Emergency Department Patient Flow: The Influence of Hospital Census Variables on Emergency Department Length of Stay

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Abstract

Objectives: The objective was to evaluate the association between hospital census variables and emergency department (ED) length of stay (LOS). This may give insights into future strategies to relieve ED crowding.

Methods: This multicenter cohort study captured ED LOS and disposition for all ED patients in five hospitals during five 1-week study periods. A stepwise multiple regression analysis was used to examine associations between ED LOS and various hospital census parameters.

Results: Data were analyzed on 27,325 patients on 161 study days. A significant positive relationship was demonstrated between median ED LOS and intensive care unit (ICU) census, cardiac telemetry census, and the percentage of ED patients admitted each day. There was no relationship in this cohort between ED LOS and ED volume, total hospital occupancy rate, or the number of scheduled cardiac or surgical procedures.

Conclusions: In multiple hospital settings, ED LOS is correlated with the number of admissions and census of the higher acuity nursing units, more so than the number of ED patients each day, particularly in larger hospitals with busier EDs. Streamlining ED admissions and improving availability of inpatient critical care beds may reduce ED LOS.

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Crowding in our nation's emergency departments (EDs) is widespread and negatively affects patient safety, quality of care, and patient and provider satisfaction.[1–3] Delays in diagnosis and treatment of time-sensitive conditions such as myocardial infarction, pneumonia, and stroke have been attributed to ED crowding.[4] In addition, according to a Joint Commission report, greater than 50% of all sentinel events secondary to delays in treatment occur in EDs, with ED crowding being cited as a contributing factor in 31% of such cases.[5]

Development of initiatives addressing this crisis relies upon accurate identification of the root causes of crowding. The 2006 Institute of Medicine report on the future of emergency care states that ''While many of the factors contributing to ED crowding are outside the immediate control of the hospital, many more are the result of operational inefficiencies in the management of hospital patient flow.''[6] Other investigators have reported on various aspects of hospital factors affecting ED crowding, such as hospital occupancy, number of elective surgical admissions, and number of admitted patients boarding in the ED.[7,8] However, these have been small reports or performed at single institutions. Identifying hospital system variables affecting ED crowding within multiple geographically and operationally disparate health care institutions may help elucidate common trends in hospital census and patient flow that

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contribute to ED crowding. This information can be valuable at the local level to guide improvements, as the greater societal and health care system issues contributing to ED crowding are beyond the control of most hospitals and health care managers.

The purpose of our study was to determine the effect of hospital census variables on ED length of stay (ED LOS) in five different hospital systems. ED LOS was chosen as a surrogate marker for crowding, as crowding is associated with longer ED LOS. Additionally, ED LOS has been rated as a valuable marker of overall ED efficiency[9] and can be easily measured before and after interventions designed to reduce crowding. We hypothesized that on a daily basis, median ED patient LOS is more closely correlated with inpatient hospital census variables than with the actual number of patients presenting for care in the ED each day.

METHODS

Study Design

This was a cohort study of a convenience sample of all ED patients presenting to the study hospitals. The study was approved by or received exemption from the institutional review board (IRB) at each participating site.

Study Setting and Population

The study setting was composed of five hospitals, each in a different state, with ED volumes ranging from 81 to 272 patients per day. The cohort included academic and community hospitals as well as trauma and nontrauma centers. Patients who presented during the second week (to avoid holidays) of each month from September 2006 until January 2007 were included.

Study Protocol

The time unit of measure for all data was 1 calendar day. All EDs in the cohort had electronic patient tracking systems capable of measuring the time of patient arrival, time of admission request, and time of patient departure from the ED. All patients were classified as admitted or discharged. Patients classified as discharged included those who were discharged back to their usual place of residence, left without being seen by a physician, left against medical advice, eloped before their final disposition, or died in the ED before an order for admission. Patients classified as admissions included admissions to inpatient units and transfers to other inpatient settings. None of the hospitals in the cohort had an ED-based observation unit.

Inpatient census counts were collected once per day at each hospital at any one point between noon and 6:00 PM and included all patients who physically occupied an inpatient bed. Participating hospitals did not report the midnight census collected for billing reasons, as this excludes late discharges and was felt to underrepresent the true census that impacts overall hospital patient flow. The noon to 6:00 PM time frame allowed data collection when a research assistant was available. A single time point was not proscribed so as to avoid potential confounders that may vary between hospitals and potentially skew the census count at certain time points (i.e., teaching rounds, shift changes, and staffing patterns of ancillary staff). At the point of the inpatient census count, patients boarding in the ED or recovery room for at least 2 hours after an order to be admitted to the hospital were also counted in that day's inpatient census. Thus, the total hospital census could exceed 100% of stated capacity. Inpatient units that rarely or never accept admissions from the ED, such as inpatient rehabilitation units or the newborn nursery, were not counted in the inpatient census. Scheduled surgical and cardiac procedures were included if they appeared on the posted schedule by 8:00 AM on each study day.

Emergency department LOS was measured in minutes as a continuous variable measuring the interval between the time of patient arrival as recorded in the electronic tracking system and the time of patient departure from the ED. Daily median ED LOS was calculated over a 24-hour period beginning at midnight. Patients whose ED stay crossed calendar days were counted in the day that they presented to the ED. Median daily ED LOS was the outcome variable of interest. Median LOS was chosen rather than mean because it is less sensitive to outliers and thus potentially more reflective of usual operations in the ED.

The purpose of the study was to measure associations between ED LOS and other census parameters that the authors hypothesized may be related to this outcome variable. Other census parameters analyzed each day included daily ED volume, daily percentage of ED patients admitted to the hospital, daily total hospital census, daily census of inpatient critical care and cardiac telemetry units, daily number of scheduled surgeries, and daily number of scheduled cardiac procedures.

Data Analysis

Descriptive analyses included frequencies, means, medians, and 95% confidence intervals (CIs) for ED LOS and the census parameters. The association between ED LOS and the census parameters was assessed using a stepwise multiple regression analysis with median ED LOS as the dependent variable. Total inpatient, intensive care unit (ICU), and cardiac telemetry census values were expressed as a percentage of occupancy (number of beds occupied by patients/total number of reported beds). ED census, surgical procedures, and cardiac procedures were expressed as a percentage of the average for the study period. ED admissions were expressed as a percentage of the ED census each day. Because the hospitals in the cohort had very few or no scheduled surgical or cardiac procedures on the weekends, weekend days were not included in the analysis for these variables. Additionally, each hospital's data were individually analyzed to see if they were similar with the aggregate results and to assess if any single hospital unduly influenced the pooled data analysis. Data were analyzed with SPSS 15.0 for Windows (SPSS Inc., Chicago, IL).

RESULTS

The study population consisted of 27,325 ED patients seen in the five hospitals. Two hospitals missed the start date of the study due to delays in IRB approval and did not report data for September 2006, yielding 161 study days. The size of the hospitals in the cohort ranged

from 218 to 681 total inpatient beds and on average operated at 86% (range = 67%–106%) of capacity during the study period. The total hospital capacity and average occupancy rate for each hospital are summarized in Table 1. The median daily ED LOS for the study population was 247 minutes. For each individual hospital the average daily ED volumes, percentage of ED patients admitted, and median ED LOS are displayed in Table 2.

Table 3 displays the regression coefficients for each of the variables in the model. For the regression model, census variables were added in a stepwise fashion in the following order: ED census, percentage of ED patients admitted, total hospital census, ICU census, telemetry census, surgical procedures, and cardiac procedures. For the cohort, three variables demonstrated a statistically significant relationship with median ED LOS: ICU census (standardized $\beta = 0.305$, $p = 0.01$), cardiac telemetry census (standardized $\beta = 0.469$, $p < 0.001$), and the percentage of ED patients admitted each day (standardized $\beta = 0.749$, $p = 0.049$). Table 4 displays the Pearson correlation coefficients between each of the studied variables and median ED LOS, showing moderate to strong correlations between these three variables and median ED LOS each day. Based on our analysis of the entire cohort, there was no significant relationship between ED LOS and ED census, total hospital census, or the number of scheduled surgical and cardiac procedures during the study period.

The Pearson correlation coefficients (r) between each individual hospital's median ED LOS and their census variables are displayed in Table 5. The daily number of ED admissions was the only variable with a statistically significant and moderately strong correlation with ED LOS across all hospitals in the group. The other variables showed significant correlations with ED LOS in some but not all other hospitals, more so in the larger and busier hospitals in the group.

To see if any single hospital influenced the analysis of the pooled data of the group, the correlation coefficients were calculated between median LOS and the studied census variables again, each time omitting one hospital from the group. The results are shown in Table 6. Data from the largest hospital in the cohort

Table 1
Hospital Capacities and Census

Hospital	Annual ED Volume	Number of Reported Inpatient Beds	Occupancy Rate During Study Period (%)		
			Average	95% CI	Range
A	29,930	278	90.6	87.8–93.5	76–106
B	36,500	215	85.0	83.4–86.6	72–91
C	60,225	305	82.3	79.1–85.5	67–125
D	81,030	681	83.5	82.3–84.7	77–89
E	99,280	637	90.9	88.4–93.4	71–101

Table 2
Characteristics of Study EDs

Hospital	Average Daily Volume (95% CI)	Percent Patients Admitted (95% CI)	Median LOS, Minutes (95% CI)
A	82 (78–86)	18 (16–20)	189 (182–196)
B	100 (95–104)	22 (21–24)	176 (168–183)
C	165 (161–170)	20 (19–21)	270 (266–275)
D	222 (215–229)	29 (28–31)	252 (251–254)
E	272 (265–279)	26 (24–27)	276 (271–282)

LOS = length of stay.

Table 4
Correlation Coefficients Between Census Parameters and ED LOS for Pooled Data

Variable	Pearson Correlation Coefficient	p-value
Median LOS	1.00	—
ED census	0.13	0.048
% ED patients admitted	0.40	0.000
Total hospital census	–0.03	0.373
ICU census	0.46	0.000
Telemetry census	0.62	0.000
Surgical procedures	–0.08	0.201
Cardiac procedures	–0.18	0.025

ICU = intensive care unit; LOS = length of stay.

Table 3
Regression Coefficients for Pooled Data

Variable	Unstandardized Coefficient (β)	Standardized Coefficient (β)	95% CIs for β	Significance (p-value)
Median LOS	Constant	Constant		
ED census	0.376	0.072	–0.372 to 1.125	0.321
% ED patients admitted	1.49	0.154	0.009 to 2.977	0.049
Total hospital census	–0.551	–0.072	–1.634 to 0.532	0.316
ICU census	0.795	0.211	0.191 to 1.398	0.010
Telemetry census	1.308	0.469	0.867 to 1.759	0.000
Surgical procedures	–0.140	–0.086	–0.383 to 0.102	0.255
Cardiac procedures	–0.074	–0.094	–0.194 to 0.045	0.222

ICU = intensive care unit; LOS = length of stay.

Table 5
Correlation Coefficients Between ED LOS and Census Variables for Each Hospital

	Hospital									
	A		B		C		D		E	
	r	p-value	*r*	p-value	*r*	p-value	*r*	p-value	*r*	p-value
ED census	0.37	0.05	0.06	ns	0.71	<0.001	0.02	ns	0.46	0.006
ED admits	0.51	0.005	0.33	0.05	0.67	<0.001	0.38	0.05	0.51	0.002
Total hospital census	0	ns	0.23	ns	0.57	<0.001	0.20	ns	0.34	0.05
ICU census	0.23	ns	0	ns	0.49	<0.001	0.21	ns	0.33	0.05
Telemetry census	0.12	ns	0	ns	0.58	<0.001	0.36	ns	0.26	ns
Surgical procedures	0.04	ns	0	ns	0.38	<0.001	0.34	ns	0.22	ns
Cardiac procedures	0	ns	0	ns	0.33	<0.001	0.22	ns	0.08	ns

ICU = intensive care unit; LOS = length of stay; ns = not significant.

Table 6
Correlation Coefficients Between Median LOS and Census Variables of Cohort Minus Each Hospital

	Hospital									
	Without A		Without B		Without C		Without D		Without E	
	r	p-value	*r*	p-value	*r*	p-value	*r*	p-value	*r*	p-value
ED census	0.13	ns	0.17	ns	0.12	ns	0.14	ns	0.12	ns
ED admits	0.60	<0.001	0.50	<0.001	0.33	<0.001	0.37	<0.001	0.27	0.002
Total hospital census	0.13	ns	–0.1	ns	–0.27	ns	0	ns	0.12	ns
ICU census	0.53	<0.001	0.60	<0.001	0.33	<0.001	0.45	<0.001	0.34	<0.001
Telemetry census	0.64	<0.001	0.45	<0.001	0.65	<0.001	0.66	<0.001	0.60	<0.001
Surgical procedures	0.1	ns	0.14	Ns	0.08	ns	0.06	ns	0.09	ns
Cardiac procedures	0.01	ns	0.07	ns	–0.01	ns	–0.02	ns	–0.02	ns

ICU = intensive care unit; LOS = length of stay.

may have influenced the group analysis, as when it was omitted the *r* values for ED admissions and ICU census were lower, even though they were still statistically significant. Otherwise the data suggest that no single hospital significantly influenced the group analysis.

The regression model for pooled data was evaluated by a plot of the residual data points against the predicted data points from the model. The plot of these points revealed no patterns, and the mean of the residual points was zero, suggesting there was no autocorrelation in the pooled data set. The residual plot is Figure 1. A variance inflationary factor (VIF) was calculated for each variable in the model to explore whether any of the predictor variables may be correlated with each other in a way that interferes with the integrity of the regression analysis. Values of VIF over 5 suggest that alternatives to the least-squares regression approach should be employed.[10] For our data, the VIF for each of the explanatory variables was less than 1.2, suggesting that there was no colinearity and that the integrity of our regression was maintained.

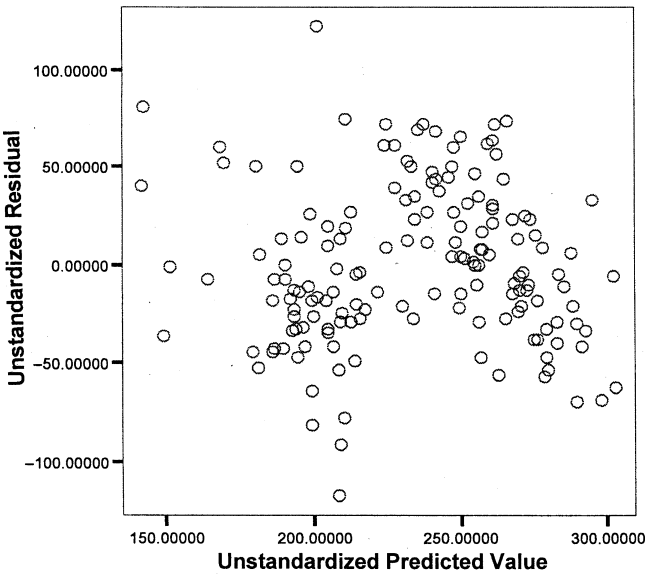

Figure 1. Plot of residual values for regression of pooled data.

DISCUSSION

This study suggests that in a wide variety of hospitals, census variables do have a correlation with LOS of all ED patients. The number of ED admissions is the single variable studied that showed a moderately strong correlation with ED LOS across all hospitals, more often than the total number of ED patients seen each day. Inpatient census affected ED LOS in a variable fashion in the larger hospitals in the cohort. When analyzed as

a group, however, the ICU census and cardiac telemetry unit had significant correlations with ED LOS in our cohort. Thus it appears that longer ED LOS, which contributes to ED crowding, is not simply a volume problem (i.e., too many patients seeking care in the ED). Instead it is a complex problem related to the time it takes to evaluate and treat the sicker patients requiring hospital admission and transitioning them to higher acuity inpatient beds. This finding is likely more true in larger hospitals with busier EDs.

This study did not find an association between total hospital occupancy and ED LOS in the pooled analysis or most of the individual hospitals in our cohort, as has been reported elsewhere.[11–14] Recently Rathlev et al.[13] undertook a similar study of over 90,000 ED visits in 626 study days in a single hospital. They found that every 5% increase in inpatient hospital occupancy was associated with a 4.1-minute increase in ED LOS. Our study may not have had the ability to demonstrate an association with such a relatively small impact on the absolute value of ED LOS. Nevertheless, Rathlev points out that even a small change in ED LOS may be quite relevant when you multiply it by the total number of patients seen each day. Other studies showing this association have been large regional database studies in Canada[11,12] or reports from single hospitals.[8]

Another explanation for lack of correlation between ED LOS and total hospital census is that it may be evident only on very high inpatient census days. Work by others[12,15,16] suggests that the total hospital occupancy rate influences ED LOS when it reaches or exceeds 90%. Average hospital occupancy for our cohort was 86%, and only 23% of study days had inpatient censuses at 90% or greater. Thus, our study likely would not find this association even though we believe that very high hospital census days do impact ED LOS. In a subanalysis of our data, the mean ED LOS was 20 minutes longer on days when the total hospital census was 90% or higher, although this difference did not achieve statistical significance with our sample size ($p = 0.08$).

This study also found no correlation between the number of scheduled surgical and cardiac procedures and ED LOS for the cohort. One reason may be that there was very little variation in the number of scheduled procedures day to day among the hospitals in the cohort, making a statistical correlation very difficult to detect. Our study only measured the number of *scheduled* surgical and cardiac cases because work by others suggests that reducing the variability in the elective surgical schedule may reduce ED LOS.[13] We did not measure the complexity of scheduled surgical or cardiac cases. Future studies examining the impact of surgical procedures on ED crowding should look not only at the number of scheduled cases, but also the number of post procedure patients requiring admission.

Above all else, this study demonstrates that in a variety of hospital settings, it is not just the overall number of ED patients, but the number of ED admissions and the inpatient census of the higher acuity nursing units that correlate with ED LOS. Therefore, the phenomenon of ED crowding is more appropriately referred to as hospital crowding and may be most effectively addressed on the hospital level. Hospitals should implement ways to identify and expedite the care of patients likely to require admission early after their presentation. Specifically, strategies to improve doctor to disposition time and disposition to departure time may be important in reducing ED LOS. A preemptive bed request by the emergency physician prior to the completion of a patient's workup is one effective strategy that can be utilized to reduce the doctor to disposition time.[17] Reducing disposition to departure times (i.e., reducing boarding in the ED) for admitted patients requires that inpatient nursing, housekeeping, and administrative structures must be properly resourced to accommodate these admissions, even in the evening hours when most EDs are at peak volume. In particular, this study suggests that ICU and cardiac telemetry units are high yield areas where resources should be concentrated to accept ED patients in a timely manner, especially in larger and busier hospitals.

LIMITATIONS

Our study looked for associations between certain census variables and ED LOS and was not designed to show causation. ED LOS is affected by many factors not measured in this study. These include patient mix and acuity, nursing and physician staffing, the availability and turnaround times for radiology and laboratory tests, the availability of on call specialists, and the presence and role of trainees, among others. However, the overall r^2 value from our regression model was 0.450, suggesting that almost half of the variability in ED LOS may be explained by the studied census variables. Furthermore, our finding is consistent with other reports suggesting that ED LOS and crowding may be associated with inpatient hospital factors.[11–13,18] One census variable not accounted for in this study was the number of inpatients boarding in the ED. Defining a ''boarder'' as a patient whose LOS extends beyond 2 hours from the decision to admit (the current widely used definition) creates a circular argument if using it as an independent variable in a model with overall LOS as the dependent variable. Because boarders typically have longer LOS, census variables we found to have an association with long LOS are likely also associated with the increased rates of boarding inpatients, although the study was not designed to evaluate this. If boarding time were used as the dependent variable in this study, we would expect the correlations found to be even larger.

Inpatient census rates were expressed with a fixed denominator based on the official number of beds reported by each hospital. It is possible that on certain study days nurse staffing shortages could have effectively reduced the functional capacity of the hospital or of particular units, making the effective census higher than measured. The *functional* capacity and occupancy rate is thus harder to define and, as such, were not measured in this study. Future studies should examine the impact of ED and inpatient staff availability on ED LOS. Furthermore, choosing a variable time period (rather than a specific point in time) for acquiring the total hospital census may affect correlation results between inpatient census and ED LOS.

Although the study included a variety of hospitals and hospital types, it was a fairly small sample relative to the number of EDs in the US. The number of sampled days may have been too small to find modest but important associations between the studied variables and ED LOS. The 24-hour unit of measurement may also have diluted or masked clinically relevant associations that occur during peaks and valleys of the ED and hospital census throughout the day. The overall conclusions of this study may only apply to hospitals with certain characteristics similar to the majority of hospitals in the group. There were some significant differences seen among the hospitals in this study, for example, the correlation between total hospital census and ED LOS (Table 5).

CONCLUSIONS

This study found that across many hospital settings, certain census variables affect ED length of stay. The number of admissions from the ED per day was the most common census variable found to correlate with median ED length of stay. Particularly in larger hospitals, ED length of stay has a moderately strong correlation with the census of the intensive care unit and cardiac telemetry units. ED length of stay was less likely to be related to the daily ED census, daily hospital census, or number of scheduled elective procedures. Future strategies to reduce ED length of stay and ultimately crowding should be aimed at streamlining the admission process of patients from the ED and increasing inpatient capacity to accept these patients in higher acuity nursing units.

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