The Effect of Emergency Department Expansion on Emergency Department Overcrowding

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Abstract

Objectives: To examine the effects of emergency department (ED) expansion on ambulance diversion at an urban, academic Level 1 trauma center.

Methods: This was a pre-post study performed using administrative data from the ED and hospital electronic information systems. On April 19, 2005, the adult ED expanded from 28 to 53 licensed beds. Data from a five-month pre-expansion period (November 1, 2004, to March 1, 2005) and a five-month postexpansion period (June 1, 2005, to October 31, 2005) were included for this analysis. ED and waiting room statistics as well as diversion status were obtained. Total ED length of stay (LOS) was defined as the time from patient registration to the time leaving the ED. Admission hold LOS was defined as the time from the inpatient bed request to the time leaving the ED for admitted patients. Mean differences (95% confidence interval [CI]) in total time spent on ambulance diversion per month, diversion episodes per month, and duration per diversion episode were calculated. An accelerated failure time model was performed to test if ED expansion was associated with a reduction in ambulance diversion while adjusting for potential confounders.

Results: From pre-expansion to postexpansion, daily patient volume increased but ED occupancy decreased. There was no significant change in the time spent on ambulance diversion per month (mean difference, 10.9 hours; 95% CI = −74.0 to 95.8), ambulance diversion episodes per month (two episodes per month; 95% CI = −4.2 to 8.2), and duration of ambulance diversion per episode (0.3 hours; 95% CI = −4.0 to 3.5). Mean (±SD) total LOS increased from 4.6 (±1.9) to 5.6 (±2.3) hours, and mean (±SD) admission hold LOS also increased from 3.0 (±0.2) to 4.1 (±0.2) hours. The proportion of patients who left without being seen was 3.5% and 2.7% (p = 0.06) in the pre-expansion and postexpansion periods, respectively. In the accelerated failure time model, ED expansion did not affect the time to the next ambulance diversion episode.

Conclusions: An increase in ED bed capacity did not affect ambulance diversion. Instead, total and admission hold LOS increased. As a result, ED expansion appears to be an insufficient solution to improve diversion without addressing other bottlenecks in the hospital.

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Keywords: ambulance diversion, emergency department overcrowding, expansion, length of stay

Emergency department (ED) overcrowding is a serious public health problem in the United States.[1,2] It causes prolonged waiting room times, increases the number of patients leaving without being seen, decreases patient satisfaction, and worsens patient pain and suffering.[1,3] There has been mounting evidence that ED overcrowding may negatively affect the quality of care.[4] ED overcrowding has been associated with increased transport times for chest pain patients,[5,6] door-to-needle times for patients with acute myocardial infarction,[4] and an increase in overall mortality.[7]

Ambulance diversion is one of the many manifestations of ED overcrowding. It occurs when the ED reaches or exceeds maximal capacity and is unable to safely care

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for additional patients. Because of the annual increases in ED volume, the aging U.S. population, and hospital and ED closures, the problems of ED overcrowding and ambulance diversion have reached a dangerous point.[3,8–10] Approaches to decrease the ED overcrowding burden are needed to maintain a safe environment. Effective and sustainable solutions to correct ED overcrowding and ambulance diversion, however, remain elusive.

To alleviate this burden and minimize ambulance diversion, expanding the square footage and bed capacity of the ED has been suggested as a potential solution.[3] The impact of ED expansion on overcrowding and ambulance diversion remains unknown. The goal of this study was to examine the effects of ED expansion on ambulance diversion at an urban, academic Level 1 trauma center.

METHODS

Study Design

This was a pre-post study performed using retrospective data. The study was declared exempt from informed consent by the local institutional review board.

Study Setting and Population

The study was conducted at an urban, academic tertiary care, Level 1 trauma center with an annual volume of more than 45,000 patient visits. The hospital is located in a medium-sized city with a population of approximately 600,000. The catchment area for local emergency medical services consists of ten hospitals. During the study period, there were no closures of area hospitals.

Study Protocol

On April 19, 2005, the adult ED expanded from 28 to 53 licensed beds with an increase in nursing and ancillary staffing; there were no changes in nurse to patient or ancillary staff to patient ratios. The number of ED beds for the expansion project was determined by estimating that one bed per 1,000 annual visits would be needed, and we anticipated a 5% increase in ED volume per year. During the postexpansion period, physician triage was initiated on July 11, 2005, seven days a week from 1 PM to 9 PM. A dedicated attending physician initiated diagnostic evaluation and treatment of patients in the waiting room. The purpose of physician triage was to shorten the time to initial physician contact and initial diagnostic testing to decrease overall ED length of stay (LOS). The triage physician was an additional physician to the existing staffing model. No other interventions occurred during the study period.

Data Collection. Data from a five-month pre-expansion period (November 1, 2004, to March 1, 2005) and a five-month postexpansion period (June 1, 2005, to October 31, 2005) were included for this analysis. We excluded data near the ED expansion to attenuate any immediate effects from the transition. Before expansion, operational changes may have occurred to facilitate transition. After expansion, we assumed that it would take at least one month for the ED staff to adapt to a new environment. The majority of the data were obtained from the ED information system that included an electronic ED whiteboard.[11] The electronic ED whiteboard is the central access point for ED information management, displaying and capturing operational capacity metrics and patient-level data in real time. The diversion status of the ED and hospital units was obtained from the hospital electronic information system.

Variables. From the ED whiteboard database, hourly rates of patients registering and leaving the ED and bed requests for admission were obtained. Hourly averages of ED occupancy, waiting room counts, and the number of admitted patients boarding in the ED (admission holds) were also recorded. Patient acuity, waiting room, and total ED LOS were also available from the database. Patient acuity was determined by the Emergency Severity Index (ESI) score obtained at triage and was used as a marker for patient complexity.[12] Total LOS was defined as the time from registration to the time when the patient left the ED; all patients, regardless of mode of arrival, went through a quick registration process before triage was performed. Waiting room LOS was defined as the time from registration to the time a patient was placed in an ED bed. Admission hold LOS was the time from when a physician requested a hospital bed to the time when the admitted patient actually left the ED.

The primary outcome variable was ambulance diversion. For the ED to go on ambulance diversion, the hospital instituted criteria that helped guide the decision to initiate or terminate ambulance diversion. The criteria were that the ED was to be at 100% occupancy and have more than ten people in the waiting room or more than ten admission holds; these criteria were established in 2003 and remained the same throughout the study period. To monitor appropriateness, every ambulance diversion episode was reviewed bimonthly by the ED and hospital leadership. The hospital had additional categories of diversion to indicate that specific portions of the hospital were at full capacity. Medical-surgical and critical care diversion indicated that medical-surgical and intensive care hospital beds, respectively, were no longer available because these areas were anticipated to be at full capacity. Potential admissions from elective surgeries or accepted outside transfers were taken into account when determining when to go on medical-surgical or critical care diversion. During these periods, new transfers from outside hospitals were not accepted. However, elective surgeries still occurred. Diversion episodes for the operating room, burn unit, labor and delivery, and trauma unit were rare events and were not considered for this analysis.

Data Analysis

For each variable, summary statistics including proportions, means, medians, standard deviations, and interquartile ranges were calculated. Comparisons between pre-expansion and post-expansion periods were performed using the two-sample t-test, Wilcoxon rank sum test, or Pearson's chi-square test, whichever was appropriate depending on the distributions of the variables and the sample sizes. Mean differences (95% confidence interval [CI]) between pre-expansion and postexpansion periods of the total time spent on diversion per month, diversion episodes per month, and duration of diversion per episode were calculated for ambulance, medical-surgical, and critical care diversion.

We further compared the time to ambulance diversion between pre-expansion and postexpansion periods using a log-normal accelerated failure time model. Using this regression model approach, we were able to adjust for potential confounders. Multivariable logistic regression was not performed because the outcome variable (ambulance diversion) and the variable measuring ED characteristics were highly autocorrelated. For this model, we used ED and waiting room measurements taken immediately after an ambulance diversion episode ended to model time to next ambulance diversion episode. The ED status was reset once it was off ambulance diversion, thus ensuring independence of the time to next diversion. Medical-surgical diversion status was considered a covariate for the model and was considered a surrogate for hospital occupancy, because the hospital had to be at 100% occupancy to meet these criteria. Because duration of the previous ambulance diversion episode was likely related to the next diversion episode, this variable was incorporated into the model. Kaplan–Meier curves were constructed for time to ambulance diversion and were compared using the Wald test. A p-value less than 0.05 was considered statistically significant. All statistical analyses were performed using *R* version 2.30 (*R* Foundation for Statistical Computing, Vienna, Austria).

RESULTS

During the study period, the ED provided care for 40,978 patients; there were 19,044 patients (46.5%) during the five-month pre-expansion period and 21,934 patients (53.5%) during the five-month postexpansion period. Patient characteristics, including mode of arrival, ESI score at triage, chief complaint, and consultations, are listed in Table 1. Although statistically significant, no clinical differences in mean age, ESI score, and proportion of female patients were observed between the pre-expansion and postexpansion periods. The pre-expansion period included a significantly higher proportion of patients arriving by ambulance, and the postexpansion period included a higher proportion of patients arriving by aeromedical transport. Small differences in the distribution of chief complaints ($p < 0.001$) and consults requested ($p < 0.001$) were observed between the pre-expansion and postexpansion periods.

Table 1
Patient Characteristics between Pre-expansion and Postexpansion Periods

	Pre-expansion	Postexpansion	p-value
Mean age, yr (±SD)	41.7 (±18.1)	40.9 (±18.2)	0.002
Mean Emergency Severity Index score (±SD)	2.6 (±0.11)	2.6 (±0.10)	<0.001
Mode of arrival			<0.001
Ambulance	3,726 (20.1)	3,798 (17.3)	
Helicopter	521 (2.7)	810 (3.7)	
Female	10,529 (55.3)	12,312 (56.1)	<0.001
Most common chief complaints			<0.001
Alcohol and drugs	406 (5.3)	458 (5.4)	
Abdominal pain	1,474 (19.2)	1,679 (19.9)	
Back pain	485 (6.3)	456 (5.4)	
Chest pain	1,296 (16.8)	1,356 (16.0)	
Dyspnea	751 (9.8)	687 (8.1)	
Genitourinary problem	518 (6.7)	483 (5.7)	
Headache	578 (7.5)	596 (7.1)	
Leg pain	548 (7.1)	661 (7.8)	
Skin infection	528 (6.9)	784 (9.3)	
Trauma, multiple	1,114 (14.5)	1,295 (15.3)	
Consults			<0.001
Cardiology	417 (8.9)	497 (8.6)	
General surgery	450 (9.6)	532 (9.2)	
Nephrology	198 (4.2)	276 (4.8)	
Neurosurgery	284 (6.1)	297 (5.1)	
Neurology	409 (8.7)	421 (7.3)	
Gynecology	183 (3.9)	249 (4.3)	
Orthopedic surgery	575 (12.3)	837 (14.5)	
Psychiatry	801 (17.1)	945 (16.3)	
Trauma	384 (8.2)	556 (9.6)	
Other	984 (21.0)	1,180 (20.4)	

All variables are expressed as *n* (%) unless otherwise indicated.

Comparisons of ambulance diversion, medical-surgical diversion, and critical care diversion between the pre-expansion and postexpansion periods are listed in Table 2. For ambulance, medical-surgical, and critical care diversions, there was no difference in the total time spent on diversion per month and duration per episode between the study periods. The total number of ambulance and critical care diversion episodes per month remained the same between the pre-expansion and postexpansion periods, but the number of medical-surgical diversions significantly increased. A retrospective power analysis was performed for total time spent on ambulance diversion per month. To detect a 10.9-hour difference in the mean time spent on ambulance diversion per month between the two study periods, we had 5.7% power at a significance level of 0.05.

Table 3 lists ED and waiting room statistics. Mean daily ED volume significantly increased by 29 patients per day and mean ED occupancy decreased by 7% after ED expansion. Although statistically significant, the numbers of admissions requests per hour were not clinically different between the pre-expansion and postexpansion periods; 4,840 patients (25.4%) in the pre-expansion period and 6,371 patients (29.0%) in the postexpansion period were admitted ($p < 0.001$). The mean waiting room count increased slightly, but there was no clinical difference in waiting room LOS. Total and admission hold LOS significantly increased during the postexpansion period. Similarly, there was a 67.7% increase in the number of admission holds in the ED during the postexpansion period ($p < 0.001$). A trend toward a decrease in the number of patients who left without being seen was observed.

Kaplan–Meier curves for time to ambulance diversion were constructed (Figure 1). During the postexpansion period, the median time between ambulance diversion episodes was shorter but not significantly different from the pre-expansion period. A multivariable analysis using the log-normal accelerated failure time model is listed in Table 4. ED expansion was not significantly associated with ambulance diversion. In the multivariable model, only waiting room count and duration of previous episode of diversion were associated with time to the next diversion episode.

Table 2
Total Duration on Diversion per Month, Episodes per Month, and Duration of Each Diversion Episode for Each Type of Diversion

Variable	Pre-expansion	Postexpansion	Difference (95% CI)
Ambulance diversion			
Total duration per month (hr)	106.9 (90.5)	117.9 (34.6)	10.9 (−74.0, 95.8)
No. of episodes per month	14.2 (6.6)	16.2 (3.4)	2.0 (−4.2, 8.2)
Duration per episode (hr)	7.5 (14.0)	7.3 (8.2)	0.3 (−4.0, 3.5)
Medical-surgical diversion			
Total duration per month (hr)	57.7 (17.9)	90.7 (66.7)	33.0 (−27.5, 93.5)
No. of episodes per month	2.0 (0.7)	4.4 (2.5)	2.4 (0.1, 4.7)
Duration per episode (hr)	28.8 (11.9)	20.6 (17.0)	−8.2 (−18.4, 2.0)
Critical care diversion			
Total duration per month (hr)	23.8 (16.5)	29.1 (30.9)	5.3 (−24.9, 35.4)
No. of episodes per month	3.0 (1.4)	2.4 (1.3)	−0.6 (−2.3, 1.1)
Duration per episode (hr)	7.9 (8.4)	12.1 (13.9)	4.2 (−4.7, 13.1)

Values are expressed as mean (±SD). Changes between pre-expansion and postexpansion periods are expressed in mean change (95% CI).

DISCUSSION

Emergency department overcrowding and ambulance diversion are significant problems in the United States.[1,3,8] According to the 2003 National Hospital Ambulatory Medical Care Survey, approximately 45% of the EDs surveyed reported being on ambulance diversion in the previous year.[13] In a survey of ED directors, 91% reported that ED overcrowding was a significant problem.[1] Unfortunately, few solutions to ED overcrowding and ambulance diversion have been objectively studied.

We found that a major ED expansion did not affect the amount of time spent on ambulance diversion. We observed an increase in total ED LOS. More importantly, admitted patients were boarding in the ED longer; consequently, more admission holds occurred during the postexpansion period. Diversion of inpatient units did not change during the study periods, suggesting that there is a strong and direct association between inpatient bed availability and ambulance diversion that cannot be alleviated by an ED expansion alone. This is contrary to previous reports. Miro et al. increased their ED bed capacity from 25 to 41 beds and observed significant decreases in the number of patients waiting to be seen and waiting room time.[14]

The absence of any effect of ED expansion on overcrowding and ambulance diversion can be explained using the conceptual model for ED overcrowding by Asplin et al. They described three interdependent components: input, throughput, and output.[15] The expansion of the ED was an attempt to increase patient throughput; more patients could be evaluated at one time. Although an increase in input (i.e., daily ED patient volume) was observed, the absence of any change in ambulance diversion and longer ED LOS were most likely driven by the higher number of admission holds and increased admission hold LOS during the postexpansion period. Admission holds have been described as the single most important factor in the etiology of ED overcrowding

Table 3
ED and Waiting Room Counts

Variable	Pre-expansion	Postexpansion	p-value
Daily patient volume	125 (78, 163)	144 (108, 177)	<0.001
Occupancy (%)	85.0 (25.8)	77.9 (18.8)	<0.001
No. of patients registered per hour	5 (0, 19)	6 (0, 20)	<0.001
No. of ED admit requests per hour	1 (0, 8)	1 (0, 8)	<0.001
No. of patients in the waiting room	3.9 (4.6)	4.1 (4.9)	0.002
Waiting room LOS (hr)	0.6 (0.7)	0.6 (0.7)	0.001
Total LOS (hr)	4.6 (1.9)	5.6 (2.3)	<0.001
No. of admission holds	3 (0, 20)	5 (0, 23)	<0.001
Admission hold LOS (hr)	3.0 (0.2)	4.1 (0.2)	<0.001
Left without being seen (%)	3.5 (3.3)	2.7 (2.3)	0.062

All count data except daily patient volume are listed per hour. Continuous variables are summarized as mean (SD), and count data are summarized as median (minimum, maximum).
LOS = length of stay.

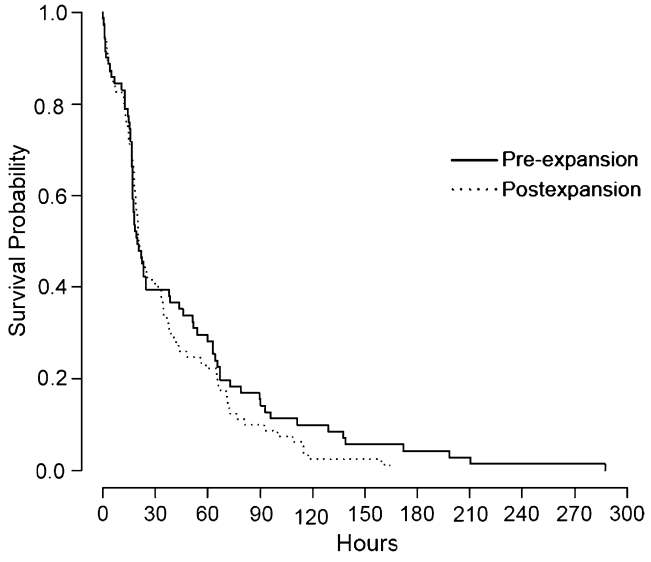

Figure 1. Kaplan–Meier curves for time to ambulance diversion between the pre-expansion and postexpansion periods. There was no difference in time to diversion episodes between the pre-expansion and postexpansion periods.

Table 4
ED Expansion and Its Association with Time to Next Ambulance Diversion Episode Using a Multivariable Log-normal Accelerated Failure Time Model

Variable	β Coefficient	p-value
ED expansion	−0.3546	0.189
Occupancy rate	−0.0162	0.168
Waiting room count	−0.0981	0.023
Mean waiting room length of stay	0.3895	0.065
Mean total length of stay	−0.0025	0.964
Registration count per hour	−0.0040	0.925
Discharge count per hour	0.0027	0.944
Admission requests per hour	−0.0653	0.043
Duration of previous ambulance diversion	−0.0003	0.040
Medical-surgical diversion	0.6416	0.088

A negative β coefficient indicates that time to next ambulance diversion is shortened as the variable increases. Each variable was measured right after ambulance diversion ended.

and ambulance diversion.[16,17] Admission holds reflect hospital occupancy and inpatient bed availability.[18] When the hospital is at near full capacity, admitted patients board in the ED until an inpatient bed becomes available.

Although the number of inpatient admissions from the ED increased during the postexpansion period, it does not adequately explain why the number of admission holds increased. A possible reason is that during the study period, the hospital was attempting to increase revenue by encouraging more elective surgeries and transfers from outside hospitals. The end result is a decrease in the number of inpatient beds available to patients admitted from the ED. Although the ED throughput was increased by expanding the bed capacity of the ED, its effect was counteracted by the increased demand and decreased ability to properly output admitted patients from the ED to an inpatient bed.

Other potential solutions to ED overcrowding and ambulance diversion have been studied. Creating an ED managed acute care unit for patients requiring prolonged evaluations and treatment has been shown to dramatically decrease the number of patients who leave the ED without being seen and the number of ambulance diversions.[19] Affecting output, such as increasing the number of hospital beds, may also improve ED overcrowding; McConnell et al. found that increasing intensive care unit capacity decreased the amount of time spent on ambulance diversion.[20] However, this effect was likely attributable to a significant decrease in ED LOS of intensive care unit patients.[20] Physician triage and point-of-care laboratory testing have also been shown to decrease ED LOS, but the effect on ambulance diversion is unknown.[21–24] Litvak et al. described how minimizing the peaks in the number of elective surgeries by redistributing the elective surgeries to Mondays and Fridays affected not only the operating room but the ED as well; mean waiting room and ED LOS decreased once the changes in operating room scheduling were implemented.[25]

LIMITATIONS

We were unable to quantify the number of elective surgeries or transfers from outside hospitals. These two factors affect hospital capacity because these two sources of patients compete with the ED for inpatient beds. Physician triage, in support of alleviating the crowding burden, was initiated during the postexpansion period. However, previous studies have shown that physician triage improves ED LOS and may bias our findings toward an improvement in ambulance diversion and ED LOS.[21–23] Physician triage may also explain why our left-without-being-seen rates decreased slightly.[21] Our study did not account for seasonal variation. However, the majority of the pre-expansion period included the winter months, when there is a higher incidence of ambulance diversion episodes.[26,27] This should have biased toward seeing an improvement in ambulance diversion and ED overcrowding. The postexpansion period, however, overlapped with the start of the academic year, during which residents advance one postgraduate level and new interns begin staffing the ED. The study periods for the pre-expansion and postexpansion periods were relatively short. However, this minimized the impact of temporal trends and other institutional changes (changing inpatient bed capacity, staffing levels, and so on). The study took place at an academic ED in tertiary care located in an urban environment. Our findings may not be generalizable to community or rural EDs. The pre-post study design may be subject to confounding biases; however, for studying the impact of ED capacity expansion, this study design was likely to be the strongest and most feasible that was applicable to a one-time, nonreversible intervention. The concept of ED overcrowding is not well defined, and an objective definition remains to be developed. Several quantitative measures of ED overcrowding have been developed but have not been well validated for use in different ED environments.[28,29] We applied ambulance diversion as a surrogate for ED overcrowding; however, criteria for ambulance diversion may differ at other hospitals. We used administrative data from our ED and hospital databases. Potential confounders, such as comorbid conditions or vital signs, were not recorded and as a result may have biased the study. Finally, we were unable to account for the ambulance diversion status of surrounding hospitals. When a large number of hospitals are on ambulance diversion, all hospitals may be forced to go off ambulance diversion. Although these were exceedingly rare events, this is an acknowledged weakness of the study.

CONCLUSIONS

Expansion of the ED did not alleviate the overcrowding burden and decrease ambulance diversion at our institution. The effects of increasing throughput may have been negated by the increase in daily patient volume (ED) and a hospital push to increase elective surgeries.

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