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Effects of Emergency Department Expansion on Emergency Department Patient Flow

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Abstract

Objectives—Emergency department (ED) crowding is an increasing problem associated with adverse patient outcomes. ED expansion is one method advocated to reduce ED crowding. The objective of this analysis was to determine the effect of ED expansion on measures of ED crowding.

Methods—This was a retrospective study using administrative data from two 11-month periods before and after the expansion of an ED from 33 to 53 adult beds in an academic medical center. ED volume, staffing, and hospital admission and occupancy data were obtained from either the electronic health record or administrative records. The primary outcome was the rate of patients who left without being treated (LWBT), and the secondary outcome was total ED boarding time for admitted patients. A multivariable robust linear regression model was used to determine whether ED expansion was associated with the outcome measures.

Results—The mean daily adult volume was 128 (SD ±14) patients before expansion, and 145 (SD ±17) patients after. The percentage of patients who LWBT was unchanged: 9.0% before expansion, vs 8.3% after expansion (difference 0.6%, 95% CI = −0.16% to 1.4%). Total ED boarding time increased from 160 to 180 hours/day (difference 20 hours, 95% CI = 8 to 32 hours). After adjusting for daily ED volume, low-acuity area volume, daily wait time, daily boarding hours, and nurse staffing, the decrease in patients who LWBT was not independently associated with ED expansion ($p = 0.053$). After adjusting for ED admissions, ED intensive care unit admissions, elective surgical admissions, hospital occupancy rate, ICU occupancy rate, and number of operational ICU beds, the increase in ED boarding hours was independently associated with the ED expansion ($p = 0.005$).

Conclusions—An increase in ED bed capacity was associated with no significant change in the percentage of patients who LWBT, but had an unintended consequence of an increase in ED boarding hours. ED expansion alone does not appear to be an adequate solution to ED crowding.

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INTRODUCTION

Emergency department (ED) crowding is an increasing problem.[1] The American College of Emergency Physicians defines crowding as occurring when "the identified need for emergency services exceeds available resources for patient care in the ED, hospital or both."[2] This phenomenon is fueled by rapidly growing numbers of ED visits combined with declining numbers of ED facilities.[3] ED crowding is associated with adverse effects on patient outcomes, including delays in thrombolytics for acute myocardial infarction,[4,5] antibiotics for pneumonia,[6,7] pain relief for numerous conditions,[8–11] and treatment for acute asthma.[12] It is also associated with higher rates of in-hospital adverse cardiac events,[13] and mortality.[14–16]

Conceptual models of ED crowding divide critical determinants of ED crowding into input, throughput, and output.[17] ED input is driven by the demand for ED care, and includes emergency care, unscheduled acute care, and safety net care. ED throughput encompasses the triage, evaluation, and diagnostic steps that influence patient length of stay (LOS) in the ED. ED output focuses on the timely disposition of ED patients. Increasing ED capacity has been advocated to increase ED throughput and reduce ED crowding.[18] Current data on the ability of ED expansion to reduce ED crowding, however, are conflicting.[19,20]

Our overall goal was to determine the effects of ED expansion on measures of ED crowding in our ED. We hypothesized that ED expansion would be associated with a decrease in the rate of patients who left without being treated (LWBT) from the pre-expansion to post-expansion period.

METHODS

Study Design

This was a retrospective, before-and-after cohort study using data from the University of California Davis health system's electronic health record (EHR) and administrative databases. This study was granted waiver of consent by our institutional review board.

Study Setting and Population

We performed this study at UC Davis, a single urban, academic ED with an annual volume of approximately 50,000 adult patients. Our hospital is a tertiary care facility with 619 licensed acute care beds and serves a 65,000-square mile area that includes 33 counties and six million residents. The pre-expansion period comprised November 1, 2009, through September 30, 2010. The post-expansion period comprised November 1, 2010, through September 30, 2011. All clinical operations were moved to the expanded ED at 7 am on October 6, 2010. October 2010 was excluded from the study to eliminate the effects that physician and staff adjustment to the new environment may have had on ED operations. No other changes in hospital processes for ED patient flow were made. We included all adult patients (age 18 years and older) who were triaged during the study period.

The old and expanded EDs used a similar operational model, with an increase in adult beds from 33 to 53. The old adult ED comprised two primary treatment "pods" with 12 licensed

beds each, a three-bed resuscitation area, and a six-bed low-acuity treatment area. The expanded adult ED also comprises two primary treatment "pods" with 12 licensed beds each, a four-bed resuscitation area, and a six-bed low-acuity treatment area. The expanded adult ED also contains two additional treatment pods, one with 12 licensed beds and the other with seven licensed beds.

No substantial changes to the resident physician staffing, nurse-to-patient ratios, or technician-to-patient ratios occurred during 2009 through 2011. State-mandated nursing ratios for the ED and hospital were set at four patients:one nurse for non-intensive care unit (ICU) patients, and two patients:one nurse for ICU-level patients throughout the study period. Starting September 16, 2010, ten hours of attending emergency physician coverage replaced ten hours of physician extender coverage in the low-acuity area of the ED, where patients with Canadian Triage and Acuity Scale[21] levels IV–V were treated from 9 am to midnight daily. Prior to this time, these patients were treated primarily by physician extenders. Beginning July 1, 2011, physician extenders were fully replaced by attending EPs who provided 15 hours of coverage daily from 9 am to midnight in the low-acuity area.

Study Protocol

The ED utilizes an electronic health record (EHR) that captures data on every patient who is triaged into the ED system. The following elements from the EHR were downloaded for each day during the study periods: 1) total number of adult patients triaged in the ED, 2) number of adult patients triaged to each of the Canadian Triage and Acuity Scale levels I–V, 3) number of adult patients who LWBT, 4) total wait time in hours for adult patients, 5) total ED length of stay in hours for all adult patients, 6) number of adult patients treated in the low-acuity area, 7) number of adult patients admitted from the ED to the hospital, 8) number of adult patients admitted from the ED to an ICU, 9) total boarding hours for all adult patients admitted from the ED, and 10) number of coded adult trauma activation patients.

The following data were obtained from these administrative records for each day during the study periods: ED nurse staffing hours, number of telemetry/ward beds occupied at midnight, number of ICU beds occupied at midnight, number of elective surgical admissions, number of operational telemetry/ward beds, and number of operational ICU beds.

Wait time was defined as the time from triage to placement in an ED treatment bed. ED length of stay LOS was defined as the time from triage to leaving the ED, regardless of disposition, for patients who were treated in the ED. Boarding hours for admitted patients were included in LOS. The trauma criteria for Level 1, 2, and 3 coded trauma activations are shown in the Data Supplement. Nurse staffing hours include the total number of nursing hours available during the 24-hour period from 7 am to 7 am. Hospital occupancy rate was defined as the percentage of operational hospital beds occupied beds at midnight, and ICU occupancy rate was defined as the percentage of operational ICU beds occupied at midnight.

Outcomes

The primary outcome measure was the rate of ED patients who LWBT, and the secondary outcome was total daily adult boarding hours. A patient was considered to have LWBT if

she or he left from the ED waiting room or left from the ED treatment room prior to being evaluated by a physician or physician extender. ED boarding was defined as the interval from one hour following admission bed request placement to the patient leaving the ED to the inpatient bed or operating suite. Boarding hours were calculated based on the patient's date of ED presentation; for example, hours that a patient stayed in the ED beyond midnight on the presenting date would be reflected in the total hours for the presenting date.

Data Analysis

Summary statistics were calculated for each variable. A multivariable robust linear regression model was used to determine whether ED expansion was associated with changes in the LWBT rate or ED boarding. Robust linear regression was used because some of the outcome data were outliers. Candidate predictor variables were selected based on literature review.[17,18,22,23] Those considered in the LWBT model included ED adult volume, ED low-acuity area volume, number of coded adult trauma activation patients, total ED wait time, total ED boarding hours, and ED nurse staffing hours. Candidate variables for the ED boarding model included number of ED admissions, number of ED admissions to the ICU, number of elective surgical admissions, hospital occupancy rate, ICU occupancy rate, and number of operational ICU beds. The pre- versus post-expansion variable was forced into the multivariable robust linear regression models. Additional variables were selected into the models using the stepwise method with the significance level of 0.15 for entry into the model, and the significance level of 0.15 for remaining in the model. We used a p-value of 0.05 as the cutpoint for statistical significance. Leverage-point diagnostics were performed using the canonical robust distance, and residuals based on robust regression estimates were used to detect vertical outliers, which are implemented in SAS PROC ROBUSTREG. Residuals were analyzed using kernel density plots and Q-Q plots. Models were reported only when regression diagnostics were met. All analyses were performed using STATA 12.0 (StataCorp LP, College Station, TX) and SAS Version 9.2 (SAS Institute, Cary, NC).

RESULTS

In the 11 month period prior to ED expansion, 42,896 adult patients were triaged (mean ± standard deviation [SD] 128 ± 14 patients/day; median 128, interquartile range [IQR] 118 to 137 patients/day]. In the 11 month period after ED expansion, 48,358 adult patients were triaged (mean 145, SD ±17 patients/day; median 144, IQR 134 to 156 patients/day). A steady increase in patient volume during the post-expansion period was noted (Figure 1). Patient acuity and trauma volume were similar in both periods. The "up front care" area of the ED handled more visits in the post-expansion period. ED nurse staffing increased from a mean of 427 hours per day pre-expansion to a mean of 487 hours per day post-expansion (Table 1).

The LWBT rate remained unchanged, at 9.0% (95% CI = 8.4% to 9.5%) pre-expansion and 8.3% (95% CI = 7.8% to 8.9%) post-expansion (difference 0.6%, 95% CI = −0.16% to 1.4%); however, ED boarding hours increased from 160 hours/day (95% CI = 152 to 168 hours/day) to 180 hours/day (95% CI = 170 to 189 hours/day). The LWBT rate followed a

similar temporal pattern over the two periods (Figure 2a), but ED boarding increased steadily in the post-expansion period (Figure 2b).

The change in the LWBT rate from the pre-expansion to post-expansion period was not significant in the multivariable robust linear regression model after adjustment for ED volume, ED low-acuity area volume, ED wait time, ED boarding hours, and ED nursing hours (Table 2). The increase in ED boarding hours from the pre-expansion to post-expansion period remained significant after adjustment for ED admissions, ED ICU admissions, elective surgical admissions, hospital occupancy rate, ICU occupancy rate, and number of operational ICU beds (Table 3).

DISCUSSION

We found that ED expansion was associated with no significant change in ED throughput as measured by the LWBT rate. We experienced a substantial increase in ED input during the post-expansion period, and we noted a decline in ED output, evidenced by increased ED boarding.

Emergency department input (volume) increased by 13% from the pre-expansion to post-expansion period, and steadily increased during the post-expansion period. This rate is higher than the national average,[3] and higher than our institution's prior annual increases, which were below 2% in the two years prior to the expansion. This "build it and they will come" phenomena is similar to the increased volume seen following an ED expansion project at a different site.[19] Following the trend in ED volume, we also experienced an increase in ED admissions by three patients per day. With a mean hospital LOS of 4.8 days,[24] this increase in ED admissions translates to 5,256 more inpatient days per year for the hospital. Future expansion projects should consider and account for the likelihood of higher-than-expected increases in ED volume and admissions following expansion.

The LWBT rate declined initially in the post-expansion period, but once a new equilibrium was established in the expanded ED, ED wait times (data not shown) and the LWBT rate returned to pre-expansion levels. Extrapolating over an entire year, a sustained 1% decrease in the LWBT rate at the study institution would result in more than 500 additional adult patients being treated. As over 10% of patients who leave without being treated return to an ED for care within 72 hours, and approximately 4% are ultimately admitted to a hospital,[22,23,25] a sustained decrease in the LWBT rate would result in more timely provision of definitive care for patients.

We believe that our ED expansion was not associated with a sustained decrease in crowding for several reasons. First, ED staffing was not substantially increased. In contrast to Miro et al., whose reorganization efforts included a 34% overall increase in staffing,[20] our expansion was accompanied by only a 14% increase in nurse staffing and no substantial changes in physician, technician, or administrative staffing. Second, inpatient treatment areas were not expanded. Thus, the additional ED treatment beds functionally became a boarding area for admitted patients rather than an active treatment area for ED patients. Although the additional boarding hours consumed nursing and ancillary resources, less

pressure to move these patients to inpatient areas was felt in the expanded ED. In a study similar to ours, Han et al. found that ED expansion was associated with no change in ambulance diversion, and increases in ED LOS and ED boarding.[19] We identified the same phenomena at our institution, suggesting that these changes are not institution-specific, and that hospitals planning ED expansion should plan to prevent an associated increase in ED boarding hours.

LIMITATIONS

The retrospective, before-after design of our study is subject to temporal trends and other institutional changes. We selected matched 11-month periods to minimize the effects of seasonal variation in ED volume, illness patterns, and resident training, and we controlled for several possible institutional changes in our multivariable regression model. Individual medical records were not abstracted, but administrative EHR information was downloaded. Thus, potential for abstractor error was minimized. Our findings represent the experience at a single urban academic medical center and may not be applicable to other settings.

While we expanded our ED by 20 beds, we were sometimes unable to use a portion of these beds due to limited nurse staffing and state-mandated nurse-to-patient ratios. Thus, we included nursing hours and ICU admissions to control for these instances. We were not able to evaluate a change in ICU boarding as our institution does not track data on the number of telemetry and ward, vs. ICU boarding hours. Our hospital and ICU occupancy rates were calculated at midnight, and may not reflect mean occupancy throughout the 24-hour day. Given that various measures of ED crowding exist without consensus on a single preferred approach, we selected outcomes that are accepted manifestations of crowding,[2,26–28] and that measure different aspects of ED crowding.[29] While ambulance diversion has been previously used as a global measure of ED crowding,[19] our hospital policy prohibited ambulance diversion throughout the study period.

CONCLUSIONS

An increase in ED bed capacity was associated with no significant change in the percentage of patients who left without being treated, and an increase in ED boarding hours. ED expansion alone does not appear to be an adequate solution to ED crowding.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Beth Morris, MPH

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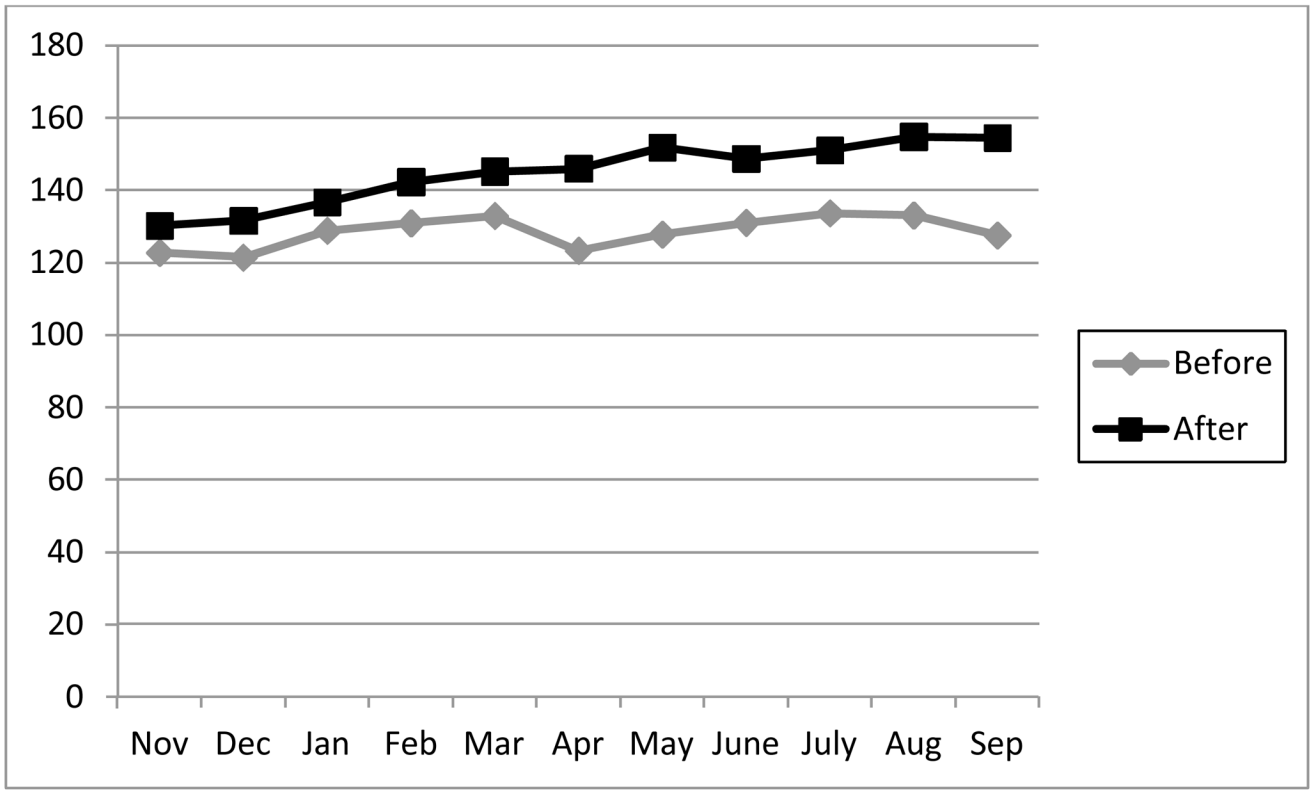

Figure 1.

Daily emergency department volume by month during pre-expansion (before) and post-expansion (after) periods.

Data shown are unadjusted.

Figure 2a.

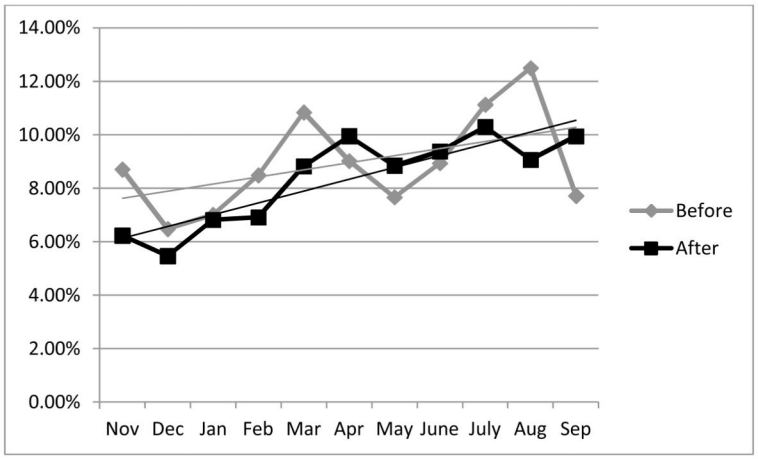

Figure 2b.

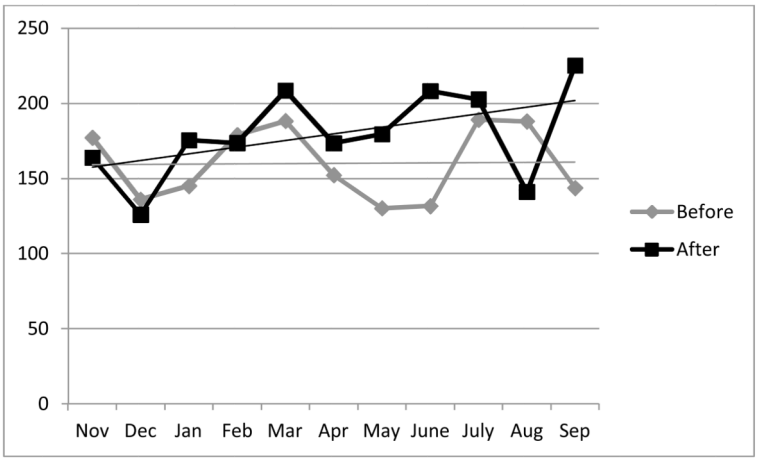

Figure 2.

Figure 2a. Left without being treated rate by month during pre-expansion (before) and post-expansion (after) periods.

Data shown are unadjusted.

Figure 2b. Emergency department boarding hours by month during pre-expansion (before) and post-expansion (after) periods.

Data shown are unadjusted.

Table 1

Characteristics of pre- and post-expansion periods.

Characteristic	Pre-expansion n = 42,896	Post-expansion n = 48,358
Daily ED volume	128 ± 14	145 ± 17
Triage level, %		
CTAS I	23	21
CTAS II	27	28
CTAS III	38	37
CTAS IV	13	14
CTAS V	0	1
Missing	1	1
Low-acuity area volume		
Visits per day	27 ± 5	34 ± 6
% of overall volume	21.0	23.2
Trauma volume (patients/day)		
Level 1	1.7 ± 1.3	1.5 ± 1.2
Level 2	2.2 ± 1.6	2.0 ± 1.5
Level 3	6.9 ± 3.3	6.9 ± 3.4
Total adult wait time per day (hours)	145 ± 68	148 ± 77
Total LOS for all patients (hours)	934 ± 184	1027 ± 218
Total LOS for discharged patients only (hours)	556 ± 120	607 ± 125
Total ED admissions per day	35 ± 6	38 ± 6
Overall admission rate	27.3	26.2
ED admissions to ICU per day	6.4 ± 2.5	7.1 ± 2.5
ICU admission rate	5.0	4.9
ED nursing hours per day	427 ± 23	487 ± 40
Elective surgical admissions per day	13 ± 9	13.5 ± 9.2
Number of hospital beds occupied	310 ± 19	316 ± 20
Hospital occupancy rate	79.1	80.7
Number of ICU beds occupied	64 ± 4	66 ± 5
ICU occupancy rate	97.0	93.2
Operational telemetry/ward beds	392 ± 0	392 ± 0
Operational ICU beds	66 ± 0	71 ± 1

Data are presented as mean ± standard deviation or percentage.

CTAS = Canadian Triage and Acuity Score; ICU = intensive care unit; LOS = length of stay

Table 2

Multivariable robust linear regression for the left without being treated rate outcome.

ED Variable	Parameter Estimate	p-value
Expansion	−0.0073	0.0532
Volume (pts/day)	0.0001	<0.0001
Low-acuity area volume (pts/day)	−0.0009	0.0001
Wait time (hours)	0.0004	<0.0001
Boarding hours	0.0001	<0.0001
Nursing hours	−0.0001	0.0944

pts = patients

$R^2 = 0.5239$

Table 3

Multivariable robust linear regression for boarding hours outcome.

Variable	Parameter Estimate	p-value
ED expansion	43.71	0.0049
ED admissions	4.13	<0.0001
ED ICU admissions	1.46	0.1056
Elective surgical admissions	1.84	<0.0001
Hospital occupancy rate	357.71	<0.0001
ICU occupancy rate	171.03	<0.0001
Operational ICU beds	−9.65	0.0016

$R^2 = 0.3710$

ICU = intensive care unit