexes can be used to measure the level of competition of hospitals within a given region.⁴ The study team calculated this index as the sum of the squared ED volume market share for the EDs in each

county. Thus, an index of 1 would represent no competition, whereas an index close to 0 would represent high levels of competition.

Impact of hospital closures

To identify hospital closures between the end of 2004 and 2010, the study team tracked hospitals that reported ED volume to the NYS DOH during the study period. The team confirmed whether those hospitals that stopped reporting had closed, and also checked to make sure that hospitals that stopped reporting did not remain open as an acquisition by another hospital, and that the subsidiaries of hospital systems did not close.

In order to model the impact of hospital closures on ED volume, spatial analytics were used to model the redistribution of ED patients from closed hospitals. Previously, attempts have been made to quantify the effect of hospital closures on ED volume using gravity models.¹⁶ These gravity models have been validated in retail markets to demonstrate how consumers choose retail stores based on proximity.²⁶ They model the probability of consumer choice based on decreasing distance parameters.^{27,28}

Similarly, the study team estimated the probability that ED visits from closed hospitals were redistributed to nearby hospitals based on a function of distance. For this analysis, it was assumed that other gravitational effects were equal among hospitals. Thus, the team proportioned visits among nearby hospitals based on the inverse of the squared distance between the closed and open hospitals and divided the sum of this function among all open hospitals. Therefore, EDs that were geographically further from closed hospitals were increasingly less likely to receive ED visits from the hospital that closed (Fig. 1).

FIG. 1. Calculating the effect of a nearby hospital closure. Sample calculation of the effect of 1 hospital closure (located in the center) on nearby hospitals. The number of new ED visits is calculated using the proportion of inverse squared distances to each of the hospitals. These results are then used to determine the predicted annualized growth related to hospital closures based on a 7-year study period and the initial number of ED visits at each nearby hospital. ED, emergency department.

To create this metric, the study team started with the number of ED visits in 2004 for hospitals that closed during the study period. The proportion of these visits that would have been distributed to each of the open hospitals was calculated based on the distance relationship described. This estimation was performed for all hospitals that closed in the study. Then, the study team calculated the total ED volume redistributed from closed hospitals to each hospital that remained open. Using these total volumes, the team calculated the predicted percent annual increase in ED volume caused by the effect of hospital closures.

Data management

Hospital addresses from the NYS DOH ICRs were geocoded by ArcGIS Desktop, version 10.0 (Environmental Systems Research Institute, Redlands, CA). These coordinates were spatially located to maps of Urbanized Areas provided by the National Historical Geographic Information System.²⁹ Driving distances between hospitals were calculated based on network street grids publicly available in the NYS Streets file.³⁰

To account for rare instances in which categorical hospital and population characteristics changed during the study period (eg, decertification of trauma centers), these definitions were limited to those hospitals that were designated as such at the beginning and end of the study period. In addition, the continuous hospital and population characteristics (eg, hospital size) were taken to be the average of values at the beginning and end of the study period.

Statistical analysis

First, the hospital and population characteristics of closed and open hospitals in the study were compared. Fisher exact tests were used for categorical variables because of the small number of observations among closed hospitals, and non-parametric Wilcoxon rank-sum tests were used for continuous variables.

Then, to identify the factors associated with changes in ED volume at the hospitals that remained open, all of the listed factors from the model were included as covariates in a fully adjusted, multivariate linear regression. To test the relative importance of these characteristics, standardized beta coefficients were calculated to determine which factors explained more of the variance in ED volume growth rates. For the analyses, a *P* value of 0.05 was used to determine factors with significant associations. All statistical analyses were performed using Stata, version 12.1 (StataCorp, LP, College Station, TX).

Results

Between the end of 2004 and 2010, there were 15 general acute care hospitals with EDs in NYS that closed and 192 remained open. Compared to the hospitals that remained open, closed hospitals were more likely to be in counties with higher populations of uninsured individuals and with higher levels of competition (Table 1). During the study period, the last 2 private for-profit hospitals in NYS also closed. Figure 2 depicts the geographic distribution of these closed hospitals along with ED volume growth rates averaged over the open hospitals in each county.

TABLE 1. HOSPITAL AND POPULATION CHARACTERISTICS OF CLOSED AND OPEN HOSPITALS FROM NEW YORK STATE IN 2004

	<i>Closed Hospitals</i> (n = 15)	<i>Open Hospitals</i> (n = 192)	<i>P value for difference</i>
Hospital Characteristics			
Hospital Size	183 beds	230 beds	0.49
Publicly Owned	1 (7%)	21 (11%)	1.00
Private for-Profit	2 (13%)	0 (0%)	0.005
Teaching Hospital	10 (67%)	102 (53%)	0.42
Tertiary Referral Centers	1 (7%)	36 (19%)	0.48
Trauma Centers	2 (13%)	42 (22%)	0.74
Safety Net Hospitals	4 (27%)	36 (19%)	0.50
Urban Hospitals	12 (80%)	125 (65%)	0.40
Critical Access Hospitals	0 (0%)	11 (6%)	1.00
Population Characteristics			
Population Growth (2004 to 2010)	0.42%	0.72%	0.82
Proportion Elderly Population	13.1%	13.4%	0.26
Proportion Nonwhite Minorities	42.2%	29.3%	0.07
Median Household Income	50,121	49,904	0.61
Proportion Uninsured Population	17.4%	15.7%	0.002
Density of Outpatient Physicians (per 1000)	2.59	2.09	0.72
Primary Care Shortage Area Designation	12 (80%)	118 (61%)	0.18
Competition for ED Visits (County Level)	0.037	0.173	0.001

Bold denotes statistically significant findings.
ED, emergency department.

For the 192 hospitals that remained open, the mean for the primary outcome, the annualized growth in ED visits was 2.7% (95% confidence interval of 2.3% to 3.0%). However, the range was wide with one ED having an 11.3% annualized increase in volume. On the other extreme, another ED had a -5.5% annualized decrease in volume.

The multivariate regression found that ED volume was increasing faster at tertiary referral centers by 2.6% compared

to non-tertiary referral centers (4.8% versus 2.2%, P value <0.01). ED volume also grew more slowly at urban hospitals by 1.6% compared to nonurban hospitals (2.1% versus 3.7%, P value 0.04). Table 2 reports the regression coefficients expressed as the percent change in growth rates for a given difference in hospital and population characteristics.

The impact of nearby hospital closures also was a significant factor that explained the variation in ED volume

FIG. 2. Geographic distribution of closed hospitals in New York State between the end of 2004 and 2010.

TABLE 2. FACTORS ASSOCIATED WITH DIFFERENCES IN EMERGENCY DEPARTMENT (ED) VOLUME GROWTH RATES

	<i>Difference in Growth Rate</i>	<i>95% Confidence Intervals</i>	<i>Standardized Coefficients</i>	<i>P values</i>
Hospital Characteristics				
Hospital Size (per 100 beds)	−0.11%	(−0.67%–0.44%)	−0.07	0.69
Publicly Owned	−0.83%	(−2.14%–0.49%)	−0.09	0.22
Teaching Hospital	0.70%	(−0.73%–2.13%)	0.12	0.33
Tertiary Referral	2.57%	(0.72%–4.42%)	0.34	<0.01
Trauma Centers	0.76%	(−0.47%–1.99%)	0.10	0.23
Safety Net Hospitals	−0.58%	(−1.99%–0.83%)	−0.07	0.42
Urban Hospitals	−1.61%	(−3.15%–−0.06%)	−0.26	0.04
Critical Access Hospitals	0.93%	(−0.78%–2.64%)	0.07	0.28
Population Characteristics				
Population Growth (% from 2004 to 2010)	0.11%	(−0.18%–0.39%)	0.06	0.46
Proportion Elderly Population (%)	−0.11%	(−0.44%–0.23%)	−0.07	0.53
Proportion Nonwhite Minorities (%)	0.02%	(−0.02%–0.06%)	0.13	0.43
Median Household Income (per \$10,000)	0.03%	(−0.48%–0.53%)	0.02	0.87
Proportion Uninsured Population (%)	0.03%	(−0.19%–0.26%)	0.03	0.76
Density of Outpatient Physicians (per 1000)	0.00%	(−0.52%–0.51%)	0.00	0.99
Primary Care Shortage Area Designation	−0.10%	(−1.49%–1.30%)	−0.02	0.89
Competition for ED Visits (County Level)	−0.36%	(−1.95%–1.24%)	−0.04	0.66
Impact of Hospital Closures				
Predicted Increase in ED Volume (%)	0.80%	(0.52%–1.07%)	0.34	<0.01

Bold denotes statistically significant findings.

growth rates. For each 1% growth predicted by the metric for the effect of hospital closures, actual ED growth increased by 0.80%. Given that there were only 15 hospital closures during the study period, only a small number of hospitals were predicted to have a high change in ED volume related to hospital closures. But overall, a linear cor-

relation was identified between the ED volume growth predicted by the measure and the actual growth at the hospitals that remained open.

Based on the standardized beta coefficient, the impact of hospital closures (0.340) was one of the strongest factors explaining the variation in ED volume growth rates. It was

FIG. 3. Fully adjusted comparison of changes in ED volume stratified by selected hospital characteristics. Growth rates adjusted for all other hospital characteristics, population characteristics, and the impact of hospital closures. Average fully adjusted growth rates stratified by hospital types (dots); 95% confidence intervals for fully adjusted growth rates (error bars). ED, emergency department.

followed closely by tertiary referral centers (0.335) and then by location in an urban region (-0.262) (Table 2). None of the population characteristics were found to be significantly associated with differences in ED volume growth rates. Figure 3 graphically compares these growth rates for selected hospital characteristics.

Discussion

This analysis of ED volume from 2004 to 2010 in NYS uniquely identifies several factors associated with higher ED volume growth. After controlling for hospital characteristics, population characteristics, and hospital closures, this study demonstrated that ED volumes at tertiary referral centers and nonurban hospitals are increasing at rates nearly twice as fast when compared respectively to non-tertiary referral centers and urban hospitals.

All but 1 of the tertiary referral centers in this study were located in urban regions. However, the single nonurban, tertiary hospital in this study was actually the one that experienced the highest growth rate among all 192 NYS hospitals. If these trends continue, it suggests that tertiary referral centers in particular must be prepared to handle increasing ED volume. They may face significantly higher burdens of overcrowding, which has been linked to higher mortality.^{31,32}

This study also found that nonurban hospitals experienced higher ED volume growth rates. The designation of urban hospitals depended on the hospital's location in densely populated Urbanized Areas as defined by the Census. Therefore, the category of nonurban hospitals likely included suburban in addition to rural hospitals. However, this study did control for designation of critical access hospitals, which are in remote rural regions. It also should be noted that the study results controlled for population growth and other characteristics primarily of urban hospitals (eg, designation of tertiary referral centers). These factors would tend to increase overall ED volume in urban environments.

This study also found that hospitals were more likely to close in counties with higher proportions of uninsured individuals and higher levels of competition. These results were based on a small sample of closed hospitals in NYS and were unadjusted for confounding factors. However, these results are similar to those found in studies of other states, which demonstrate that hospital closures differentially affect vulnerable populations.^{33–35} In addition, a comprehensive study of factors associated with ED closures in the United States has shown that EDs are more likely to close if they are characterized by for-profit ownership, location in a competitive market, safety net status, and low profit margin when fully adjusting for other factors.⁴

This study also demonstrates that spatial analysis can be used to predict changes in ED volume related to hospital closures. The metric predicts the redistribution of ED volume based on geographic distances between closed and open hospitals. It was not only statistically significant in predicting actual changes in ED volume, but it was one of the strongest factors that explained the variability of ED volume growth rates in comparison to other hospital and population factors. However, based on the results of this study, the metric predicted higher changes in ED volume than actually occurred through the study period. For each

1% growth predicted by the model for the effect of hospital closures, actual ED growth increased by 0.80%.

One explanation for this difference is that the study metric assumes that all ED visits from closed hospitals would be redistributed to nearby hospitals. But when a hospital closes, some patients who would have visited that hospital's ED for care may decide not to access emergency care because of distance or other factors, or may instead go to a nearby urgent care center or other alternative to emergency care.³⁶ This drop-off in demand for emergency services that occurs after a hospital closure has not been previously explored to the study team's knowledge.³⁷

Because all volume from closed EDs may not redistribute to nearby hospitals, this study offers one way of estimating this drop-off in demand. The correlation coefficient (0.80% actual change per 1% predicted change) calculated by the multivariate model describes the difference between actual changes in ED volume and those changes predicted by hospital closures assuming no drop-off in demand. Thus, only 80% of the predicted ED volume related to hospital closures was actually seen at nearby EDs based on this analysis. However, it should be noted that the confidence intervals around this estimate are wide, and this analysis assumes that ED patients redistribute by geographic distance alone.

This analysis of the redistribution of ED volume is only one type of spatial model and others exist.^{38,39} This model was chosen because it also allowed the creation of an estimate for the impact of hospital closures without making further assumptions about the effect of hospital closures, such as the number of nearby hospitals affected or the distance within which hospitals would be affected. Because an absolute distance (eg, 20 miles) has a different value depending on the region, the advantage of this method is that it proportionally scales distances between urban and rural regions.

Although this study adjusts for hospital and population factors, the metric used to measure the impact of hospital closures does not take into consideration that certain hospitals may be more attractive to certain patient populations.^{40,41} Because the dynamics of how patients redistribute to other hospitals have not been fully explored, no assumptions can be made regarding these effects. This analysis at least demonstrates that the impact of hospital closures is an important factor associated with changes in ED volume and that it is possible to quantify its effects.

The study team believes that this study has important implications at several levels.⁴² In regard to further research, this study demonstrates that the variation in ED volume growth rates should be interpreted within the context of hospital and population characteristics associated with these EDs. Furthermore, this study provides a methodology for evaluating the impact of hospital closures on ED utilization at nearby hospitals. Predicting the effect of hospitals closures is critical because it can inform policy makers and affected communities as to whether a given hospital closure may lead to unsustainable strains on nearby hospitals or if remaining capacity will be sufficient to meet the demand for health services. As for clinical practice, understanding where ED volume is increasing the fastest has a direct impact on maintaining appropriate emergency staffing levels, which is all the more important as significant

strains on ED capacity can have adverse effects on health outcomes.⁵⁻⁷

As the provider of critical emergency services and safety net of the health care system, EDs play a vital role in providing care for populations with acute medical needs or barriers in accessing health care.¹ Therefore, maintaining timely access to emergency care is essential for the maintenance of population health. Overall increases in ED use and events such as hospital closures threaten to reduce access to ED care.⁴ Thus, one must understand where ED volume is increasing the fastest in order to manage health resources and sustain population health. The study team believes their models will play an important role in population health management by predicting these changes in ED utilization.

Limitations

This study is an analysis of secondary data, which is subject to errors in coding. As with all observational studies, the findings should be considered to be associations, and the statistical significance of the results do not imply causation. It is also possible that key variables were omitted in the regression analysis that are additional predictors or confounders to the correlations in this study.

In developing the measure to predict the impact of hospital closures, the study team studied the effects of closures over the entire study period. Based on the timing of hospital closures, the more immediate effects may be temporarily larger and then more moderate as time passes. The team does not account for the possibility of this lagged effect in this model. However, the hospital closures studied were distributed throughout the study period. Therefore, the analysis of the sample estimated an overall effect for more recent and remote hospital closures.

In addition, this study predates implementation of the Affordable Care Act (ACA), which has changed health insurance coverage and potentially primary care access and hospital utilization patterns. This study's findings may not apply to periods after passing of the ACA, though lack of insurance or access to primary care was not found to be significantly associated with ED volume growth. If any measured effect of the ACA has been suggested by other studies, it has been increases in ED utilization among the newly insured.⁴³

Finally, because data from the AHRF were used, population characteristics were analyzed at the county level. It may be that this geographic level was not sufficiently granular to distinguish between hospitals based on these factors. Finally, the cohort was limited to hospitals in NYS. These attributes of ED utilization may not be generalizable to other states in which these factors may have a different impact on ED volume.

Conclusions

In conclusion, this study found that in NYS from 2004 to 2010, there was significant variation in ED volume growth rates. This variability can be explained in part by certain hospital characteristics. ED volume increased nearly twice as fast in hospitals that were tertiary referral centers and in nonurban hospitals, when adjusted for other relevant factors. However, this study also found that hospital closures play a significant and quantifiable role in the increase of ED volume

at nearby hospitals that remain open. This study provides an understanding of how ED volume growth is distributed within a statewide network of hospitals. Given the continuing trend of hospital closures, this study also provides a basis for predicting the effect of future closures on ED utilization within an entire region. Understanding the impact of these factors on ED use is essential to ensure that these populations have access to critical emergency services.

Author Disclosure Statement

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