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Emergency Department Crowding Predicts Admission Length-of-Stay But Not Mortality in a Large Health System

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Abstract

Background—Emergency department (ED) crowding has been identified as a major threat to public health.

Objectives—We assessed patient transit times and ED system crowding measures based on their associations with outcomes.

Research Design—Retrospective cohort study.

Subjects—We accessed electronic health record data on 136,740 adults with a visit to any of 13 health system EDs from January 2008 to December 2010.

Measures—Patient transit times (waiting, evaluation and treatment, boarding) and ED system crowding [nonindex patient length-of-stay (LOS) and boarding, bed occupancy] were determined. Outcomes included individual inpatient mortality and admission LOS. Covariates included demographic characteristics, past comorbidities, severity of illness, arrival time, and admission diagnoses.

Results—No patient transit time or ED system crowding measure predicted increased mortality after control for patient characteristics. Index patient boarding time and lower bed occupancy were associated with admission LOS (based on nonoverlapping 95% CI vs. the median value). As boarding time increased from none to 14 hours, admission LOS increased an additional 6 hours. As mean occupancy decreased below the median (80% occupancy), admission LOS decreased as much as 9 hours.

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Conclusions—Measures indicating crowded ED conditions were not predictive of mortality after case-mix adjustment. The first half-day of boarding added to admission LOS rather than substituted for it. Our findings support the use of boarding time as a measure of ED crowding based on robust prediction of admission LOS. Interpretation of measures based on other patient ED transit times may be limited to the timeliness of care.

Keywords

emergency medicine; ED crowding; length-of-stay; emergency care; inpatient mortality

Emergency department (ED) crowding has become a public health crisis.[1] National and regional measures of ED crowding have demonstrated a steady increase in crowding over the past decade.[2–5] In the United States, 1 ambulance per minute is diverted away from the nearest hospital because of dangerously crowded ED conditions,[6] and 91% of ED directors report that crowding is an important problem at their facility.[7] The American College of Emergency Physicians has identified ED crowding as a critical threat to the quality of emergency care.[8]

Monitoring ED crowding has the potential to help improve the quality of emergency care. For quality measures to be useful, they must be meaningful in themselves or linked to outcomes, it must be feasible to measure them, and they must be actionable. The Centers for Medicare and Medicaid Services (CMS) has begun public reporting of ED length-of-stay (LOS) and boarding time for admitted patients as clinical quality measures of timely and effective care.[9] Although the CMS crowding measures are feasible and seem to be actionable, their link and that of other potential ED crowding measures to health outcomes is not entirely clear.[10–19]

ED crowding is a complex concept and is difficult to measure and validate against outcomes.[20–22] Measures have been based on patient transit time intervals (waiting, evaluation and treatment, boarding) which together equal LOS, volume of patients, and bed occupancy.[21] Theoretically, measuring individual patient's exposure to crowding and outcomes would yield the best estimate of the association between crowding and inpatient outcomes; however, such detailed measurement has rarely been done.[14,18,23,24] Moreover, understandable concerns exist that the relative performance of EDs on transit times, or other measures of crowding, may vary with patient case-mix.[25] The CMS ED measures, for example, are not case-mix adjusted.[26] Studies of ED crowding and inpatient outcomes have not adjusted for prior comorbidities as well as presenting acuity of illness and diagnoses.

In this study, we examine the relationship between the individual patient's experience of ED crowding and the outcomes of inpatient mortality and admission LOS in a large health system. We hypothesized that crowded ED conditions would be associated with increased inpatient mortality and admission LOS. To help inform ED clinical quality measurement, we tested whether crowding measures were robustly associated with outcomes regardless of extensive adjustment for patient characteristics.

METHODS

Study Design and Setting

We conducted a retrospective cohort study of Kaiser Permanente Southern California (KPSC) members who visited a health plan ED from January 1, 2008 to December 31, 2010. This study was approved by the Institutional Review Boards of KPSC and the University of California, Los Angeles.

KPSC is an integrated health system that provides comprehensive care to 3.5 million members at 14 medical centers and 197 offices. All members have very similar health care benefits, including coverage of emergency services within and outside the health system. Members of the health plan are generally representative of the population of Southern California, which is a racially and socioeconomically diverse region. About 7% of members enroll through Medicaid and 10% through Medicare, the government-sponsored health plans for the economically disadvantaged and the elderly, respectively. There were 13 EDs in operation during the study period. None were American College of Surgeons level 1 or 2 trauma centers. The number of staffed ED beds ranged from 12 to 62.

Selection of Subjects

All patients who visited health plan EDs during the study period were included to create measures of ED crowding as described below. Only health plan members were included in analyses of ED crowding and outcomes because of limited data on nonmembers. No minimum enrollment history was required. We restricted analyses to age above 17 years given that rates of events are low in children and care processes may differ. Analyses included only visits resulting in inpatient admission. We excluded patients placed into observation status because they were cared for outside of the ED and are usually (two thirds) discharged rather than admitted. Hospice patients were excluded on the basis that the goal of therapy is palliative and not directed at extending life. Transfers from other hospitals were also excluded as they were initially evaluated elsewhere.

Data Sources

Electronic health record (EHR) data were accessed on all member and nonmember visits to health plan EDs and on member inpatient admissions. Membership and demographic information were obtained from administrative records. Past history of diagnoses as far back as the 1980s was obtained from research data archives. Not every ED was using the EHR at the start of the observation period; the latest start date was May 5, 2009. The EHR system contained time stamps for patient registration, triage, assignment to provider (usually just before seen), disposition order (inpatient admission, observation admission, discharge to home or care facility), and discharge time. The EHR contained <1% missing time stamps with the exception of ED discharge to the ward, which was 4.1% missing. We used the inpatient admission record to determine arrival time to the inpatient ward (regular, monitored, and ICU beds) if discharge time was missing. Arrival from home or another facility was recorded.

Outcomes

The first study outcome was mortality during the inpatient admission following ED evaluation. Health system mortality files used for vital statistics reporting were used to capture inpatient deaths. The second study outcome was inpatient admission LOS, measured from the time of the admission order to the time of hospital discharge or inpatient death. Admission LOS included boarding time while in the ED.[18,19,27] All inpatient admissions had an assignable outcome.

Patient Transit Times and ED System Crowding Measures

All our measures are consistent with the Input-Throughput-Output model of ED crowding and include the individual-level data that is aggregated to create the CMS measures.[22] We determined patient transit times using EHR time stamps as described in Table 1. Patient transit times included the overall LOS and its subdivision into intervals: waiting, evaluation and treatment, and boarding.[20,22,28] A figure describing these points of measurement is available (Fig. A1.1, Supplemental Digital Content 1, http://links.lww.com/MLR/A722, diagram of ED transit times). Patient transit times were hypothesized to demonstrate a U-shaped mortality risk before case-mix adjustment to account for very short transit times in those with severe illness.

We determined 2 types of ED system crowding measures: (1) the transit times of all other, nonindex patients during the index patient's visit, and (2) bed occupancy, defined by the ratio of patients to staffed beds. The ED transit times of nonindex patients were expected to be far less affected by the index patient's condition than the index patient's own transit times. Each of these crowding measures was defined as the mean during the time period of the index patient's ED stay. We also identified system crowding at the moment of registration as this has the advantage of being relatively easily collected for quality reporting purposes.[28] ED system crowding measures were hypothesized to demonstrate increased mortality at values that represented extreme crowding (J-shaped risk) regardless of case-mix adjustment.

There were a small number (< 0.1% of potential subjects) with either missing or clearly erroneous date entries (negative or excessively long ED LOS); these records were dropped. Examination of the remaining potential subjects revealed that <0.1% had ED LOS of >48 hours. Subjects were limited to those with an ED LOS of ≤48 hours to exclude extreme cases.

Demographic and Case-Mix Measurement

We collected data to control for the index patient's characteristics and case-mix. Patient demographic characteristics included age strata (18–39, 40–49, 50–59, 60–69, 70–79, and 80 plus), sex, and race/ethnicity (Asian and Pacific Islander, black, Hispanic, Native American and Alaskan Native, Multiple, other, white, unknown). Preexisting comorbidities were identified from inpatient and outpatient discharge diagnosis codes and organized into the Elixhauser classification system, which includes indicators for 30 chronic conditions for case-mix adjustment.[29] The primary hospital discharge diagnosis or cause of death was categorized using the Clinical Classification Software (CCS) developed by the Agency for

Healthcare Research and Quality.[30] We expanded the 18 multilevel CCS categories into 38 diagnosis categories to account for a variety of acute illnesses deemed relevant to ED care.[31] Ambulance arrival, triage heart rate and blood pressure, and the Emergency Severity Index triage score (ESI, categorized as 1–2 for high acuity, 3, and 4+) were obtained.[32]

Analysis

All eligible patients were included to maximize study power. We compared patient characteristics between decedents and survivors at the first ED visit using the Wilcoxon rank-sum test and the χ^2 test. A similar comparison of patient characteristics was made between the top and bottom quartiles of admission LOS. Patient transit times and ED system crowding measures were compared with outcomes in the same manner. An initial phase of regression analyses were used to identify specific measures for closer scrutiny (see document, Supplemental Digital Content 1, http://links.lww.com/MLR/A722, details on methods and results). During this phase, we explored the hypothesis that transit times and bed occupancy are better predictors of outcomes when both indicate crowding (ie, long transit times, high occupancy). Interactions between bed occupancy and transit times were tested using quintiles of each measure.

In all regression analyses, we determined the association of patient transit times and ED system crowding measures with outcomes across all study sites and years using a baseline regression model that adjusted for site and year using indicator variables. A second model that adjusted for patient characteristics included all demographic, comorbidity, and illness severity covariates; we also included indicators for shift (00:00–8:00, 08:00–16:00, 16:00–00:00), weekend versus weekday, and month at the time of the visit.

Our main analyses used generalized estimating equations, with a correlation structure for repeated visits by individuals, and logistic and linear link functions for the outcomes of inpatient mortality and admission LOS, respectively. Admission LOS was log-transformed to adjust for skew. Our main results are represented graphically to demonstrate the dynamic relationship between patient transit times, ED system crowding measures, and outcomes. Because of nonlinear relationships observed in the data, we modeled each measure using a main effect, square, and cubic terms. Graphs of predicted mortality or admission LOS versus each measure were prepared using the mean values of all covariates. In graphs showing mortality risk, the reference mortality rate was chosen to correspond to the median value of the predictor measure. We present here selected graphs of measures that demonstrated associations with either outcome after adjustment with patient characteristics, as well as the CMS measures. For clarity, these graphs show values up to the 99.9th percentile of the predictor measure.

Graphs of each patient transit time and ED system crowding measure in fully adjusted models are available in Appendices 2 (mortality) and 3 (admission LOS) (see PDFs, Supplemental Digital Content 2, http://links.lww.com/MLR/A723 and Supplemental Digital Content 3, http://links.lww.com/MLR/A724 graphs of all measures). In a sensitivity analysis of mortality, we restricted the attribution of death to within 3 days of admission, and there was no important difference in results (not shown). All data management (S.C.Y.) and analysis (V.Y.C.) were performed with SAS 9.2 (SAS Institute, Cary, NC).

RESULTS

Characteristics of Study Subjects

There were a total of 1,153,688 patients with 2,089,775 ED visits during the study period. After applying study exclusion criteria, the final study cohort included 136,740 subjects with 208,706 visits. The details of study cohort assembly are available online (Fig. A1.2, Supplemental Digital Content 1, http://links.lww.com/MLR/A722 cohort assembly flow chart). The mean (SD) length of subjects' health plan enrollment was 15.7 (13.4) years. Selected characteristics of subjects are shown in Table 2. There were significant differences ($P < 0.001$) in almost all of these characteristics between decedents and survivors, and between the top and bottom quartile of admission LOS.

Main Results

The associations between patient transit times, ED system crowding measures, and outcomes unadjusted for participant characteristics are shown in Table 2. Inpatient mortality was associated ($P < 0.001$) with 2 measures of patient transit time: shorter waiting time and longer boarding time. The top and bottom quartiles of admission LOS (36 and 105 h, respectively) were associated ($P < 0.001$) with an increase in all patient transit times and ED system crowding measures, but the absolute difference was often very small (eg, 0.96 h for ED LOS, 4% for time-averaged bed occupancy). Initial regression tests did not indicate a need for using a combination of occupancy and transit times: interactions between time-averaged bed occupancy and each patient transit time were nonsignificant (all $P > 0.1$).

Inpatient mortality was not associated with patient transit times or ED system crowding measures after adjustment for patient characteristics in regression analyses. The patient-level correlates of the 2 CMS measures are displayed in Figures 1 and 2. Index patient ED LOS was unrelated to inpatient mortality in both unadjusted (Fig. 1A) and adjusted analyses (Fig. 1B). Index patient boarding time was associated with inpatient mortality when unadjusted for patient characteristics (Fig. 2A): mortality risk increased by about 40% as boarding time increased from none to a peak value at about 12 hours. After adjustment for patient characteristics, however, there was no significant trend in mortality across a large range of patient boarding time (Fig. 2B).

Admission LOS was associated with index patient boarding time. Longer index patient boarding time was generally associated with increasing admission LOS, regardless of adjustment for patient characteristics (Fig. 3A). As admission LOS included boarding time, an increase in admission LOS >1 hour for every hour of boarding suggests wasted time, whereas a horizontal movement indicates complete substitution of inpatient time by boarding time. Admission LOS increased about 20 hours as boarding time changed from none to about 14 hours, indicating about 6 hours of added time to admission LOS. After about 14 hours of boarding, there was no substantial change in admission LOS until about 24 hours. After 24 hours, every hour of boarding produced the same increase in admission LOS. Of note, the time-averaged boarding of all nonindex patients was not associated with admission LOS.

Admission LOS varied somewhat with patient evaluation and treatment time, increasing as evaluation and treatment time increased past the median, but then declining afterward (Fig. A1.4, Supplemental Digital Content 1, http://links.lww.com/MLR/A722 admission LOS vs. evaluation time). Although ED LOS was also associated with admission LOS (Fig. A1.5, Supplemental Digital Content 1, http://links.lww.com/MLR/A722 admission LOS vs. ED LOS), the relationship necessarily depended on boarding time and evaluation and treatment time, as waiting time was not predictive of admission LOS. Finally, there was an association between time-averaged bed occupancy and admission LOS, which decreased by about 9 hours from the median (80% occupancy) to the 1st percentile (10% occupancy, Fig. 3B).

DISCUSSION

We observed a wide range of ED crowding among 13 EDs from a large integrated health system but found no association between crowding and subsequent admission mortality. Although it is reassuring that the risk of mortality does not necessarily rise under crowded conditions, we did not assess “near-misses,” morbidity, and the patient’s subjective experience. We did find an association between crowding and admission LOS. As boarding time increased, admission LOS was extended without substitution of boarding for inpatient time until after a long boarding period. Although bed occupancy also predicted admission LOS, it was a somewhat impractical measure as it was predictive only when ED beds were mostly unoccupied. Waiting time was not predictive of outcomes among admitted patients.

We put particular emphasis on the 2 measures of timely and effective ED care that are publicly reported by CMS: LOS (waiting+evaluation and treatment+boarding time) and boarding time. Transit times are potentially useful measures because they represent crowded conditions,[22,28] have face validity, and may guide process of care improvement. We tested the validity of the CMS measures as operationalized at a patient-level to predict individual health outcomes, with and without adjustment for patient characteristics. Boarding time was the more useful of these 2 measures as it is more easily interpreted and predicted admission LOS equally well. If boarding is necessary, then time in boarding ideally would be equivalent to inpatient time. We found that boarding time is most often not exchanged for inpatient time, but rather is added time; thus, there are potentially large cost implications due to boarding. In another study at 1 medical center, hourly pediatric boarding time was also positively associated with admission LOS despite extensive case-mix adjustment.[18] In other studies in which total ED LOS was compared within conditions or diagnosis-related groups, ED LOS was positively associated with inpatient LOS.[24,27] In the 2002 study by Richardson, the curving relationship between ED LOS and inpatient LOS was similar to our results (Fig. 3A).

Bed occupancy was our most direct measure of physical crowding, and the association of uncommonly low occupancy with shorter admission LOS is intriguing. A possible explanation is that additional assessment in the ED when excess capacity exists may reduce admission evaluation or complications and help avoid a longer stay. Hourly occupancy has been positively correlated with left-without-being-seen and ambulance diversion, and has predicted individual-level transit times.[28,33] In contrast to our study, the top quartile of shift

occupancy has been associated with increased mortality in 1 study without adjustment for comorbidity and severity of illness.[13]

Our findings differ from that of some prior studies that reported an association between ED crowding measures and mortality among adults.[12–15,19] Possible explanations for varying results between studies include differences in the measurement of ED crowding, in the extent of casemix adjustment, in mortality measurement, and in study populations and delivery systems. We focus here on studies with individual-level analyses. In these studies, crowding was variably measured as: number of weekly visits,[12] the top quartile of shift occupancy,[13] a scale combining hospital occupancy and the percentage of patients boarding >8 hours,[15] boarding time strata from 2 to >24 hours,[14] and ambulance diversion days (top quartile for facility).[19] The recent study of ambulance diversion in California led by an author of this study (B.C.S.) showed an association between diversion and mortality; however, case-mix adjustment was limited to presenting diagnoses. Mortality has been measured at fixed time intervals (eg, 10 d),[13,15,34–36] in the inpatient setting like our study,[14,16,1918]; or the ED and inpatient setting.[17] The study by Singer et al[14] closely matched ours but was conducted at a single site and did not adjust for prior diagnoses or vital signs upon presentation. Their results on boarding time are similar to our unadjusted analyses (Figs. 2A, 3A). A number of prior studies of ED crowding had limited case-mix adjustment[11–13,15,34] or were conducted at a single site.[12–14,18,35] A study of pediatric patients at 1 site that used extensive case-mix adjustment also found no association between boarding time and mortality.[18] It is possible that different health care organizations and sites variably adapt to chronically crowded conditions to attenuate possible adverse effects. For example, at all study EDs, boarded patients were cared for in the ED area by “inpatient” nurses and hospitalists in conjunction with ED physicians, thus relieving the ED staff of significant responsibility for ongoing care.

There are potential limitations to consider in interpreting these results. First, the health system EDs in our study may not represent the most crowded conditions among the busiest, safety-net hospitals, or in other health systems and regions of the country. Second, we did not measure deaths within the ED because we could not reliably distinguish patients who arrived under resuscitation without chart review and because these deaths may be less reflective of ED care. Third, we did not use ambulance diversion hours as an indicator of crowding because of difficulties obtaining moment-to-moment data for all EDs. The need for ambulance diversion data is mitigated by direct measures of patient transit time and bed occupancy. Diversion can exist independently of other ED crowding measures,[37] and thus may partly depend on factors such as the emergency medical system. Fourth, as our focus was on population outcomes, we did not focus on high-risk conditions (eg, pneumonia). It is possible that crowding has a more robust association with mortality in specific high-risk scenarios, such as reported for acute myocardial infarction,[36] trauma,[16] pneumonia,[35] or critical illness.[23]

Finally, inpatient capacity (eg, available beds, staffing) on the admitting service was not used to adjust for outcomes. It is possible that admission LOS after long boarding may be increased due to persistent inpatient capacity issues. The fact that nonindex patient, time-averaged boarding was not associated with index patient admission LOS suggests that

general inpatient capacity issues were not driving the association between index patient boarding and admission LOS. Mandated nurse-to-patient ratios also help mitigate concerns that inpatient capacity significantly confounds the association between index patient boarding time and admission LOS.

In summary, we found that the first half-day of boarding added to admission LOS rather than substituted for it. Our findings support the use of boarding time as a robust predictor of admission LOS. We also found that patient transit times through the ED and system crowding measures were not associated with inpatient mortality after patient case-mix adjustment. Interpreters of the CMS measures should consider that the key outcome of inpatient mortality may not vary predictably with performance on these measures.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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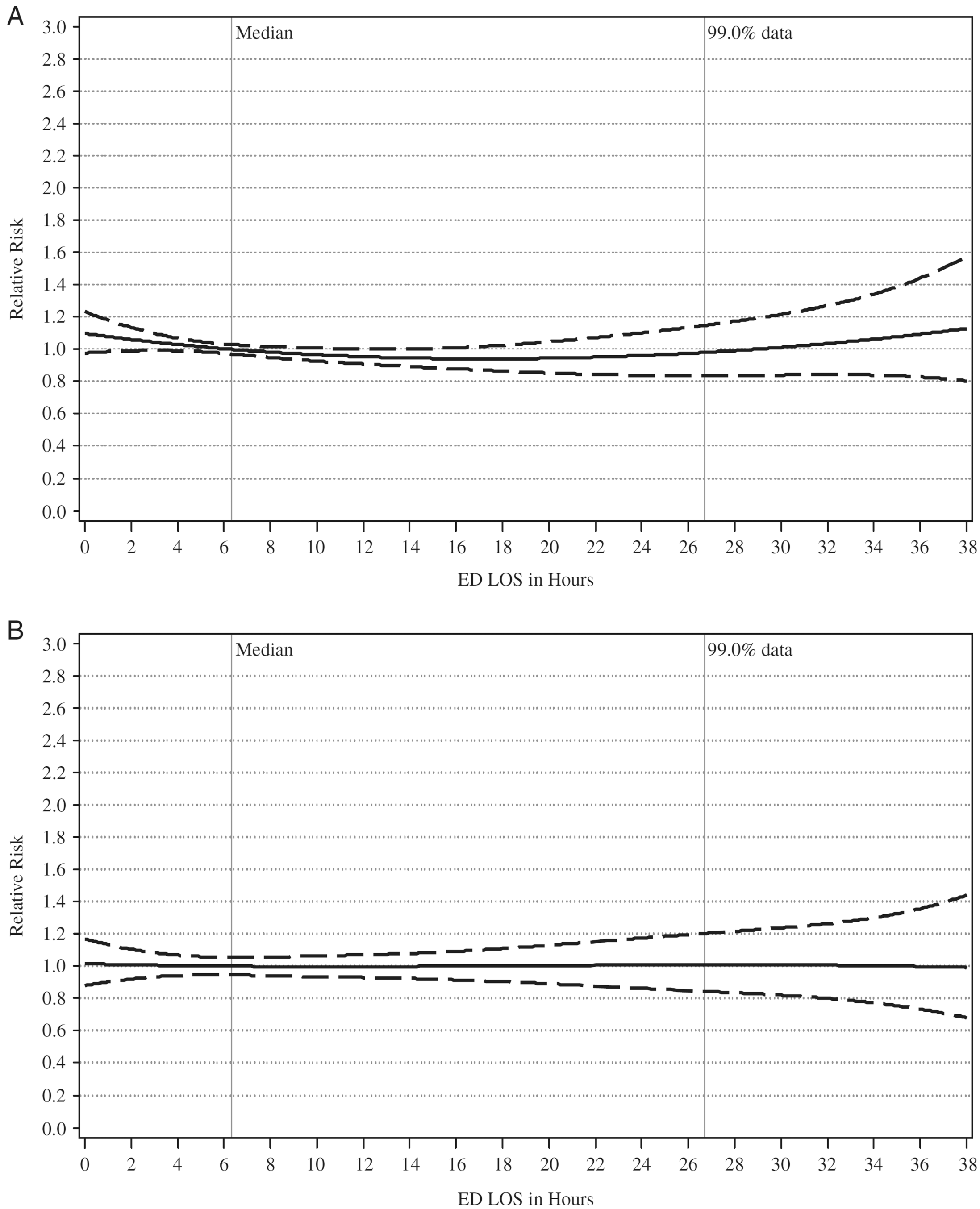

FIGURE 1.

A, ED LOS and inpatient mortality, not adjusted for patient characteristics. B, ED LOS and inpatient mortality, adjusted for patient characteristics. Note that these measures correspond with the Center for Medicare and Medicaid Services (CMS) ED-1b Measure.[9] For clarity, these graphs show up to the 99.9th percentile of LOS (*x*-axis). The *y*-axis denotes the predicted probability at any given hour divided by the predicted probability at the median number of hours. All models were adjusted for ED site of care (a dummy variable for site and year). The model adjusted for patient characteristics included age strata (18–39, 40–49,

50–59, 60–69, 70–79, 80 plus), sex, race/ethnicity, and preexisting comorbidities (Elixhauser category), ambulance versus nonambulance arrival, triage blood pressure and pulse, ESI triage score, preexisting comorbidities (Elixhauser category), primary discharge diagnosis (expanded CCS multilevel categories), shift (12 AM–8 AM, 8AM–4 PM, 4PM–12 AM), weekend versus weekday, and month CCS indicates Clinical Classification Software; ED, emergency department; ESI, Emergency Severity Index; LOS, length-of-stay.

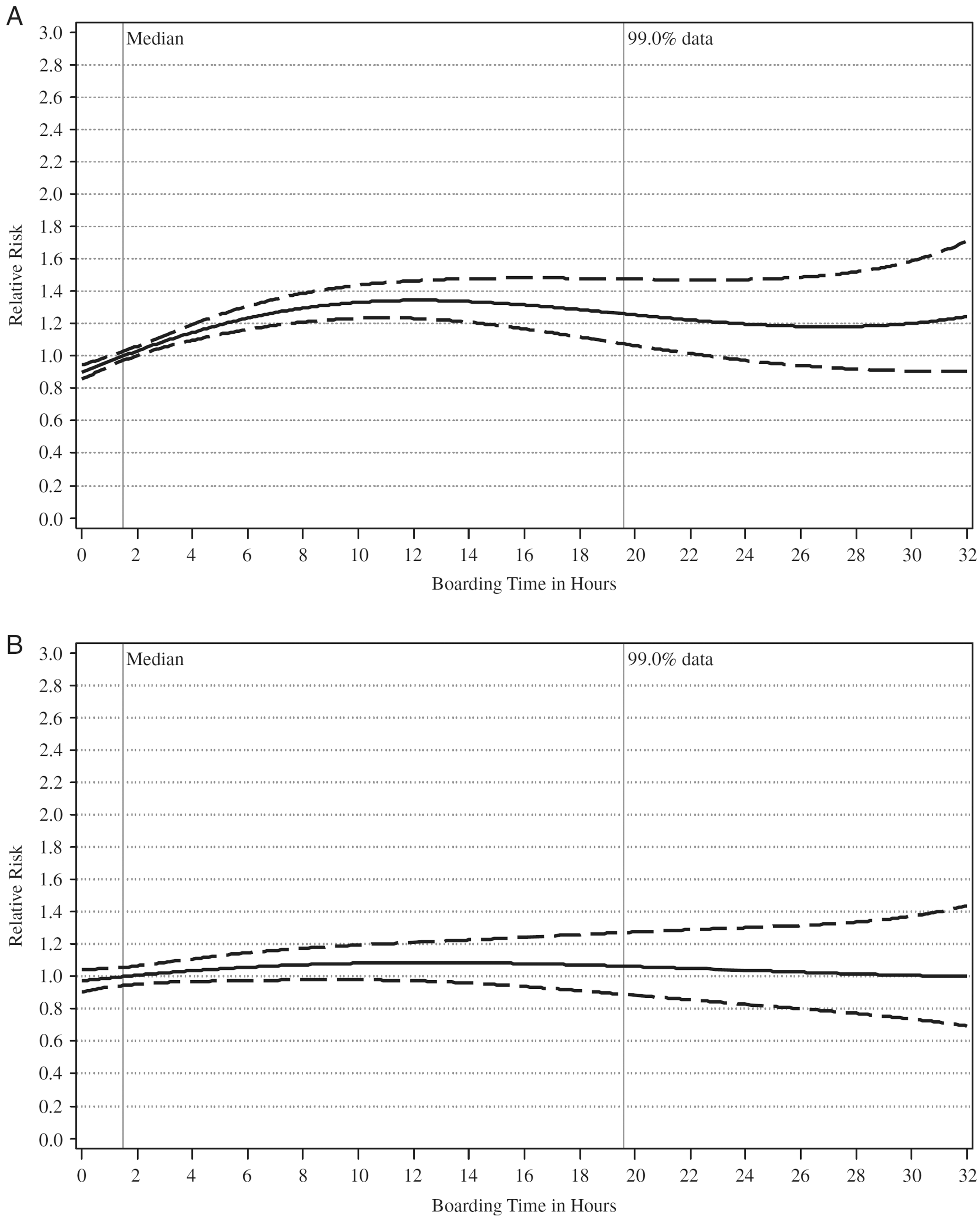

FIGURE 2.

A, Boarding time and inpatient mortality, not adjusted for patient characteristics. B, Boarding time and inpatient mortality, adjusted for patient characteristics. Note that these measures correspond with the Center for Medicare and Medicaid Services (CMS) ED-2b Measure.[9] For clarity, these graphs show up to the 99.9th percentile of boarding time (*x*-axis). The *y*-axis denotes the predicted probability at any given hour divided by the predicted probability at the median number of hours. All models were adjusted for ED site of care (a dummy variable for site and year). The model adjusted for patient characteristics included

age strata (18–39, 40–49, 50–59, 60–69, 70–79, 80 plus), sex, race/ethnicity, and preexisting comorbidities (Elixhauser category), ambulance versus nonambulance arrival, triage blood pressure and pulse, ESI triage score, preexisting comorbidities (Elixhauser category), primary discharge diagnosis (expanded CCS multilevel categories), shift (12 AM–8 AM, 8AM–4 PM, 4PM– 12 AM), weekend versus weekday, and month. CCS indicates Clinical Classification Software; ED, emergency department; ESI, Emergency Severity Index.

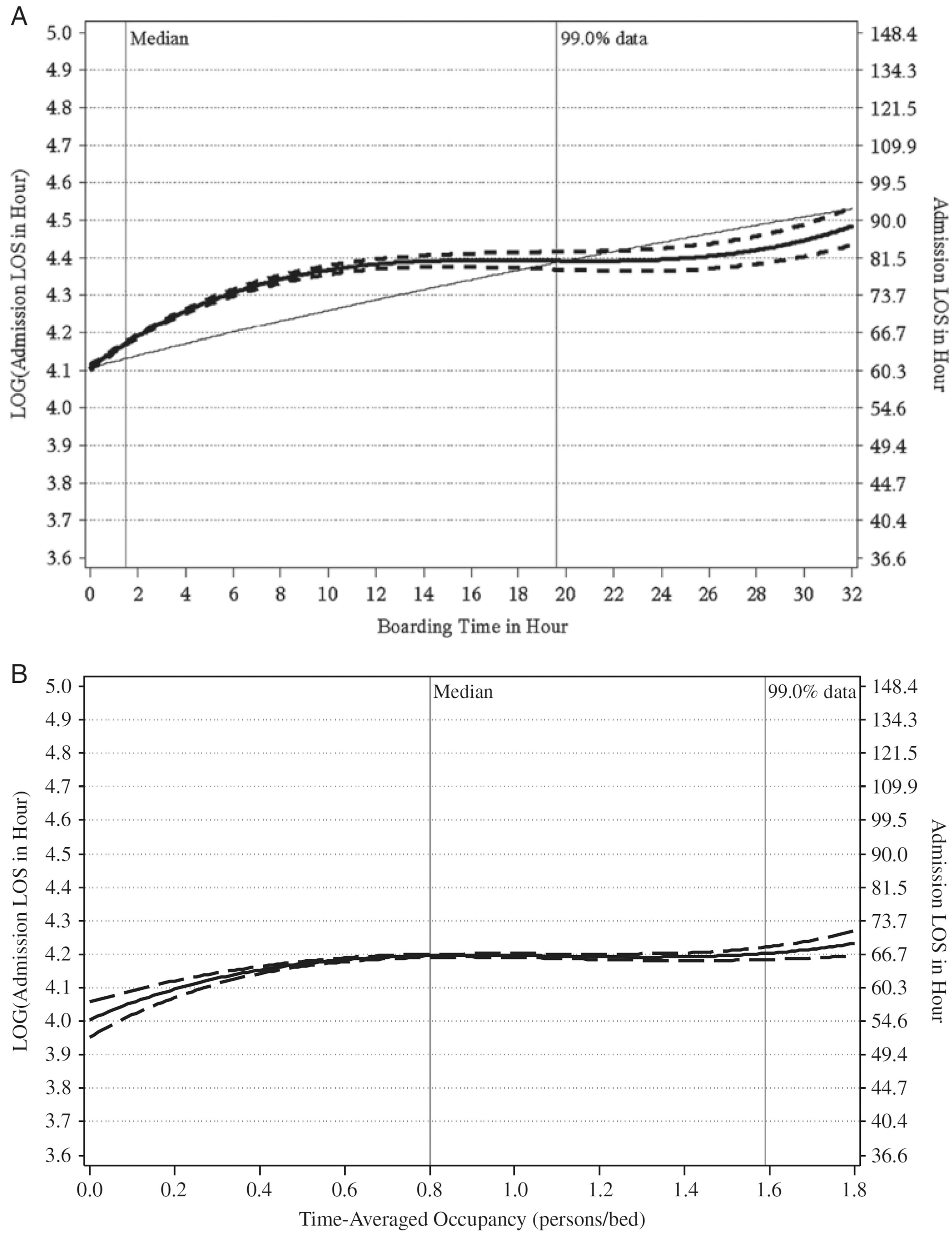

FIGURE 3.

A, Boarding time and admission LOS, adjusted for patient characteristics. B, Time-averaged occupancy and admission LOS, adjusted for patient characteristics. Note that a reference line is used to aid interpretation. As admission LOS included boarding time, an increase in admission LOS >1 hour for every hour of boarding suggests wasted time (when the curve rises above the reference line). Below the reference line, admission LOS increases <1 hour for every hour of boarding. A horizontally moving curve indicates complete substitution of inpatient time by boarding time. Graphs show up to the 99.9th percentile of each predictor

(*x*-axis). The *y*-axis denotes the predicted probability at any given hour divided by the predicted probability at the median number of hours. All models were adjusted for ED site of care (a dummy variable for site and year). The model adjusted for patient characteristics included age strata (18–39, 40–49, 50–59, 60–69, 70–79, 80 plus), sex, race/ethnicity, and preexisting comorbidities (Elixhauser category), ambulance versus nonambulance arrival, triage blood pressure and pulse, ESI triage score, preexisting comorbidities (Elixhauser category), primary discharge diagnosis (expanded CCS multilevel categories), shift (12 AM–8 AM, 8AM–4 PM, 4PM–12 AM), weekend versus weekday, and month. CCS indicates Clinical Classification Software; ED, emergency department; ESI, Emergency Severity Index; LOS, length-of-stay.

TABLE 1

Patient Transit Times and Measures of ED System Crowding

Measures	Definition
Patient transit times	
Waiting time	Time (hours) from check-in until seen by the first treating physician for the index patient
Evaluation and treatment time	Time (hours) from first physician assignment until the order to discharge or admit for the index patient
Boarding time	The time period (hours) after the order to admit until the index patient left the ED or arrived at the inpatient ward
ED LOS	The LOS (hours) in the ED of the index patient as defined by registration time until the patient left the ED or arrived at the inpatient ward
ED system crowding*	
Occupancy at entry	The number of patients under evaluation in the ED at the time of the index patient's registration
	Operationalized as (a) patients per staffed ED bed, and (b) within-ED percentile score for number of patients†
Time-averaged occupancy‡	The mean number of other patients occupying beds in the ED during the index patient's visit
	Operationalized as (a) persons per staffed ED bed, and (b) within-ED percentile corresponding to the number of patients
ED LOS at entry§	The mean LOS (hours) for other patients undergoing evaluation and treatment up to the moment of the index patient's registration
Time-averaged ED LOS‡	The mean LOS (hours) for other patients under evaluation during the index patient's visit
Boarding time at entry	The mean boarding time (hours) for other patients up to the moment of the index patient's registration
Time-averaged boarding time‡	The mean boarding time (hours) for other patients under evaluation during the index patient's visit

The Center for Medicare and Medicaid Services (CMS) measures include[9]: (a) CMS ED-1b: median time (in minutes) from ED arrival to ED departure for patients admitted to the facility from the ED, which is also known as LOS; and (b) CMS ED-2b: median time (in minutes) from admit decision time to time of departure from the ED for patients admitted to the facility, which is also known as boarding time.

*Includes all patients except the index patient.

†On the basis of distribution of the numbers of patients under evaluation at the moment of check-in within each ED site and for the entire time period of the study.

‡Time-average numbers were prepared by taking the mean across 5-minute intervals during the index patient's stay of: (a) the number of other patients per beds at that point in time, (b) the LOS of other patients to that point in time, or (c) the boarding time of other patients to that point in time.

§LOS was defined for nonindex patients by the registration time stamp until (a) discharge, or (b) observation room arrival, or (c) inpatient ward arrival.

ED indicates emergency department; LOS, length-of-stay.

TABLE 2

Participant Characteristics, Transit Times, Measures of ED System Crowding, and Their Association With Outcomes Based on the First Visit

Characteristics and Measures	Total Cohort (N=136,740)	Inpatient Mortality: Decedents (n=2784)	Inpatient Mortality: Survivors (n=133,956)	Inpatient Mortality: *P*[*]	Admission LOS: 1st Quartile (36 h)	Admission LOS: 4th Quartile (105 h)	Admission LOS: *P*
Patient characteristics							
Age, mean (SD) (y)	61.5 (18.4)	73.8 (14.6)	61.2 (18.4)	< 0.0001	56.8 (18.6)	65.0 (17.5)	< 0.0001
Male (%)	47.0	50.2	46.9	0.0005	48.0	47.2	0.0394
Race (%)				< 0.0001			< 0.0001
White	47.7	58.1	47.5		43.2	52.1	
Black	13.9	15.3	13.8		12.4	15.0	
Hispanic	29.1	18.7	29.3		33.2	24.7	
Asian	8.0	7.1	8.0		9.3	7.1	
Other/multiple	1.1	0.7	1.1		1.5	0.9	
Unknown	0.2	0.2	0.2		0.3	0.2	
Ambulance arrival (%)	23.5	47.3	23.0	< 0.0001	17.8	30.4	< 0.0001
Systolic blood pressure, mean (SD) (mm Hg)	136.2 (26.1)	124.6 (30.7)	136.4 (25.9)	< 0.0001	138.3 (25.1)	133.7 (27.2)	< 0.0001
Heart rate, mean (SD) (#/min)	88.3 (21.7)	95.9 (25.2)	88.2 (21.6)	< 0.0001	84.6 (20.6)	91.8 (22.2)	< 0.0001
Triage (ESI) score (%)				< 0.0001			< 0.0001
1–2	8.6	25.4	8.2		7.6	10.7	
3	85.3	71.8	85.6		86.2	83.4	
4+	5.7	1.9	5.8		5.9	5.3	
Missing	0.4	0.9	0.4		0.3	0.5	
Inpatient hospital days (%) (d)				< 0.0001			
< 1	40.1	24.3	40.4		N/A	N/A	
2	19.3	10.1	19.5		N/A	N/A	
3+	40.6	65.6	40.1		N/A	N/A	
Shift, time of day (%)				< 0.0001			< 0.0001
00:00–07:59	14.4	14.1	14.4		18.7	12.8	
08:00–15:59	45.9	51.4	45.7		41.6	47.0	
16:00–23:59	39.8	34.5	39.9		39.7	40.2	

Characteristics and Measures	Total Cohort (N=136,740)	Inpatient Mortality: Decedents (n=2784)	Inpatient Mortality: Survivors (n=133,956)	Inpatient Mortality: *P*[*]	Admission LOS: 1st Quartile (36 h)	Admission LOS: 4th Quartile (105 h)	Admission LOS: *P*
Day (%)				0.6886			0.3267
Weekday	74.6	74.3	74.7		76.0	75.7	
Weekend	25.4	25.7	25.3		24.0	24.3	
Patient transit times							
Waiting time, mean (SD) (h)	0.56 (0.67)	0.46 (0.53)	0.56 (0.67)	< 0.0001	0.56 (0.66)	0.55 (0.69)	< 0.0001
Evaluation and treatment time, mean (SD) (h)	4.32 (2.67)	4.25 (2.38)	4.32 (2.68)	0.6476	4.24 (2.84)	4.46 (2.61)	< 0.0001
Boarding time, mean (SD) (h)	2.53 (3.55)	2.76 (3.74)	2.53 (3.54)	< 0.0001	2.13 (2.78)	2.86 (4.01)	< 0.0001
ED LOS, mean (SD) (h)	7.34 (4.59)	7.38 (4.58)	7.34 (4.59)	0.2990	6.85 (4.12)	7.81 (4.92)	< 0.0001
ED system crowding							
Occupancy at entry, persons/bed [mean (SD)]	0.79 (0.33)	0.78 (0.33)	0.79 (0.33)	0.0953	0.77 (0.33)	0.80 (0.33)	< 0.0001
Time-averaged occupancy, persons/bed [mean (SD)]	0.83 (0.29)	0.84 (0.30)	0.83 (0.29)	0.2510	0.80 (0.29)	0.84 (0.30)	< 0.0001
Boarding time at entry, mean (SD) (h)	2.18 (3.05)	2.18 (3.13)	2.18 (3.05)	0.2772	2.14 (3.02)	2.29 (3.13)	< 0.0001
Time-averaged ED boarding time, mean (SD) (h)	2.09 (2.52)	2.07 (2.52)	2.09 (2.53)	0.5875	2.06 (2.57)	2.19 (2.56)	< 0.0001
ED LOS at entry, mean (SD) (h)	3.09 (1.26)	3.13 (1.26)	3.09 (1.26)	0.1288	3.09 (1.27)	3.14 (1.27)	< 0.0001
Time-averaged ED LOS, mean (SD) (h)	3.17 (1.12)	3.17 (1.07)	3.17 (1.12)	0.1333	3.18 (1.16)	3.22 (1.12)	< 0.0001

[*] The Wilcoxon rank-sum test or the χ^2 statistic.

ESI indicates Emergency Severity Index Score.