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Emergency Department Crowding and Outcomes After Emergency Department Discharge

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Abstract

Study objective—We assess whether a panel of emergency department (ED) crowding measures, including 2 reported by the Centers for Medicare & Medicaid Services (CMS), is associated with inpatient admission and death within 7 days of ED discharge.

Methods—We conducted a retrospective cohort study of ED discharges, using data from an integrated health system for 2008 to 2010. We assessed patient transit-level (n=3) and ED system-level (n=6) measures of crowding, using multivariable logistic regression models. The outcome measures were inpatient admission or death within 7 days of ED discharge. We defined a clinically important association by assessing the relative risk ratio and 95% confidence interval (CI) difference and also compared risks at the 99th percentile and median value of each measure.

Results—The study cohort contained a total of 625,096 visits to 12 EDs. There were 16,957 (2.7%) admissions and 328 (0.05%) deaths within 7 days. Only 2 measures, both of which were patient transit measures, were associated with the outcome. Compared with a median evaluation time of 2.2 hours, the evaluation time of 10.8 hours (99th percentile) was associated with a relative risk of 3.9 (95% CI 3.7 to 4.1) of an admission. Compared with a median ED length of stay (a CMS measure) of 2.8 hours, the 99th percentile ED length of stay of 11.6 hours was associated with a relative risk of 3.5 (95% CI 3.3 to 3.7) of admission. No system measure of ED crowding was associated with outcomes.

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Author contributions: GZG, SFD, and BCS conceived the study and designed the analysis. BCS obtained research funding. JPJ linked the data. VYC and SCY managed the data, conducted the analyses, and provided statistical advice. CAS aided in study design and oversight. GZG drafted the article, and all authors contributed substantially to its revision. BCS takes responsibility for the paper as a whole.

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Conclusion—Our findings suggest that ED length of stay is a proxy for unmeasured differences in case mix and challenge the validity of the CMS metric as a safety measure for discharged patients.

INTRODUCTION

Background and Importance

The Institute of Medicine and the American College of Emergency Physicians have identified emergency department (ED) crowding as a critical threat to the quality of emergency care.¹ ED crowding adversely affects clinical outcomes and is associated with poor patient satisfaction and clinical care experience.^{2,3} Since January 2014, the Centers for Medicare & Medicaid Services (CMS) has mandated the collection and public reporting of ED crowding measures for both admitted and discharged patients as quality-of-care markers. For discharged patients, this includes waiting time and length of stay.⁴

Although several studies suggest that ED crowding leads to greater mortality and worse patient outcomes in hospitalized patients,⁵⁻⁸ its effect on discharged patients is less clear. Given that more than 85% of patients who visit an ED in the United States are discharged,⁹ even small effects of ED crowding on patient safety may have large aggregate effects. A single Canadian study reported an association between the average ED length of stay for a given shift and increased short-term deaths and unscheduled hospital admissions for discharged patients.¹⁰ However, these findings have not been replicated in US health care settings and are limited by the use of single measures of ED crowding. Because of CMS pay-for-reporting requirements and public reporting of ED timeliness measures, assessing the link with outcomes has important policy implications.

Goals of This Investigation

Using data from a large integrated health system, we assessed the relationship between multiple measures of ED crowding and their association with 7-day admissions and deaths after discharge. We evaluated 9 measures of ED crowding, including those that correspond to the CMS ED throughput measures of waiting time and length of stay.⁴ We hypothesized that both patient transit and ED system measures would be associated with higher rates of postdischarge hospitalizations and death. Possible causal pathways for this hypothesis include delays in diagnosis and treatment, missed diagnoses because of cognitive overload, and pressure to decompress the ED, leading to premature discharge.

MATERIALS AND METHODS

Study Design and Setting

We conducted a multisite retrospective cohort study of ED visits. This study was approved by the institutional review boards of Kaiser Permanente Southern California and the University of California, Los Angeles.

We analyzed administrative data of Kaiser Permanente Southern California, an integrated health system that provides comprehensive care to 3.5 million members at 14 medical centers and 197 offices throughout Southern California. There were 13 health system EDs in

operation during the study period. All members have similar health care benefits, including coverage of emergency services both 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. Approximately 7% of members enroll through Medicaid and 10% through Medicare.

All members are assigned a unique health number that can be used for data linkage. All study medical centers had training programs for residents but none had emergency medicine residency programs. None of the study EDs were American College of Surgeons Level I or Level II trauma centers. The number of staffed ED beds ranged from 12 to 62.

Selection of Participants

Study subjects were members of Kaiser Permanente Southern California, with at least 1 ED visit and discharge from January 1, 2008, to December 31, 2010. A subject had to be a member of the health plan at the ED visit; however, no minimum enrollment history was required. We restricted analyses to adults (>18 years), given that rates of events are low in children and care processes differ. All subjects were discharged from the ED to home or a non-acute care facility such as a nursing home or rehabilitation facility. Transfers to observation status from the ED were also excluded. We excluded patients receiving hospice care because the goal of this care is to provide palliative services rather than prolong life. Patients who were transferred to and from other hospitals were also excluded. If a patient had multiple ED visits during the study period, then we selected the first ED visit to analyze for this study.

Patients who left without being seen by a health care provider were excluded. The small number (<0.1%) of records that had potentially erroneous day and time entries resulting in either negative or excessively long ED lengths of stay (>48 hours) were dropped from the analysis.

Data Collection and Processing

The complete electronic health record (termed HealthConnect) contained records of all member visits to health plan EDs during the study period. This system contains history, mode of arrival, vital signs, staff notes, orders, diagnoses, and test results. Standardized data fields from ED visits provided time stamps for patient registration, triage, assignment to provider, and disposition order (discharge to home or a care facility). HealthConnect was also used to identify the *International Classification of Diseases*, ninth revision, diagnoses and Current Procedural Terminology codes associated with the ED visit.

Outcome Measures

The primary outcome was an inpatient admission within 7 days of discharge from the ED. The admission could be to either to a Kaiser Permanente Southern California or non-Kaiser Permanente Southern California hospital bed. Observation stays were excluded from the outcome. We focus on inpatient admissions because the coding of "observation" was inconsistent during the study period. Hospital case managers also use objective, proprietary

criteria to identify patients who meet inpatient versus observation criteria, implying that the 2 categories are qualitatively different.

We chose the 7-day follow-up period as the primary time frame for several reasons. Admission within a week is more likely to be a consequence of the index ED visit than more distant periods, and preliminary analyses suggested sufficient time for accumulating outcomes. Moreover, 1 week is a reasonable period for arranging follow-up care and has clinical relevance and implications for health policy decisions, and has been used in previous studies.¹⁰⁻¹² Although the frequency of death after discharge was spread more equally within 1 month after discharge, we chose the 7-day time frame to capture death for consistency. In sensitivity analyses, we also evaluated the outcomes of admission and death at 30 days after ED discharge.

Information about admissions after discharge was obtained through billing data. The secondary outcome was death within 7 days of ED discharge. Mortality data were linked to the patient records with the California Vital Statistics files for in-state death and the Social Security Death Index for out-of-state deaths. For the final week of 2010, the 7-day follow-up period included the first week of 2011.

There is currently no single, consensus measure of ED crowding.¹³ We created and assessed a panel of 9 crowding measures at the patient transit level (3) and ED system level (6) according to the input-throughput-output model of ED crowding.¹⁴ These measures represent an individual patient's experience (patient transit level) and surrounding exposure (ED system level) to crowding while in the ED. All measures were derived with electronic time stamps.

Patient transit-level measures were straightforward to measure and included the patient's overall or total length of stay and its subdivision of waiting time and evaluation time.^{14,15} Two of these measures correspond to the CMS measures of ED throughput: waiting time (corresponds to OP-20, door to diagnostic evaluation by a qualified medical professional) and median length of stay (corresponds to OP-18b, median time from ED arrival to ED departure for discharged ED patients).⁴

The ED system-level measures were created with a composite of individual-level data on all patients in the ED, excluding the index patient. Because these measures evaluated the ED environment during the index patient's visit, they were obtained when the index patient checked in to the ED (termed "at entry") and during their entire ED stay (termed "time averaged"), which describe the mean time of the crowding measure during the index patient's entire evaluation. These measures avoid direct confounding by index patient-level characteristics and included occupancy, length of stay, and boarding time. To calculate the occupancy rates, we divided the number of patients in the ED at a given time by the number of staffed beds at a given site. For example, "boarding time at entry" describes the boarding time of all patients in the ED when the index patient checks in to the ED, whereas "time averaged boarding time" describes the mean boarding time of all patients who are boarding during the duration of the index patient's ED stay. Figure 1 describes the measures.

We adjusted for the demographic variables of age, sex, and race or ethnicity. We identified 30 preexisting comorbidities from inpatient and outpatient discharge diagnosis codes for health encounters before the ED visit and organized comorbidities with the Elixhauser classification system.¹⁶ ED primary discharge diagnoses were classified into 39 categories with the Clinical Classification Software developed by the Agency for Healthcare Research and Quality. We have previously described the rationale and development of this classification system.¹¹ We also adjusted for mode of arrival, ED triage vital signs (pulse rate, blood pressure), weekend versus weekday visit, shift of visit (midnight to 8 AM, 8 AM to 4 PM, and 4 PM to midnight), month of the visit, and the Emergency Severity Index score (categorized as 1 to 2, 3, and 4)¹⁷ in the analysis. The Emergency Severity Index triage category 1 to 5 classifies illness severity, with 1 indicating the most acutely ill patients. Because different medical centers started using electronic data at different times, we also adjusted for medical center and year, as well as the interaction term between medical center and year.

Primary Data Analysis

We estimated the incidence and descriptive statistics of admissions and mortality within 7 days of discharge from the ED. We compared patient characteristics with the Wilcoxon's rank sum test and χ^2 test, with significant testing at $P < .05$.

To determine the relationship between a crowding measure and either 7-day admission or death, we used separate logistic regression models for each crowding measure, controlling for all described covariates. In all analyses, the first ED visit was used. We first examined scatter plots and analyzed the data in quintiles and found that some variables had a curving relationship to outcomes. Because of the observed nonlinear relationships in the data and large numbers of subjects, we chose to model the association of each ED crowding measure with outcomes, using a main effect, square, and cubic terms. The main effect incorporates a linear relationship; the square term, a U-shaped relationship; and the cubic, an S-shaped relationship. All 3 terms were included in the same model. For example, to assess the association between the patient transit-level measure of waiting time and outcomes, we modeled the main term, its square, and its cubic form, as well as all described covariates in a single model.

The interpretation of model coefficients is not straightforward because of nonlinearity. To illustrate our findings intuitively, we generated polynomial graphs of admissions and mortality risks for all the crowding measures. Predicted probabilities of each outcome were calculated from regression models with the mean values of all covariates. The ratio of the predicted probability of the outcome for a given value of an ED crowding measure versus the predicted probability at the median value of the crowding measure was then graphed. This ratio is an estimate of the relative risk for the “average” subject. The graphs plot relative risks for all observed values of the crowding measures. We included vertical lines to show the median (with relative risk indexed to equal 1) and the 99th percentile value of each crowding measure. Our threshold for a clinically relevant association was a relative risk ratio that was significantly different from 1 (ie, 95% confidence interval [CI] did not contain 1). We chose this threshold because 95% CIs were relatively narrow at the 99th percentile value

of ED measures. We also believed that using the 99th percentile value would maximize sensitivity for detecting associations (ie, “low threshold” for defining ED crowding). All data management and analysis were performed with SAS (version 9.3; SAS Institute, Inc., Cary, NC).

Our primary focus was to evaluate the effect of a crowding measure, such as evaluation time, on the outcome of inpatient admission within 7 days of ED discharge. There are approximately 5 per 10,000 admissions per discharge. Our current data show a moderate association between the variable of interest and other covariates ($R^2=0.25$). Our post hoc power analysis indicates that the minimum relative risk we may detect is 1.20 with 80% power, comparing 1 SD away from the mean value of the predictor value versus the mean value of the predictor value. In other words, if the relative risk between the SD from the mean and the mean of evaluation time is at least 1.20, we can have 80% power to detect such difference. For our 7-day mortality analysis, our estimate of the relative risk was 1.30.

RESULTS

Characteristics of Study Subjects

The final study cohort contained 625,096 health plan members who were discharged from a Kaiser Permanente Southern California ED between January 1, 2008, and December 31, 2010 (Figure 2). The rate of an admission and death within 7 days of ED discharge was 2.7% and 0.05%, respectively. All patient characteristics differed among patients with and without the outcome (Table 1). We found patients especially at risk for admission to be older, to be white, to be men, to arrive by ambulance, and to present with an Emergency Severity Index score of 1 to 3. We found similar differences among survivors and decedents.

Table E1 (available online at <http://www.annemergmed.com>) describes the unadjusted associations for each of the 9 crowding measures. Tables E2 and E3 (available online at <http://www.annemergmed.com>) describe the median and interquartile ranges of the crowding measures. In Table E4 (available online at <http://www.annemergmed.com>), we describe the coefficients and CIs of each crowding measure modeled in its main effect, squared, and cubic terms.

Main Results

Figure 3A to 3I shows polynomial function graphs of the crowding measures. The first 3 graphs (Figure 3A, B, and C) depict the measures that were either significantly associated with the outcome or were reported by CMS.⁴ The only 2 measures associated with a short-term admission after discharge were the patient transit-level measure of evaluation time (Figure 3A) and total length of stay (Figure 3C). Compared with a median evaluation time of 2.2 hours, the 99th percentile evaluation time of 10.8 hours was associated with a relative risk of 3.9 (95% CI 3.7 to 4.1) of being admitted. Compared with a median ED length of stay of 2.8 hours, the 99th percentile ED length of stay of 11.6 hours was associated with a relative risk of 3.5 (95% CI 3.3 to 3.7) of being admitted. None of the other ED crowding measures had a significant relative risk ratio at the 95th percentile value compared with the median value.

These findings are robust to sensitivity analyses. There was no difference in findings when we used 30-day rather than 7-day outcomes (Table E5, available online at <http://www.annemergmed.com>). We found similar results when we repeated the analyses by assessing the relationship between outcomes and quintile values of ED measures (Table E6, available online at <http://www.annemergmed.com>).

LIMITATIONS

Strengths of our study include large sample size, multiple hospitals, and detailed information on outcomes, ED crowding measures, and potential confounding variables. These features strengthen the internal validity of our findings. However, there may be potential limitations.

First, our results may not generalize to other settings. Our study hospitals are likely to be different from safety net hospitals that may be most vulnerable to the effects of crowding.¹⁸ Kaiser Permanente Southern California members have access to follow-up care that patients in other settings may lack, which may be why we did not observe an association between a number of the crowding measures and either an admission or death shortly after discharge. However, our study demonstrates that it may be possible to mitigate the previously reported associations between ED crowding and outcomes in specific health systems. Furthermore, our findings are directly applicable to integrated care systems, which represent a major share of health markets on the US West Coast.

Second, our admission outcome did not include observation stays because of concerns about coding reliability. Given the increasing use of observation services, however, future studies should consider incorporating them into admission outcomes.

Third, there were relatively few deaths after ED discharge, and we may have lacked statistical power to identify clinically relevant associations between ED crowding measures and mortality.

Fourth, one limitation was inherent to the type of study performed and the lack of available administrative information on the chief complaint and extent of management or treatment performed. Also, we do not know why patients were admitted after discharge from the ED. It is probable that the patients who had the longest length of stay during their ED visit had all possible testing conducted to prevent an admission, yet it is also possible they were admitted on returning because there were no additional tests to obtain.

DISCUSSION

In this integrated health system, we found patients at greatest risk of a 7-day admission after discharge to have an extended total length of stay (time from triage to discharge) and evaluation time (time under evaluation by a physician). Contrary to our initial hypothesis, we did not find any of the ED system-level measures of crowding to be associated with either an admission or death within 7 days of ED discharge.

Because we found no association between ED system-level measures of crowding and outcomes, unmeasured case mix and more complex presentations are likely to explain the

relationship between evaluation time and admission within 7 days of discharge. For example, a diagnosis such as chest pain can result in various degrees of concern and diagnostic evaluation regardless of the patient's medical history. As a result, patients with complex care needs are likely to have an extensive ED evaluation, longer lengths of stay, and a greater likelihood of requiring an admission shortly after discharge.

Our findings are consistent with those of Pines et al,¹⁹ who found when analyzing 2008 to 2009 National Hospital Ambulatory Medical Care Survey data that case mix was associated with increased waiting times and lengths of the visit. Similarly, Pitts et al²⁰ reviewed 2001 to 2008 survey data and found that factors most strongly associated with increasing levels of ED occupancy were measures of increased patient management intensity, such as use of laboratory and imaging studies.

To our knowledge, there have been no large-scale US studies evaluating the association between ED crowding and outcomes after a discharge home from the ED. The study conducted by Guttman et al¹⁰ found an association between length of stay and waiting time and outcomes after discharge in Ontario, Canada. Our study found no association between any of the ED system crowding variables and mortality, and we also found no association between waiting time and outcomes after discharge. One potential explanation of our different findings could be the different health systems and populations. Another explanation is the differences in case-mix adjustment between the studies. In our preliminary analyses in models that used minimal covariates (age and sex) and no patient transit-level comorbidities or severity of illness covariates, the risk of admission and death was increased; however, these associations were largely attenuated after case-mix adjustment.

CMS has reported an aggregated annual patient transit-level measure of ED length of stay and waiting time per facility since early 2014.⁴ Our results suggest that the length-of-stay measure is sensitive to unmeasured confounding and disease severity and that waiting time is not associated with outcomes. These findings challenge the validity of the CMS measures as patient safety indicators. Although our study focused on patient safety measures in discharged patients, ED crowding may affect other patient-oriented outcomes such as timeliness of care and patient satisfaction.

In recent years, ED crowding has become a national crisis resulting in reduced patient satisfaction, poor clinical care experience, and increased patient morbidity for specific conditions.^{2,3,5,6,8,21-25} Our study found that in the Kaiser Permanente Southern California health system, ED crowding measures were not associated with admission or death shortly after discharge. Kaiser Permanente Southern California does not have standardized ED crowding measures or a regional protocol about how to address crowded ED conditions. All interventions to address crowding are handled at the individual hospital level and vary within each department. Our study findings suggest that this integrated health system, possibly at the individual hospital level, has potentially found ways to manage and discharge ED patients so the patients do not experience admission or death after ED discharge. This could be because patients of the integrated health system have access to outpatient clinics, case management, and other health service resources that may not be readily available in other settings.

In summary, in this integrated health system, no ED system-level measures were significantly associated with an admission or death after discharge. Our findings suggest that ED length of stay is a proxy for unmeasured case mix or illness severity and challenge the validity of the CMS metrics as safety metrics in discharged patients.

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Editor's Capsule Summary**What is already known on this topic**

Regulatory bodies use emergency department (ED) crowding measures as a quality measure.

What question this study addressed

Are ED crowding factors or patient care intervals related to hospital admission or death within 7 days of discharge?

What this study adds to our knowledge

In a cohort of 625,096 discharged ED patients within a mature, integrated health care system in 1 California region, prolonged times to evaluate and to discharge patients linked to 7-day admission or death. No ED crowding measure linked to these outcomes.

How this is relevant to clinical practice

In this system, ED crowding metrics did not correlate with bad outcomes for discharged patients.

Crowding Measure	Definition
Patient transit level	
Waiting time	Time (hours) from check-in until seen by the first treating physician for the index patient.
Evaluation time	Time (hours) from first physician assignment until the order to discharge or admit for the index patient.
Total LOS	The LOS (hours) in the ED of the index patient as defined by registration time until the patient left the ED.
ED system level	
Occupancy at entry*	The number of patients under evaluation in the ED at the index patient's registration. Operationalized as (1) persons per staffed ED bed, and (2) within-ED percentile score for number of patients.
Time-averaged occupancy [†]	The number of other patients occupying beds in the ED during the index patient's visit. Operationalized as (1) persons per staffed ED bed, and (2) within-ED percentile corresponding to the number of patients.
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 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. Boarding time is defined as the interval between an order to admit was placed to the time a patient left the ED or arrived at the inpatient ward.
Time-averaged boarding time [†]	The mean boarding time (hours) for other patients under evaluation during the index patient's visit.
<i>LOS, Length of stay.</i>	
*Based on distribution of the numbers of patients under evaluation at the moment of check-in within each ED site and for the entire period of the study.	
[†] Based on the average measure of all patients except the index patient during the index patient's ED visit within each ED site and for the entire period of the study.	

Figure 1.
Measures of ED crowding.

Figure 2.
Study cohort. *KPSC*, Kaiser Permanente South California.

Figure 3.

A-I, Logistic regression assessing the association between crowding measures and 7-day admission after ED discharge. Relative risks of the odds of admission was calculated according to the odds ratio divided by the median odds ratio. Each graph is a representation of a model that adjusts for age, sex, race or ethnicity, ambulance versus nonambulance arrival, triage blood pressure and pulse, ESI triage score, preexisting comorbidities, primary

discharge diagnosis, shift, weekend versus weekday, month, medical center, year, and interaction between medical center and year. The dotted line depicts the 95% CI.

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Table 1

Characteristics of cohort with 7-day admissions or death after ED discharge.

Patient Characteristics	Total Cohort (n = 625,096)	Admission (n = 16,957)	No Admission (n = 608,139)	Group Difference and 95% CI	Decedents (n = 321)	Survivors (n = 624,775)	Group Difference and 95% CI
Age (years), mean (SD), y	47.4 (18.5)	54.1 (19.8)	47.2 (18.5)	6.9 (6.5 to 7.1)	73.0 (16.7)	47.4 (18.5)	25.6 (23.8 to 27.4)
Men (%)	265,350 (42.4)	7,640 (45.1)	257,710 (42.4)	2.7 (1.9 to 3.4)	183 (57.0)	265,167 (42.4)	14.6 (9.2 to 20.0)
Race (%)							
White	223,399 (35.7)	8,233 (48.6)	215,166 (35.4)	13.2 (12.4 to 13.9)	198 (61.7)	223,201 (35.7)	26.0 (20.6 to 31.3)
Black	84,501 (13.5)	2,233 (13.2)	82,268 (13.5)	-0.3 (-0.9 to 0.2)	48 (15.0)	84,453 (13.5)	1.5 (-2.5 to 5.3)
Hispanic	226,894 (36.3)	4,935 (29.1)	221,959 (36.5)	-7.4 (-8.1 to -6.7)	60 (18.7)	226,834 (36.3)	-17.6 (-21.9 to -13.3)
Asian	51,324 (8.2)	1,198 (7.1)	50,126 (8.2)	-1.1 (-1.6 to -0.8)	10 (3.1)	51,314 (8.2)	-5.1 (-7.0 to -3.2)
Other/multiple	21,955 (3.5)	241 (1.4)	21,714 (3.6)	-2.2 (-2.3 to -2.0)	2 (0.6)	21,953 (3.5)	-2.9 (-3.8 to -2.0)
Unknown	17,023 (2.7)	117 (0.7)	16,906 (2.8)	-2.1 (-2.2 to -2.0)	3 (0.9)	17,020 (2.7)	-1.8 (-2.8 to -0.7)
Ambulance arrival (%)	46,178 (7.4)	3,053 (18.0)	43,125 (7.1)	10.9 (10.3 to 11.5)	112 (34.9)	46,066 (7.4)	27.5 (22.3 to 32.7)
Vital signs							
Systolic blood pressure (mmHg), mean (SD)	136 (21)	137 (23)	136 (21)	1 (1 to 2)	129 (27)	136 (21)	-7(-10 to 4)
Pulse rate (bpm), mean (SD)	83 (17)	87 (19)	82 (16)	5 (4 to 5)	89 (21)	83 (17)	6 (4 to 8)
Triage (ESI) score (%) *							
1, 2	13,559 (2.2)	1,466 (8.6)	12,093 (2.0)	6.6 (6.3 to 7.1)	25 (7.8)	13,534 (2.2)	5.6 (2.7 to 8.6)
3	347,432 (55.6)	12,620 (74.4)	334,812 (55.1)	19.3 (18.7 to 20.0)	260 (81.0)	347,172 (55.6)	25.4 (21.1 to 29.7)
4, 5	262,587 (42.0)	2,802 (16.5)	259,785 (42.7)	-26.2 (-26.8 to -25.6)	33 (10.3)	262,554 (42.0)	-31.7 (-35.1 to -28.4)
Elixhauser comorbidities (%)							
Congestive heart failure	26,321 (4.2)	1,973 (11.6)	24,348 (4.0)	7.6 (7.1 to 8.1)	88 (27.4)	26,233 (4.2)	23.2 (18.3 to 28.1)
Valvular disease	21,862 (3.5)	1,301 (7.7)	20,561 (3.4)	4.3 (3.9 to 4.7)	55 (17.1)	21,807 (3.5)	13.6 (9.5 to 17.8)
Pulmonary circulation disease	8,929 (1.4)	682 (4.0)	8,247 (1.4)	2.6 (2.4 to 3.0)	39 (12.1)	8,890 (1.4)	10.7 (7.2 to 14.3)
Peripheral vascular disease	33,347 (5.3)	2,323 (13.7)	31,024 (5.1)	8.6 (8.1 to 9.1)	120 (37.4)	33,227 (5.3)	32.1 (26.8 to 37.4)
Paralysis	11,940 (1.9)	844 (5.0)	11,096 (1.8)	3.2 (2.8 to 3.5)	30 (9.3)	11,910 (1.9)	7.4 (4.3 to 10.6)
Other neurologic disorders	34,126 (5.5)	2,192 (12.9)	31,934 (5.3)	7.6 (7.2 to 8.2)	103 (32.1)	34,023 (5.4)	26.7 (21.5 to 31.7)
Chronic pulmonary disease	136,594 (21.9)	5,056 (29.8)	131,538 (21.6)	8.2 (7.5 to 8.9)	129 (40.2)	136,465 (21.8)	18.4 (13.0 to 23.7)

Patient Characteristics	Total Cohort (n = 625,096)	Admission (n = 16,957)	No Admission (n = 608,139)	Group Difference and 95% CI	Decedents (n = 321)	Survivors (n = 624,775)	Group Difference and 95% CI
Diabetes without chronic complications	88,833 (14.2)	4,153 (24.5)	84,680 (13.9)	10.6 (9.9 to 11.2)	115 (35.8)	88,718 (14.2)	21.6 (16.4 to 26.9)
Diabetes with chronic complications	66,169 (10.6)	3,251 (19.2)	62,918 (10.3)	8.9 (8.2 to 9.4)	103 (32.1)	66,066 (10.6)	21.5 (16.4 to 26.6)
Hypothyroidism	45,723 (7.3)	1,867 (11.0)	43,856 (7.2)	3.8 (3.3 to 4.3)	44 (13.7)	45,679 (7.3)	6.4 (2.6 to 10.2)
Renal failure	42,486 (6.8)	2,705 (16.0)	39,781 (6.5)	9.5 (8.9 to 10.0)	127 (39.6)	42,359 (6.8)	32.8 (27.4 to 38.1)
Liver disease	25,592 (4.1)	1,191 (7.0)	24,401 (4.0)	3.0 (2.6 to 3.4)	25 (7.8)	25,567 (4.1)	3.7 (0.8 to 6.6)
Peptic ulcer disease × bleeding	959 (0.2)	61 (0.4)	898 (0.1)	0.3 (0.1 to 0.3)	2 (0.6)	957 (0.2)	0.4 (−0.4 to 1.3)
AIDS	1,886 (0.3)	74 (0.4)	1,812 (0.3)	0.1 (0 to 0.2)	1 (0.3)	1,885 (0.3)	0 (−0.6 to 0.6)
Lymphoma	3,460 (0.6)	228 (1.3)	3,232 (0.5)	0.8 (0.6 to 1.0)	15 (4.7)	3,445 (0.6)	4.1 (1.8 to 6.4)
Metastatic cancer	10,989 (1.8)	753 (4.4)	10,236 (1.7)	2.7 (2.4 to 3.1)	54 (16.8)	10,935 (1.8)	15.0 (11 to 19.2)
Solid tumor without metastasis	41,321 (6.6)	2,188 (12.9)	39,133 (6.4)	6.5 (6.0 to 7.0)	110 (34.3)	41,211 (6.6)	27.7 (22.5 to 32.9)
Rheumatoid arthritis/collagen vas	19,927 (3.2)	909 (5.4)	19,018 (3.1)	2.3 (1.9 to 2.6)	29 (9.0)	19,898 (3.2)	5.8 (2.7 to 9.0)
Coagulopathy	11,962 (1.9)	926 (5.5)	11,036 (1.8)	3.7 (3.3 to 4)	42 (13.1)	11,920 (1.9)	11.2 (7.5 to 14.9)
Obesity	158,310 (25.3)	5,272 (31.1)	153,038 (25.2)	5.9 (5.2 to 6.6)	78 (24.3)	158,232 (25.3)	−1.0 (−5.7 to 3.7)
Weight loss	24,124 (3.9)	1,886 (11.1)	22,238 (3.7)	7.4 (7.0 to 7.9)	103 (32.1)	24,021 (3.8)	28.3 (23.1 to 33.3)
Fluid and electrolyte disorders	82,457 (13.2)	4,930 (29.1)	77,527 (12.7)	16.4 (15.6 to 17.0)	183 (57.0)	82,274 (13.2)	43.8 (38.4 to 49.3)
Chronic blood loss anemia	22,388 (3.6)	799 (4.7)	21,589 (3.6)	1.1 (0.8 to 1.5)	26 (8.1)	22,362 (3.6)	4.5 (1.5 to 7.5)
Deficiency anemias	99,826 (16)	4,974 (29.3)	94,852 (15.6)	13.7 (13 to 14.4)	175 (54.5)	99,651 (16.0)	38.5 (33.1 to 44.0)
Alcohol abuse	32,825 (5.3)	2,234 (13.2)	30,591 (5.0)	8.2 (7.6 to 8.7)	32 (10.0)	32,793 (5.2)	4.8 (1.4 to 8.0)
Drug abuse	27,111 (4.3)	2,049 (12.1)	25,062 (4.1)	8.0 (7.5 to 8.5)	16 (5.0)	27,095 (4.3)	0.7 (−1.7 to 3.0)
Psychoses	85,600 (13.7)	5,015 (29.6)	80,585 (13.3)	16.3 (15.6 to 17.0)	64 (19.9)	85,536 (13.7)	6.2 (1.9 to 10.6)
Depression	129,910 (20.8)	6,019 (35.5)	123,891 (20.4)	15.1 (14.4 to 15.9)	86 (26.8)	129,824 (20.8)	6.0 (1.2 to 10.9)
Hypertension	226,683 (36.3)	8,932 (52.7)	217,751 (35.8)	16.9 (16.1 to 17.6)	260 (81.0)	226,423 (36.3)	44.7 (40.5 to 49.0)

ESI, Emergency Severity Index.

* 0.2% of the cohort had missing ESI triage scores.

Table E1

Distributions of the crowding measures and 7-day admissions and death after ED discharge.*

Crowding Measure	Total Cohort (n = 625,096)	7-Day Admissions			7-Day Death		
		Admission (n = 16,957)	No Admission (n = 608,139)	Difference (95% CI)	Decedents (n = 321)	Survivors (n = 624,775)	Difference (95% CI)
Patient transit level							
Waiting time to mean (SD), h	0.68 (0.71)	0.60 (0.64)	0.68 (0.71)	−0.08 (−0.10 to −0.08)	0.50 (0.50)	0.68 (0.71)	−0.18 (−0.24 to −0.13)
Evaluation time, mean (SD), h	2.67 (2.39)	4.47 (3.27)	2.62 (2.34)	1.85 (1.80 to 1.90)	4.99 (3.62)	2.67 (2.39)	2.32 (1.92 to 2.72)
Total LOS, mean (SD), h	3.33 (2.47)	5.03 (3.31)	3.28 (2.42)	1.75 (1.70 to 1.80)	5.43 (3.67)	3.33 (2.46)	2.10 (1.70 to 2.51)
ED system level							
Occupancy at entry, mean (SD), persons/bed	0.78 (0.33)	0.77 (0.34)	0.78 (0.33)	−0.01 (−0.01 to 0)	0.77 (0.35)	0.78 (0.33)	−0.01 (−0.05 to 0.02)
Time-averaged occupancy, mean (SD), persons/bed	0.82 (0.31)	0.81 (0.31)	0.82 (0.31)	−0.01 (−0.01 to 0)	0.85 (0.32)	0.82 (0.31)	0.03 (−0.01 to 0.06)
LOS at entry, mean (SD), h	3.09 (1.28)	3.11 (1.28)	3.09 (1.28)	0.02 (0 to 0.03)	3.10 (1.33)	3.09 (1.28)	0.01 (−0.13 to 0.15)
Time-averaged LOS, mean (SD), h	3.10 (1.17)	3.13 (1.13)	3.10 (1.17)	0.03 (0.01 to 0.05)	3.04 (1.04)	3.10 (1.17)	−0.06 (−0.17 to 0.06)
Boarding time at entry, mean (SD), h	2.14 (3.08)	2.13 (3.00)	2.14 (3.08)	−0.01 (−0.06 to 0.03)	2.09 (3.42)	2.14 (3.08)	−0.05 (−0.42 to 0.33)
Time-averaged boarding time, mean (SD), h	2.08 (2.83)	2.04 (2.66)	2.08 (2.84)	−0.04 (−0.09 to 0)	1.95 (2.66)	2.08 (2.83)	−0.13 (−0.44 to 0.18)

* Data are presented as the mean value and SD of the crowding measures.

Table E2

Median and ranges of crowding measures for admission within 7 days.

Crowding Measures	No Admission Hours (N = 608,139)	Admission Hours (N = 16,957)	Total Hours (N = 625,096)
Patient transit level Waiting time			
Median	0.5	0.4	0.5
Q1, Q3	0.3, 0.8	0.2, 0.7	0.3, 0.8
Range	0-27.5	0-12.2	0-27.5
Evaluation time			
Median	2.1	3.8	2.2
Q1, Q3	1.1, 3.4	2.4, 5.6	1.1, 3.5
Range	0-45.7	0-46.4	0-46.4
Total LOS			
Median	2.8	4.4	2.8
Q1, Q3	1.7, 4.2	3.0, 6.2	1.8, 4.2
Range	0-46.3	0-46.7	0-46.7
ED system level Occupancy at entry			
Median	0.8	0.7	0.8
Q1, Q3	0.5, 1.0	0.5, 1.0	0.5, 1.0
Range	0-2.8	0-2.4	0-2.8
Time-averaged occupancy			
Median	0.8	0.8	0.8
Q1, Q3	0.6, 1.0	0.6, 1.0	0.6, 1.0
Range	0-2.7	0.1-2.2	0-2.7
LOS at entry			
Median	2.8	2.9	2.8
Q1, Q3	2.3, 3.6	2.3, 3.6	2.3, 3.6
Range	0-19.6	0-17.4	0-19.6
Time-averaged LOS			
Median	2.9	2.9	2.9
Q1, Q3	2.3, 3.6	2.4, 3.6	2.3, 3.6
Range	0-17.4	0.5-11.7	0-17.4
Boarding time at entry			
Median	1.0	1.1	1.0
Q1, Q3	0.1, 2.6	0.2, 2.6	0.1, 2.6
Range	0-45.1	0-37.6	0-45.1
Time-averaged boarding time			
Median	1.0	1.0	1.0
Q1, Q3	0.4, 2.5	0.5, 2.4	0.4, 2.5
Range	0-43.9	0-28.6	0-43.9

Q1, 25th Percentile; Q3, 75th percentile.

Table E3

Median and ranges of crowding measures for death within 7 days.

Crowding Measures	No Death (N = 624,775)	Death (N = 321)	Total (N = 625,096)
Patient transit level Waiting time			
Median	0.5	0.4	0.5
Q1, Q3	0.3, 0.8	0.2, 0.7	0.3, 0.8
Range	0-27.5	0-4.2	0-27.5
Evaluation time			
Median	2.2	4.2	2.2
Q1, Q3	1.1, 3.5	2.8, 6.1	1.1, 3.5
Range	0-46.4	0.3-22.7	0-46.4
Total LOS			
Median	2.8	4.7	2.8
Q1, Q3	1.8, 4.2	3.2, 6.5	1.8, 4.2
Range	0-46.7	0.2-22.9	0-46.7
ED system level Occupancy at entry			
Median	0.8	0.7	0.8
Q1, Q3	0.5, 1.0	0.5, 1.0	0.5, 1.0
Range	0-2.8	0.1-1.9	0-2.8
Time-averaged occupancy			
Median	0.8	0.8	0.8
Q1, Q3	0.6, 1.0	0.6, 1.0	0.6, 1.0
Range	0-2.7	0.2-1.8	0-2.7
LOS at entry			
Median	2.8	2.8	2.8
Q1, Q3	2.3, 3.6	2.3, 3.6	2.3, 3.6
Range	0-19.6	0.9-10.0	0-19.6
Time-averaged LOS			
Median	2.9	2.8	2.9
Q1, Q3	2.3, 3.6	2.4, 3.5	2.3, 3.6
Range	0-17.4	1.1-8.7	0-17.4
Boarding time at entry			
Median	1.0	1.1	1.0
Q1, Q3	0.1, 2.6	0, 2.4	0.1, 2.6
Range	0-45.1	0-33.6	0-45.1
Time-averaged boarding time			
Median	1.0	0.9	1.0
Q1, Q3	0.4, 2.5	0.4, 2.1	0.4, 2.5
Range	0-43.9	0-16.0	0-43.9

Table E4

Crowding measures and their association with 7-day admissions and death after ED discharge.*

Measure, 7-Day Admission	Coefficient (95% CI)		
	Main Term	Squared Term	Cubic Term
Patient transit-level			
Waiting time	-0.26 (-0.36 to -0.15) [†]	0.10 (0.036 to 0.15) [†]	-0.01 (-0.02 to -0.002) [†]
Evaluation time	0.43 (0.41 to 0.45) [†]	-0.02 (-0.03 to -0.02) [†]	0.0004 (0.00035 to 0.00043) [†]
Total LOS	0.40 (0.38 to 0.42) [†]	-0.022 (-0.024 to -0.02) [†]	0.00032 (0.00028 to 0.00036) [†]
ED system level			
Occupancy at entry	-0.38 (-0.89 to 0.13)	0.40 (-0.19 to 0.98)	-0.12 (-0.33 to 0.8)
Time-averaged occupancy	0.52 (-0.12 to 1.15)	-0.63 (-1.3 to 0.05)	0.20 (-0.03 to 0.43)
LOS at entry	0.07 (-0.02 to 0.16)	-0.01 (-0.03 to 0.01)	0.0004 (-0.0006 to 0.001)
Time-averaged LOS	0.25 (0.13 to 0.37) [†]	-0.04 (-0.06 to -0.01) [†]	0.002 (-0.0001 to 0.003)
ED boarding time at entry	0.03 (0.01 to 0.05) [†]	-0.002 (-0.005 to -0.0004) [†]	0.00005 (-0.00001 to 0.0001)
Time-averaged boarding time	0.04 (0.02 to 0.06) [†]	-0.005 (-0.007 to -0.002) [†]	0.0001 (0 to 0.0002)
7-Day death Patient transit level			
Waiting time	-0.34 (-0.89 to 0.21)	-0.01 (-0.23 to 0.22)	0.0005 (-0.01 to 0.01)
Evaluation time	0.11 (-0.09 to 0.30)	0.005 (-0.02 to 0.03)	-0.0004 (-0.001 to 0.0003)
Total LOS	0.03 (-0.18 to 0.24)	0.01 (-0.01 to 0.03)	-0.0005 (-0.001 to 0.0002)
ED system level			
Occupancy at entry	-3.39 (-7.02 to 0.24)	3.12 (-1.16 to 7.40)	-1.0 (-2.20 to 0.59)
Time-averaged occupancy	-1.28 (-6.26 to 3.71)	1.20 (-4.13 to 6.53)	-0.39 (-2.18 to 1.40)
LOS at entry	-0.51 (-1.21 to 0.19)	0.10 (-0.04 to 0.25)	-0.005 (-0.014 to 0.004)
Time-averaged LOS	-0.41 (-1.59 to 0.77)	0.08 (-0.20 to 0.35)	-0.0047 (-0.02 to 0.01)
ED boarding time at entry	-0.03 (-0.15 to 0.08)	0.003 (-0.009 to 0.014)	-0.000008 (-0.00024 to 0.00023)
Time-averaged boarding time	-0.16 (-0.38 to 0.07)	0.03 (-0.1 to 0.07)	-0.001 (-0.003 to -0.0008)

* We present the coefficients for crowding measures of distinct models. The model adjusts for age, sex, race or ethnicity, ambulance versus nonambulance arrival, triage blood pressure and pulse, ESI triage score, preexisting comorbidities, primary discharge diagnosis, shift, weekend versus weekday, month, medical center, year, and interaction between medical center and year.

[†] Significant. The main coefficient describes a linear relationship; the squared, a U-shaped association; and the cubic term, an S-shaped association with the outcome.

Table E5

Crowding measures and their association with 30-day admissions and death after ED discharge.*

Measure, 30-Day Admission	Coefficient (95% CI)		
	Main Term	Squared Term	Cubic Term
Patient transit level			
Waiting time	-0.13 (-0.19 to -0.07) [†]	0.03 (0.005 to 0.06)	-0.003 (-0.006 to 0.0004) [†]
Evaluation time	0.32 (0.30 to 0.33) [†]	-0.02 (-0.019 to -0.017) [†]	0.0003 (0.00025 to 0.00031) [†]
Total LOS	0.30 (0.28 to 0.31) [†]	-0.015 (-0.017 to -0.014) [†]	0.00023 (0.0002 to 0.00026) [†]
ED system level			
Occupancy at entry	-0.13 (-0.51 to 0.26)	0.1 (-0.34 to 0.54)	-0.015 (-0.17 to 0.14)
Time-averaged occupancy	0.55 (0.06 to 1.03) [†]	-0.61 (-1.13 to -0.09) [†]	0.20 (0.03 to 0.38) [†]
LOS at entry	0.06 (-0.003 to 0.12)	-0.01 (-0.02 to 0.002)	0.0006 (-0.0001 to 0.001)
Time-averaged LOS	0.18 (0.08 to 0.27) [†]	-0.03 (-0.05 to -0.01) [†]	0.002 (0.0004 to 0.003) [†]
ED boarding time at entry	0.01 (-0.004 to 0.02)	-0.0007 (-0.002 to 0.0009)	0.00005 (-0.00004 to 0.00005)
Time-averaged boarding time	0.02 (0.0001 to 0.03) [†]	-0.002 (-0.004 to 0.0007)	0.00002 (-0.00005 to 0.00009)
30-Day death Patient transit level			
Waiting time	-0.16 (-0.40 to 0.07)	0.02 (-0.07 to 0.10)	-0.0006 (-0.007 to 0.006)
Evaluation time	0.26 (0.19 to 0.32) [†]	-0.015 (-0.02 to -0.010) [†]	0.0002 (0.0001 to 0.0004) [†]
Total LOS	0.22 (0.16 to 0.29)	-0.01 (-0.017 to -0.006) [†]	0.0002 (0.00008 to 0.0003) [†]
ED system level			
Occupancy at entry	0.60 (-1.08 to 2.27)	-1.23 (-3.04 to 0.58)	0.52 (-0.07 to 1.12)
Time-averaged occupancy	0.49 (-1.69 to 2.67)	-0.86 (-3.05 to 1.34)	0.34 (-0.35 to 1.04)
LOS at entry	-0.24 (-0.58 to 0.11)	0.04 (-0.03 to 0.12)	-0.002 (-0.006 to 0.003)
Time-averaged LOS	-0.04 (-0.42 to 0.34)	-0.004 (-0.08 to 0.07)	0.0008 (-0.004 to 0.005)
ED boarding time at entry	-0.02 (-0.04 to 0.08)	-0.004 (-0.01 to 0.003)	0.0001 (-0.00005 to 0.00025)
Time-averaged boarding time	-0.04 (-0.15 to 0.06)	0.006 (-0.01 to 0.02)	-0.0003 (-0.001 to 0.0005)

* We present the coefficients for crowding measures of distinct models. The model adjusts for age, sex, race/ethnicity, ambulance vs non-ambulance arrival, triage blood pressure and pulse, ESI triage score, pre-existing comorbidities, primary discharge diagnosis, shift, weekend vs weekday, month, medical center, year, and interaction between medical center and year.

[†] Significant. The main coefficient describes a linear relationship; the squared, a U-shaped association; and the cubic term, an S-shaped association with the outcome.

Table E6

Crowding measures in quintiles and their association with 7-day admissions and death after ED discharge.*

Measure, 7-Day Admission	Quintile, OR (95% CI)			
	First	Second	Fourth	Fifth
Patient transit level				
Waiting time	1.07 (1.02-1.13) [†]	1.06 (0.99-1.11)	0.99 (0.94-1.04)	0.91 (0.86-0.96) [†]
Evaluation time	0.55 (0.51-0.60) [†]	0.70 (0.65-0.75) [†]	1.50 (1.42-1.58) [†]	2.53 (2.41-2.66) [†]
Total LOS	0.60 (0.55-0.65) [†]	0.77 (0.73-0.83) [†]	1.47 (1.40-1.55) [†]	2.35 (2.23-2.47) [†]
ED system level				
Occupancy at entry	1.06 (0.99-1.12)	1.00 (0.95-1.06)	1.04 (0.99-1.10)	1.03 (0.98-1.09)
Time-averaged occupancy	1.02 (0.97-1.09)	1.01 (0.96-1.06)	0.98 (0.94-1.04)	0.96 (0.91-1.01)
LOS at entry	0.96 (0.91-1.02)	0.97 (0.93-1.02)	1.01 (0.96-1.06)	1.02 (0.97-1.07)
Time-averaged LOS	0.90 (0.85-0.95) [†]	0.96 (0.92-1.01)	1.02 (0.97-1.07)	1.02 (0.97-1.07)
ED boarding time at entry	0.93 (0.89-0.98) [†]	0.96 (0.90-1.01)	1.05 (1.00-1.11) [†]	1.00 (0.94-1.05)
Time-averaged boarding time	0.83 (0.79-0.88) [†]	0.99 (0.94-1.04)	0.99 (0.94-1.04)	0.99 (0.94-1.05)
7-Day death Patient transit level				
Waiting time	1.37 (0.98-1.90)	0.97 (0.64-1.47)	1.22 (0.85-1.74)	0.71 (0.46-1.09)
Evaluation time	1.42 (0.77-2.61)	0.72 (0.39-1.33)	1.21 (0.81-1.82)	1.88 (1.30-2.72)
Total LOS	1.63 (0.93-2.84)	0.62 (0.35-1.10)	1.27 (0.86-1.88)	1.76 (1.22-2.53)
ED system level				
Occupancy at entry	1.67 (1.11-2.51)	1.50 (1.03-2.21)	1.45 (0.99-2.13)	1.25 (0.83-1.88)
Time-averaged occupancy	0.98 (0.64-1.50)	0.90 (0.62-1.30)	1.06 (0.75-1.50)	0.87 (0.59-1.29)
LOS at entry	1.22 (0.83-1.79)	1.18 (0.83-1.68)	0.96 (0.66-1.39)	1.31 (0.91-1.90)
Time-averaged LOS	1.27 (0.87-1.85)	1.20 (0.85-1.70)	1.05 (0.74-1.47)	1.04 (0.71-1.52)
ED boarding time at entry	1.12 (0.79-1.57)	0.60 (0.38-0.95)	1.14 (0.81-1.60)	0.88 (0.60-1.30)
Time-averaged boarding time	0.85 (0.55-1.31)	1.32 (0.94-1.85)	0.99 (0.69-1.42)	0.98 (0.66-1.44)

* We present the odds ratios for crowding measures of distinct models with quintiles of the crowding measures. Quintiles are presented in comparison to the middle third quintile. The model adjusts for age, sex, race or ethnicity, ambulance versus nonambulance arrival, triage blood pressure and pulse, ESI triage score, preexisting comorbidities, primary discharge diagnosis, shift, weekend versus weekday, month, medical center, year, and interaction between medical center and year.

[†]Significant.