Associations Between Crowding and Ten-Day Mortality Among Patients Allocated Lower Triage Acuity Levels Without Need of Acute Hospital Care on Departure From the Emergency Department

Lena M. Berg, RN, PhD*; Anna Ehrenberg, RN; Jan Florin, RN; Jan Östergren, MD; Andrea Discacciati, PhD; Katarina E. Göransson, RN

*Corresponding Author. E-mail: lena.berg@sll.se.

Study objective: We describe the association between emergency department (ED) crowding and 10-day mortality for patients triaged to lower acuity levels at ED arrival and without need of acute hospital care on ED departure.

Methods: This was a registry study based on ED visits with all patients aged 18 years or older, with triage acuity levels 3 to 5, and without need of acute hospital care on ED departure during 2009 to 2016 (n=705,699). The sample was divided into patients surviving (n=705,076) or dying (n=623) within 10 days. Variables concerning patient characteristics and measures of ED crowding (mean length of stay and ED occupancy ratio) were extracted from the hospital's electronic health records. ED length of stay per ED visit was estimated by the average length of stay for all patients who presented to the ED during the same day and shift and with the same acuity level. The 10-day mortality after ED discharge was used as the outcome measure. Multivariable logistic regression analyses were conducted.

Results: The 10-day mortality rate was 0.09% (n=623). The event group had larger proportions of patients aged 80 years or older (51.4% versus 7.7%) and triaged with acuity level 3 (63.3% versus 35.6%), and greater comorbidity (age-combined Charlson comorbidity index median interquartile range 6 versus 0). We observed an increased 10-day mortality for patients with a mean ED length of stay greater than or equal to 8 hours versus less than 2 hours (adjusted odds ratio 5.86; 95% confidence interval [CI] 2.15 to 15.94) and for elevated ED occupancy ratio. Adjusted odds ratios for ED occupancy ratio quartiles 2, 3, and 4 versus quartile 1 were 1.48 (95% CI 1.14 to 1.92), 1.63 (95% CI 1.24 to 2.14), and 1.53 (95% CI 1.15 to 2.03), respectively.

Conclusion: Patients assigned to lower triage acuity levels when arriving to the ED and without need of acute hospital care on departure from the ED had higher 10-day mortality when the mean ED length of stay exceeded 8 hours and when ED occupancy ratio increased. [Ann Emerg Med. 2019;74:345-356.]

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INTRODUCTION

Background

Emergency department (ED) crowding has been considered a threat to patient safety for many years[1-3] by resulting in extended ED length of stay,[4,5] increased morbidity,[6,7] and increased mortality[8-11] for patients and by having negative effects on clinicians' (physicians' and registered nurses') workload[2] and work satisfaction.[12] Several studies have investigated the effects of ED crowding, mostly for critically ill patients or patients admitted to inhospital care,[4,9,13] but there is a knowledge gap concerning the influence of ED crowding on patient outcomes for patients assigned to lower triage levels on arrival to the ED and without the need for acute hospital care on departure from the ED. However, one study found an association between longer mean ED length of stay and a greater risk of short-term (7-day) mortality for patients discharged from the ED.[8]

Several measures of crowding have been presented in the literature, and ED length of stay and ED occupancy ratio are the most commonly used. ED length of stay in this study represented the average ED length of stay of all patients with the same triage acuity level who presented to the ED during the same shift, and is considered a good proxy measure of crowding.[6,7,14] ED occupancy ratio is a measure of how many patients are present in the ED during a certain period divided by the number of established

Editor's Capsule Summary

What is already known about this topic

Several studies have found that emergency department (ED) crowding is associated with short-term mortality, particularly for high-acuity patients.

What question this study addressed

This observational registry study of 705,000 Swedish ED patients estimated the effect of ED crowding on the 10-day mortality rate of lower-acuity patients discharged from 2 EDs during an 8-year period.

What this study adds to our knowledge

Longer ED length of stay and higher quartiles of the ED occupancy rate were associated with increased odds of death within 10 days of discharge.

How this is relevant to clinical practice

Presenting to an ED during a crowded shift is associated with a greater risk of short-term death among lower-acuity patients discharged from the ED.

treatment beds (fixed number) in the ED, with crowding defined as a ratio greater than 1.0.[15]

Importance and Goals of This Investigation

There is a knowledge gap about whether there is an association between ED length of stay and short-term mortality for patients assigned to lower triage acuity levels, and to the best of our knowledge only one study has performed such an investigation.[8] Therefore, inspired by the study by Guttmann et al,[8] we used a similar approach to investigate whether there is an association between extended ED length of stay and short-term mortality, but we also included ED occupancy ratio as a crowding measure. Thus, the aim of this study was to describe the association between ED crowding and 10-day mortality for patients assigned to lower triage acuity levels at ED arrival (Rapid Emergency Triage and Treatment System [RETTS] triage acuity levels 3 to 5) and without need of acute hospital care on departure from the ED.

MATERIALS AND METHODS

Study Design and Setting

This retrospective study was based on ED visits at the Karolinska University Hospital in Sweden from 2009 to 2016. The hospital has EDs at 2 sites and is 1 of 4 emergency hospitals in Stockholm, Sweden, which has approximately 2 million inhabitants. Both sites host their own EDs for adults, with ED visits per year of approximately 77,000 (site 1) and 73,000 (site 2). Patients with internal medicine, surgical, orthopedic, neurologic, and infectious conditions are treated at both EDs. Site 1, which is also a Level I trauma center, also treats patients with ear, nose, and throat complaints and patients with ongoing oncologic treatments. Both EDs use the RETTS,[16-18] a 5-level triage scale descending from red (1) to blue (5), in which red represents the most urgent level. RETTS is based on one main principle: whether the patient is assessed as unstable or stable during triage. Unstable patients are experiencing potentially life-threatening conditions and are allocated to 1 of the 2 highest triage levels (1 to 2), whereas stable patients are allocated to 1 of the 3 lowest triage levels (3 to 5). Stable patients need medical attention but are considered able to wait because they are not at any obvious medical risk. RETTS uses a combination of vital signs and 59 chief complaint algorithms to allocate the triage level. The vital signs have cutoff levels for each triage level, and the chief complaint algorithms are known as emergency symptoms and signs for emergency care. Each emergency symptom and sign includes one or more chief complaints and is classified according to the *International Statistical Classification of Diseases and Related Health Problems, 10th Revision, 2007* (*ICD-10*), and a logistic process is attached to each algorithm. The triage levels in RETTS do not have time frames for maximum waiting time, and RETTS does not take pain into account for triage placement. Instead, RETTS gives recommendations for each ED to consider and make decisions according to local guidelines. The time frames for time to assessment by a physician according to the local guidelines for the hospital in the study are red (1), immediate assessment; orange (2), within 15 minutes; yellow (3), within 60 minutes; green (4), within 120 minutes; and blue (5), within 240 minutes. One example of a patient with allocated triage acuity level 3 is one with moderate abdominal pain without constitutional symptoms and with vital signs within the cutoff levels for triage acuity level 3 or 4. A patient with triage acuity level 4 could be one with mild abdominal pain and vital signs within the cutoff level for triage acuity level 4. Patients allocated triage acuity level 5 have an isolated injury or chief complaint (for example, a sprained ankle), and hence vital signs are not collected for them.

RETTS cannot be automatically compared with other triage scales (for example, the Canadian Triage and Acuity Scale [CTAS][19] or Emergency Severity Index)[20] because they have different time frames for time to physician assessment for high versus low triage levels. We believe that RETTS triage levels 3 to 5 can be interpreted to CTAS triage levels 4 to 5, rather than CTAS levels 3 to 5, because the time frame for time to physician assessment for triage acuity level 3 according to RETTS corresponds to triage acuity level 4 for CTAS. Also, the time frame of 30 minutes to assessment by a physician that is used for CTAS does not exist in RETTS, in which instead these patients are triaged as level 2, and the time frame of 240 minutes for RETTS triage acuity level 5 does not exist in CTAS.

Selection of Participants

All data used in this study were retrieved from the patients' electronic health records, which were drawn from the hospital's central data warehouse that holds data from 2009 onward. During 2009 to 2016, a total of 1,063,806 records relating to ED visits by patients aged 18 years or older were extracted (Figure). Inclusion criteria were patients with RETTS triage acuity levels 3 to 5 and without need of acute hospital care on departure from the ED (ie, discharged or referred to geriatric care) (n=705,813). The reason for including both patients discharged from the ED and those admitted to a geriatric hospital is that both groups are not in need of acute inhospital care in our hospital setting. Exclusion criteria were patients with RETTS triage acuity levels 1 to 2 or with missing RETTS level and patients admitted to inhospital care or who died before ED discharge (n=357,993). Patients who left the ED without being seen or against medical advice were included in the study because they were not able to be separated from those who followed through with the ED visit because of shortcomings in the data registry. Finally, after the manual audit explained below, a total of 705,699 ED visits were marked for the analyses, corresponding to 366,665 unique patients (mean of 1.9 visits/patient).

A manual audit of the patients' electronic health records was conducted for the complete subset of ED visits relative to patients with triage acuity levels 3 to 5, without need of acute hospital care on departure from the ED, and who died within 10 days (n=737). This was done to validate the extracted data. The electronic health record audits were

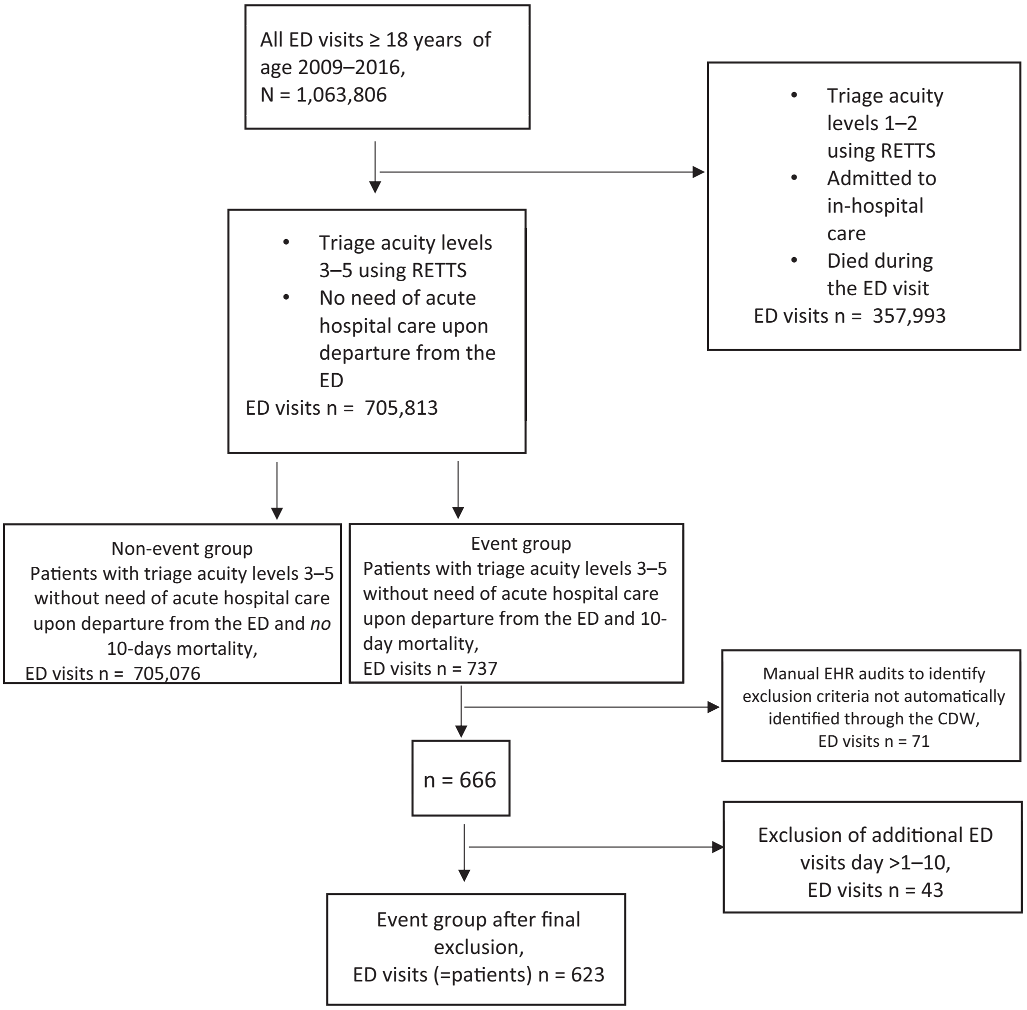

Figure. Process for inclusion and exclusion of patient visits to ED care, 2009 to 2016.

conducted by L.M.B., and a subsample (29%) of the electronic health records was coaudited by a research assistant. The audit identified 71 ED visits (10%) that were excluded for various reasons, mainly because of inclusion of patients who had RETTS triage acuity levels 1 to 2, who were admitted to inhospital care, or who were referred to other hospitals (Table E1, available online at http://www.annemergmed.com). This inaccurate inclusion was due to technical shortcomings in the electronic health records. During the chart review, only one specific section of the electronic health record was reviewed and checked for patients' triage acuity level and where they went after ED discharge. No additional information from the chart was used for the results; hence, many known sources of potential bias during chart review[21] were not relevant in this study. Finally, some patients had multiple ED visits during the 10-day period before their date of death. To deal with the complexity of multiple visits in relation to death as the outcome measure, all ED visits in this period were excluded apart from the earliest one in the time frame of days 1 to 10 (n=43). A total of 623 subjects were assigned to triage acuity levels 3 to 5, were without need of acute hospital care on departure from the ED, and died within 10 days. The inclusion and exclusion process is visualized in the Figure.

Methods of Measurement

Since 2009, all patient data from the electronic health record system have been downloaded to a hospital central data warehouse every 24 hours. The warehouse also imports external information such as date of birth and death, sex, and the personal identity number from the Swedish Population Register every 24 hours. Thus, when the ED establishes an electronic health record for a patient, the system automatically retrieves information from the Swedish Population Register, and all previous hospital visits appear. Furthermore, the central data warehouse makes it possible to retrospectively collect all information that can be retrieved from a patient's electronic health record from all ED visits to the hospital. Information about ED occupancy ratios in this study was extracted in 2-hour slots during 2009 to 2016. The decision on 2-hour slots was based on the notion of investigating a shorter time frame than what had been investigated in previous research, one that could make sense in capturing the fluctuations in ED occupancy ratio from a clinical perspective but simultaneously create a manageable amount of data.

The following variables were retrieved from the electronic health record through the central data warehouse for each ED visit: the patient's age, sex, chief complaint, arrival mode, triage acuity level, *ICD-10* codes, date and time of arrival or discharge from the ED, admittance to inhospital care, and date of death. Furthermore, the following ED crowding variables were calculated for each patient visit: ED length of stay (extracted from the central data warehouse through time stamps for time of arrival to the ED, which are automatically entered when an electronic health record is established, and time stamps for time of discharge from the ED, which are manually entered when the patient leaves the ED), and ED occupancy ratio (extracted from the central data warehouse through automatically entered information about the number of patients present in the ED at a given time slot divided by the number of established treatment beds [a fixed number], added manually to the algorithm by the research group).

The variables for ED length of stay and ED occupancy ratio were designed by the research group and a systems scientist at the Department of E-Health and Strategic IT at the Karolinska University Hospital. ED length of stay was calculated separately for each ED and shift on each day as the mean length of stay from registration until discharge of all patients who presented at that ED during that shift and had the same triage acuity level, including those admitted and waiting for beds in the hospital. When there was only one patient present with a certain triage acuity level, ED length of stay was reported as a total value and not as a mean one. The ED occupancy ratio variable was calculated by assigning the mean ED occupancy ratio value for the interval of each ED visit.

The age-combined Charlson comorbidity index[22] and the number of ED visits within the previous year were used as measures of comorbidity. An algorithm for the index was built in the central data warehouse that used all previously registered *ICD-10* codes (ie, for all hospital visits, not only to the ED), the *ICD-10* code for the current ED visit, and current age in the patients' electronic health records to calculate an age-combined Charlson comorbidity index score for each unique patient visit. Because the hospital's 2 ED sites have catchment areas with various socioeconomic groups, we conditioned the regression models on ED site to adjust for socioeconomic status.

Outcome Measures

Mortality within 10 days for the group of patients with triage acuity levels 3 to 5 and without need of acute hospital care on departure from the ED was used as the outcome measure. Information about date of death is automatically imported from the Swedish Population

Register to the electronic health record and was collected through the central data warehouse for the study. Ten-day mortality was chosen over 7-day mortality, which is a more commonly used measure of short-term mortality, because others[8] have suggested that more than 80% of adverse events occur within the first 10 days after an ED visit.[23]

Primary Data Analysis

Categoric variables are presented as frequencies and percentages and were compared with the χ^2 test. Continuous variables are presented as medians and interquartile ranges because of lack of a normal distribution of the data, and were compared with the Wilcoxon rank sum test. Multivariable conditional logistic regression models, conditioning on EDs as fixed effects, were used to estimate odds ratios and 95% confidence intervals (CIs) to analyze the association of mean ED length of stay (<2 hours, 2 to <3 hours, etc, until >8 hours) and ED occupancy ratio (quartiles) with 10-day mortality. The 2 crowding variables were analyzed with separate models. Both models used ED visits as the unit of analysis. We used clustered robust standard errors to account for the potential correlation in the outcome at the patient level because a single patient could contribute to the analyses with repeated ED visits. Models were adjusted for the following potential confounders: age (18 to 39, 40 to 64, 65 to 79, and ≥80 years), sex, triage acuity levels (3 to 5), number of ED visits during the previous year (0, 1, 2, and ≥3), age-combined Charlson comorbidity index, arrival by emergency medicine services (EMS) transport (yes/no), arrival time of day (daytime [7 AM to 3:59 PM], evening [4 PM to 8:59 PM], and night [9 PM to 6:59 AM]), and chief complaint (top 3/others). Missing values for the potential confounders were treated as separate categories. *P* values were 2 sided, and statistical significance was set at .05. All statistical analyses were performed with Stata (version 14.2; StataCorp, College Station, TX).

This study was approved by the Regional Ethical Review Board in Stockholm, and permissions were obtained from the managers of the EDs. Deidentified data were extracted from the central data warehouse, and the code key was kept at the Department of E-Health and Strategic IT. However, for the event group the Swedish personal identity numbers were obtained to facilitate electronic health record audits. Finally, all data are presented at a group level.

RESULTS

Characteristics of Study Subjects

The entire sample consisted of 705,699 ED visits (Table 1) and the 10-day mortality rate for the entire study group was 0.09% (n=623). For patients allocated to triage acuity level 3, the 10-day mortality rate was 0.16% (n=394); for those with triage acuity level 4, 0.06% (n=173); and for those with triage acuity level 5, 0.03% (n=56). The sex distribution was similar within the group of patients with triage acuity levels 3 to 5 who had no need of acute hospital care on departure from the ED with 10-day mortality (the event group) and the group with no 10-day mortality (the nonevent group). However, the event group had larger proportions of patients aged 80 years or older (51.4% versus 7.7%), triaged with higher (ie, 3) acuity level (63.3% versus 35.6%), and transported by EMS to the ED (59.7% versus 11.0%). Finally, the age-combined Charlson comorbidity index median interquartile range was higher for patients in the event group compared with those in the nonevent group (6 versus 0), indicating that those in the event group had higher comorbidity; for example, cancer and cardiovascular diseases. The patient characteristics for mean ED length of stay (Table 2) and ED occupancy ratio (Table 3) did not vary much according to the different crowding levels. Of the nearly 217,000 ED visits with ED length of stay exceeding 4 hours, the majority of patients were allocated to triage level 3. For ED occupancy ratio, the only variable that differed was time of arrival, in which ED occupancy ratio greater than 1 was not as common during the night shift compared with the day shift.

The proportion of patients during periods with a mean ED length of stay greater than or equal to 4 hours and with ED occupancy ratio in the second, third, or fourth quartile was greater in the event group than in the nonevent group (Table 4).

Main Results

The multivariable adjusted logistic regression showed an increased 10-day mortality for mean ED length of stay greater than or equal to 8 hours versus less than 2 hours (adjusted odds ratio 5.86; 95% CI 2.15 to 15.94) and for elevated ED occupancy ratio. Adjusted odds ratios for ED occupancy ratio quartiles 2, 3, and 4 versus quartile 1 were 1.48 (95% CI 1.14 to 1.92), 1.63 (95% CI 1.24 to 2.14), and 1.53 (95% CI 1.15 to 2.03), respectively (Table 5). As a sensitivity analysis, because the manual audit was conducted only on the electronic health records of ED visits relative to patients who died within 10 days, we ran the same regression models as for Table 5, including ED visits that had been excluded as a result of the audit (n=67). The results turned out to be robust (Table E2, available online at http://www.annemergmed.com).

Table 1. Patient characteristics and 10-day mortality of patients with RETTS triage acuity levels 3 to 5 on admission to ED care during 2009 to 2016 (ED visits n=705,699).

	Patients With RETTS Triage Acuity Levels 3–5 Without Need of Acute Hospital Care on Departure From the ED Who Survived 10 Days	Patients With RETTS Triage Acuity Levels 3–5 Without Acute Hospital Care on Departure From the ED Who Died Within 10 Days	Total	Overall *P* Value for Each Variable
No. of ED visits	705,076	623	705,699	
Patient age, No. (%), y				<.001
18–39	279,234 (39.6)	15 (2.4)	279,249 (39.6)	
40–64	261,279 (37.1)	100 (16.1)	261,379 (37.0)	
65–79	110,252 (15.6)	188 (30.2)	110,440 (15.6)	
≥80	54,311 (7.7)	320 (51.4)	54,631 (7.7)	
Sex, No. (%)				.10
Women	365,880 (51.9)	304 (48.8)	366,184 (51.9)	
Men	336,421 (47.7)	319 (51.2)	336,740 (47.7)	
Missing	2,775 (0.4)	0	2,775 (0.4)	
Triage acuity level, No. (%)*				<.001
3 (yellow)	251,242 (35.6)	394 (63.2)	251,636 (35.7)	
4 (green)	288,452 (40.9)	173 (27.8)	288,625 (40.9)	
5 (blue)	165,382 (23.5)	56 (9.0)	165,438 (23.4)	
ED visits in the previous 365 days, No. (%)				.001
0	472,621 (67.0)	385 (61.8)	473,006 (67.0)	
1	133,963 (19.0)	122 (19.6)	134,085 (19.0)	
2	47,854 (6.8)	65 (10.4)	47,919 (6.8)	
≥3	50,638 (7.2)	51 (8.2)	50,689 (7.2)	
ACCI† score, median (IQR)	0 (0–1)	6 (4–8)	0 (0–1)	<.001
Arrival by EMS‡ transport, No. (%)				<.001
Yes	77,554 (11.0)	372 (59.7)	77,926 (11.0)	
No	627,522 (89.0)	251 (40.3)	627,773 (89.0)	
Time of arrival, No. (%)				.05
Day (7 AM–3:59 PM)	419,371 (59.5)	395 (63.4)	419,766 (59.5)	
Evening (4 PM–8:59 PM)	160,156 (22.7)	139 (22.3)	160,295 (22.7)	
Night (9 PM–6:59 AM)	125,549 (17.8)	89 (14.3)	125,638 (17.8)	
Chief complaint, No. (%)				.40
Top 3 (dyspnea, chest pain, or stomach pain)	144,765 (20.5)	131 (21.0)	144,896 (20.5)	
Other	509,910 (72.3)	424 (68.1)	510,334 (72.3)	
Missing	50,401 (7.1)	68 (10.9)	50,469 (7.2)	

ACCI, Age-combined Charlson comorbidity index; *IQR*, interquartile range.
*Based on the 5-level RETTS triage scale, in which triage acuity level red (1) represents the most urgent level (ie, in need of immediate medical assistance).
†ACCI scores on a scale of 0 to 3.
‡For example, ambulance or helicopter staffed by paramedics.

Table 2. Patient characteristics presented according to ED length-of-stay groups.

	Mean ED LOS, Hours									
	<2	**2–<3**	**3–<4**	**4–<5**	**5–<6**	**6–<7**	**7–<8**	**≥8**	**Total**	**Overall *P* Value for Each Variable**
No. of ED visits	46,302	174,498	267,560	152,906	46,378	13,182	3,388	1,474	705,688	
Patient age, No. (%), y										<.001
18–39	22,710 (49)	77,191 (44.2)	101,329 (37.9)	54,096 (35.4)	16,937 (36.5)	5,133 (38.9)	1,332 (39.3)	515 (34.9)	279,243 (39.6)	
40–64	16,185 (35.0)	64,049 (36.7)	100,873 (37.7)	56,696 (37.1)	16,924 (36.5)	4,819 (36.6)	1,245 (36.7)	584 (39.6)	261,375 (37.0)	
65–79	5,434 (11.7)	23,334 (13.4)	43,554 (16.3)	27,234 (17.8)	8,027 (17.3)	2,096 (15.9)	522 (15.4)	238 (16.1)	110,439 (15.6)	
≥80	1,973 (4.3)	9,924 (5.7)	21,804 (8.1)	14,880 (9.7)	4,490 (9.7)	1,134 (8.6)	289 (8.5)	137 (9.3)	54,631 (7.7)	
Sex, No. (%)										<.001
Women	21,561 (46.6)	87,107 (49.9)	141,698 (53.0)	81,690 (53.4)	24,581 (53.0)	7,017 (53.2)	1,760 (51.9)	762 (51.7)	366,176 (51.9)	
Men	24,568 (53.1)	86,751 (49.7)	124,809 (46.6)	70,648 (46.2)	21,586 (46.5)	6,088 (46.2)	1,591 (47.0)	696 (47.2)	336,737 (47.7)	
Missing	173 (0.4)	640 (0.4)	1,053 (0.4)	568 (0.4)	211 (0.5)	77 (0.6)	37 (1.1)	16 (1.1)	2,775 (0.4)	
Triage acuity level, No. (%)*										<.001
3 (yellow)	776 (1.7)	16,789 (9.6)	91,333 (34.1)	96,733 (63.3)	32,909 (71.0)	9,705 (73.6)	2,485 (73.3)	905 (61.4)	251,635 (35.7)	
4 (green)	3,645 (7.9)	68,180 (39.1)	149,742 (56.0)	50,755 (33.2)	12,015 (25.9)	3,033 (23.0)	801 (23.6)	446 (30.3)	288,617 (40.9)	
5 (blue)	41,881 (90.5)	89,529 (51.3)	26,485 (9.9)	5,418 (3.5)	1,454 (3.1)	444 (3.4)	102 (3.0)	123 (8.3)	165,436 (23.4)	
ED visits in the previous 365 days, No. (%)										<.001
0	29,676 (64.1)	115,156 (66.0)	179,788 (67.2)	104,277 (68.2)	31,778 (68.5)	9,008 (68.3)	2,353 (69.5)	962 (65.3)	472,998 (67.0)	
1	10,197 (22.0)	35,449 (20.3)	50,122 (18.7)	27,089 (17.7)	8,109 (17.5)	2,296 (17.4)	537 (15.9)	285 (19.3)	134,084 (19.0)	
2	3,354 (7.2)	12,077 (6.9)	18,210 (6.8)	10,116 (6.6)	3,011 (6.5)	841 (6.4)	220 (6.5)	90 (6.1)	47,919 (6.8)	
≥3	3,075 (6.6)	11,816 (6.8)	19,440 (7.3)	11,424 (7.5)	3,480 (7.5)	1,037 (7.9)	278 (8.2)	137 (9.3)	50,687 (7.2)	
ACCI,† point median (IQR)	0 (0–0)	0 (0–0)	0 (0–1)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–2)	0 (0–1)	<.001
Arrival by EMS‡ transport, No. (%)										<.001
Yes	1,409 (3.0)	11,246 (6.4)	30,446 (11.4)	23,344 (15.3)	8,096 (17.5)	2,431 (18.4)	664 (19.6)	290 (19.7)	77,926 (11.0)	
No	44,893 (97.0)	163,252 (93.6)	237,114 (88.6)	129,562 (84.7)	38,282 (82.5)	10,751 (81.6)	2,724 (80.4)	1,184 (80.3)	627,762 (89.0)	
Time of arrival, No. (%)										<.001
Day (7 AM–3:59 PM)	26,951 (58.2)	110,760 (63.5)	174,533 (65.2)	88,186 (57.7)	17,093 (36.9)	1,844 (14.0)	250 (7.4)	149 (10.1)	419,766 (59.5)	
Evening (4 PM–8:59 PM)	7,430 (16.0)	27,893 (16.0)	54,026 (20.2)	41,834 (27.4)	19,015 (41.0)	7,235 (54.9)	1,998 (59.0)	855 (58.0)	160,286 (22.7)	
Night (9 PM–6:59 AM)	11,921 (25.7)	35,845 (20.5)	39,001 (14.6)	22,886 (15.0)	10,270 (22.1)	4,103 (31.1)	1,140 (33.6)	470 (31.9)	125,636 (17.8)	

Table 2. Continued.

	Mean ED LOS, Hours									Overall P Value for Each Variable
	<2	2–<3	3–<4	4–<5	5–<6	6–<7	7–<8	≥8	Total	
Chief complaint, No. (%)										<.001
Top 3 (dyspnea, chest pain, or stomach pain)	2,196 (4.7)	22,369 (12.8)	60,425 (22.6)	41,361 (27.0)	13,168 (28.4)	3,925 (29.8)	1,015 (30.0)	434 (29.4)	144,893 (20.5)	
Other	38,369 (82.9)	135,748 (77.8)	189,330 (70.8)	103,570 (67.7)	31,306 (67.5)	8,767 (66.5)	2,270 (67.0)	971 (65.9)	510,331 (72.3)	
Missing	5,737 (12.4)	16,381 (9.4)	17,805 (6.7)	7,975 (5.2)	1,904 (4.1)	490 (3.7)	103 (3.0)	69 (4.7)	50,464 (7.2)	

LOS, Length of stay.
*Based on the 5-level RETTS triage scale, in which triage acuity level red (1) represents the most urgent level (ie, in need of immediate medical assistance).
†ACCI scores on a scale of 0 to 3.
‡For example, ambulance or helicopter staffed by paramedics.

LIMITATIONS

All data were retrieved from the patients' electronic health records through the central data warehouse. All variables that had been entered manually in the electronic health record, such as chief complaint, arrival mode, and triage acuity level, have a potential risk of being less valid than those that are automatically imported from the Swedish Population Register, such as age, sex, and date of death. To ensure internal validity, L.M.B. validated all variables extracted from the central data warehouse, together with a systems scientist from the University Hospital, where the programming codes for extraction were validated by comparison of extracted data with actual patient information in the electronic health record. The first author's knowledge of the clinical setting and of how patient data are registered in the electronic health record made it possible to take both the validity and reliability of the data into consideration and to identify potential sources of error for further scrutiny.

The structure of the central data warehouse caused some challenges in identifying ED visits that should have been excluded according to the exclusion criteria. In the event group (n=737), 71 ED visits (10%) were manually excluded for reasons presented in the "Materials and Methods" section. Despite repeated efforts, we were unable to determine why 10% of the patient visits in the event group were included despite fulfilling the exclusion criteria of the patients' being assigned to triage acuity level 1 to 2 or having inhospital admission. Hence, it cannot be ruled out that a similar proportion of inaccurately included visits occurred in the entire study group. This might have led to the nonevent group's potentially consisting of patients who were allocated to high triage acuity levels or were admitted to inhospital care, which is a limitation because the 2 groups (event versus nonevent) might not have been as homogenous as expected. The extraction of data, validation of the data quality, and the electronic health record audit were discussed continuously within the research group during the validation process. Furthermore, ED visits by patients who left without being seen or against medical advice were not possible to identify in the central data warehouse but required a manual chart review. During the chart reviews of the event group, 17 patients (2.3%) were identified as having left without being seen, and it cannot be ruled out that the same proportion existed in the nonevent group. However, because it was not possible to find these visits in the nonevent groups, they were included in the entire study (ie, in both the event and nonevent groups).

Residual confounding needs to be taken into consideration. It cannot be ruled out that there might

Table 3. Patient characteristics presented according to ED occupancy ratio groups.

	Mean ED Occupancy Ratio During ED Visit, Quartile					
	1 (0.04–0.94)	**2 (0.94–1.25)**	**3 (1.25–1.54)**	**4 (1.54–3.11)**	**Total**	**Overall *P* Value for Each Variable**
No. of ED visits	176,440	179,380	175,375	174,228	705,423	
Patient age, No. (%), y						<.001
18–39	77,507 (43.9)	71,445 (39.8)	66,095 (37.7)	64,078 (36.8)	279,125 (39.6)	
40–64	64,566 (36.6)	66,918 (37.3)	65,099 (37.1)	64,678 (37.1)	261,261 (37.0)	
65–79	23,629 (13.4)	27,499 (15.3)	29,076 (16.6)	30,213 (17.3)	110,417 (15.7)	
≥80	10,738 (6.1)	13,518 (7.5)	15,105 (8.6)	15,259 (8.8)	54,620 (7.7)	
Sex, No. (%)						<.001
Women	86,769 (49.2)	93,389 (52.1)	93,062 (53.1)	92,828 (53.3)	366,048 (51.9)	
Men	88,856 (50.4)	85,200 (47.5)	81,694 (46.6)	80,852 (46.4)	336,602 (47.7)	
Missing	815 (0.5)	791 (0.4)	619 (0.4)	548 (0.3)	2,773 (0.4)	
Triage acuity level, No. (%)*						<.001
3 (yellow)	61,968 (35.1)	62,821 (35.0)	60,988 (34.8)	65,830 (37.8)	251,607 (35.7)	
4 (green)	74,299 (42.1)	73,924 (41.2)	71,827 (41.0)	68,512 (39.3)	288,562 (40.9)	
5 (blue)	40,173 (22.8)	42,635 (23.8)	42,560 (24.3)	39,886 (22.9)	165,254 (23.4)	
ED visits in the previous 365 days, No. (%)						<.001
0	115,213 (65.3)	119,561 (66.7)	119,195 (68.0)	118,851 (68.2)	472,820 (67.0)	
1	34,566 (19.6)	34,505 (19.2)	32,777 (18.7)	32,193 (18.5)	134,041 (19.0)	
2	12,446 (7.1)	12,196 (6.8)	11,563 (6.6)	11,691 (6.7)	47,896 (6.8)	
≥3	14,215 (8.1)	13,118 (7.3)	11,840 (6.8)	11,493 (6.6)	50,666 (7.2)	
ACCI[†] point median (IQR)	0 (0–0)	0 (0–1)	0 (0–1)	0 (0–2)	0 (0–1)	<.001
Arrival by EMS[‡] transport, No. (%)						<.001
Yes	23,465 (15.0)	19,009 (10.6)	17,010 (9.7)	15,434 (8.9)	77,918 (11.0)	
No	149,975 (85.0)	160,371 (89.4)	158,365 (90.3)	158,794 (91.1)	627,505 (89.0)	
Time of arrival, No. (%)						<.001
Day (7 AM–3:59 PM)	55,431 (31.4)	96,324 (53.7)	122,159 (69.7)	145,716 (83.6)	419,630 (59.5)	
Evening (4 PM–8:59 PM)	25,233 (14.3)	59,297 (33.1)	47,966 (27.4)	27,739 (15.9)	160,235 (22.7)	
Night (9 PM–6:59 AM)	95,776 (54.3)	23,759 (13.2)	5,250 (3.0)	773 (0.4)	125,558 (17.8)	
Chief complaint, No. (%)						<.001
Top 3 (dyspnea, chest pain, or stomach pain)	41,301 (23.4)	36,332 (20.3)	33,905 (19.3)	33,335 (19.1)	144,873 (20.5)	
Other	122,163 (69.2)	130,497 (72.7)	128,977 (73.5)	128,507 (73.8)	510,144 (72.3)	
Missing	12,976 (7.4)	12,551 (7.0)	12,493 (7.1)	12,386 (7.1)	50,406 (7.1)	

*Based on the 5-level RETTS triage scale, in which triage acuity level red (1) represents the most urgent level (ie, in need of immediate medical assistance).
[†]ACCI scores on a scale of 0 to 3.
[‡]For example, ambulance or helicopter staffed by paramedics.

be covariates for patient acuity that were not included in the model but that may be measured by the crowding measures.

We chose to include previously validated measures of ED crowding such as ED length of stay and ED occupancy ratio. It cannot, however, be ruled out that the association

Table 4. Crowding measures and 10-day mortality for patients (n=705,699) admitted to ED care during 2009 to 2016.

	Patients With RETTS Triage Acuity Levels 3–5 Without Need of Acute Hospital Care on Departure From the ED Who Survived 10 Days	Patients With RETTS Triage Acuity Levels 3–5 Without Need of Acute Hospital Care on Departure From the ED Who Died Within 10 Days	Total	Unadjusted Odds Ratio	95% CI	Overall *P* Value for Each Crowding Measure
Mean ED LOS, No. (%), h						<.001
<2	46,241 (6.6)	10 (1.6)	46,302 (6.6)	1.00		
2–<3	174,411 (24.7)	87 (14.0)	174,498 (24.7)	2.31	1.20–4.44	
3–<4	267,320 (37.9)	240 (38.5)	267,560 (37.9)	4.16	2.21–7.82	
4–<5	152,713 (21.7)	193 (31.0)	152,906 (21.7)	5.85	3.10–11.05	
5–<6	46,316 (6.6)	62 (10.0)	46,378 (6.6)	6.20	3.17–12.09	
6–<7	13,164 (1.9)	18 (2.9)	13,182 (1.9)	6.33	2.92–13.72	
7–<8	3,382 (0.5)	6 (1.0)	3,388 (0.5)	8.21	2.98–22.61	
≥8	1,467 (0.2)	7 (1.1)	1,474 (0.2)	22.09	8.40–58.12	
Missing	11	0	11			
Mean ED occupancy ratio during ED visit by quartile, No. (%)						<.001
1 (0.04–0.94)	176,331 (25.0)	109 (17.5)	176,440 (25.0)	1.00		
2 (0.94–1.25)	179,216 (25.4)	164 (26.3)	179,380 (25.4)	1.48	1.16–1.89	
3 (1.25–1.54)	175,192 (24.8)	183 (29.4)	175,375 (24.9)	1.69	1.33–2.14	
4 (1.54–3.11)	174,061 (24.7)	167 (26.8)	174,228 (24.7)	1.55	1.22–1.98	
Missing	276	0	276			

identified would have been different if other measures of ED crowding (eg, the National ED Overcrowding Scale) had been used.

In regard to external validity, the organization was essentially unaltered as pertains to staffing and how ED work was organized during the study period. The results are thus likely to be generalizable to other EDs in a Swedish context because both health care and ED care are organized within the national health care system and are tax funded and thus similarly configured across the entire country. Also, generalization to other countries with similar demographics and health care systems is likely possible because ED crowding is an international problem partly related to an increasingly ageing population, a shortage of inhospital beds, and long ED length of stay. In most Swedish EDs, patients are cared for at different treatment areas in the ED according to their chief complaints (eg, at an orthopedic area or an internal medicine area). In contrast, in many Anglo-Saxon countries (United States, Canada, United Kingdom, Ireland, Australia, and New Zealand) EDs are organized with treatment areas based on triage levels (eg, acute or minor need of care). In a Swedish context, it might have been more suitable to use treatment area in the ED instead of triage level when calculating the mean ED length of stay. However, using triage level makes it easier to generalize the results to an international ED context. The choice of 10-day mortality as outcome measure, instead of the more commonly used 7-day mortality, made it possible to capture more events of short-term mortality, but this makes it more difficult to compare the results with those of other studies. However, there is no consistent way of presenting mortality in the literature.

DISCUSSION

Our findings from a large sample during an 8-year period showed that a relatively large proportion of the patients with triage acuity levels 3 to 5, without need of acute hospital care on departure from the ED, and who died within 10 days were aged 80 years or older, had been allocated to more urgent triage acuity levels (ie, 3 [yellow]), and had higher comorbidity than those who did not die. However, after adjusting for confounders there was still an increased risk of 10-day mortality when the mean ED length of stay was greater than 8 hours compared with less than 2 hours and for elevated ED occupancy ratio (quartiles 2 to 4 versus quartile 1).

The group of patients assigned to lower triage acuity levels and without need of acute hospital care on departure from the ED (ie, patients who are not expected to die shortly after discharge) has not been a common study object of interest,

Table 5. Adjusted odds ratios and 95% CIs for 10-day mortality within the group of patients with RETTS triage acuity levels 3 to 5 and without need of acute hospital care on departure from the ED (n=705,699).

Independent Variables	Adjusted Odds Ratio*	95% CI	Overall *P* Value for Each Crowding Measure
Mean ED LOS, h			.03
<2	1 [Reference]		
2–<3	1.68	0.87–3.24	
3–<4	1.81	0.92–3.55	
4–<5	1.79	0.90–3.54	
5–<6	1.80	0.88–3.69	
6–<7	1.98	0.88–4.47	
7–<8	2.49	0.88–7.09	
≥8	5.86	2.15–15.94	
ED occupancy ratio (n) by quartile			.01
1 (0.04–0.94)	1 [Reference]		
2 (0.94–1.25)	1.48	1.14–1.92	
3 (1.25–1.54)	1.63	1.24–2.14	
4 (1.54–3.11)	1.53	1.15–2.03	

*Odds ratios of 2 separate multivariable logistic regression models controlling for age, sex, triage acuity level, number of ED visits during the previous year, ACCI score, arrival by EMS transport, arrival time of day, chief complaint, and ED site.

even when such studies have been called for.[24] Most previous research has focused on outcomes for critically ill patients and those in need of inhospital admission.[6,9,13,24-28] However, 1 study based on Medicare claims showed that 12,375 of 10,093,678 discharged patients (0.12%) died within 7 days despite that no diagnosis of a life-threatening illness was recorded in their claims.[29] No explanation for this association was identified. The study by Guttmann et al[8] identified an association between ED crowding, measured as increased mean ED length of stay, and short-term mortality. The authors included discharged patients from all triage acuity levels, presented in subgroups of high versus low triage acuity scores. The mortality rate in our study is higher than in the subgroup with low triage acuity levels in the study by Guttmann et al[8] (0.087% versus 0.027%). When the mortality rate in our study was broken down to triage levels, patients with triage acuity level 3 had a mortality rate of 0.16% compared with 0.06% for those with triage acuity level 4 and 0.03% for triage acuity level 5. Thus, the majority of the patients in our study who died within 10 days after ED discharge were allocated to triage acuity level 3. The differences between the mortality rates in the 2 studies might be explained by the fact that different triage scales were used (RETTS versus CTAS), and these cannot automatically be compared. Thus, it is possible that the group of patients triaged to lower triage acuity levels in the study by Guttmann et al[8] contained different patients than our study did, even if, according to us, RETTS triage levels 3 to 5 can be interpreted to CTAS triage levels 4 to 5, rather than CTAS levels 3 to 5. Another possible explanation is that our study extended the range for short-term mortality from 7 to 10 days to capture more patients with short-term mortality,[8,23] and 31% of all deaths took place during days 8 to 10. Thus, we believe that the results in our study are in line with those published by Guttmann et al[8] concerning the association between an increased mean ED length of stay and short-term mortality. Furthermore, we conducted manual electronic health record audits of all patients who died within 10 days. Through these audits, it was found that many of the patients with 10-day mortality had high comorbidity (eg, cancer in a palliative stage, severe heart failure); however, on only 8 occasions was it mentioned in the physicians' chart notes for the ED visit that short-term mortality was expected.

We found that an ED occupancy ratio less than 1 was not as common during the night shift compared with the day shift, probably because there are fewer patients seeking ED care during the night compared with the day and evening, but the number of beds is constant. Furthermore, an increased ED occupancy ratio was associated with 10-day mortality in the current study. This result adds to the body of knowledge in regard to short-term mortality as an outcome measure when ED occupancy ratio is studied[9,10,24,27] because our study focused on patients assigned to lower triage acuity levels rather than critically ill patients and those in need of inhospital care.[9,24,27] To our knowledge, only one study has included both discharged and admitted patients.[10] Furthermore, our results show that an increased mean ED length of stay was also associated with 10-day mortality even when the patients were assigned to lower triage acuity levels and without need of acute hospital care on departure from the ED.

In summary, our results identified an increased risk of 10-day mortality among patients triaged to lower triage acuity levels and without need of acute hospital care on departure from the ED when the mean ED length of stay exceeded 8 hours (>8 hours compared with <2 hours), as well as when ED occupancy ratio increased (quartiles 2 to 4 versus quartile 1). Further research is called for to investigate why increased ED length of stay and ED occupancy ratio are associated with increased short-term mortality.

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Author affiliations: From the Department of Medicine, Solna (Berg, Östergren, Göransson) and Department of Neurobiology, Care Sciences and Society, Division of Nursing (Berg, Florin), Unit of Biostatistics, Institute of Environmental Medicine (Discacciati), Karolinska Institutet, Stockholm, Sweden; the Functional Area of Emergency Medicine Solna (Berg, Östergren) and Emergency Medicine Function (Göransson), Karolinska University Hospital, Stockholm, Sweden; and the School of Education, Health and Social Studies, Dalarna University, Falun, Sweden (Ehrenberg, Florin).

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REFERENCES

1. Boyle A, Beniuk K, Higginson I, et al. Emergency department crowding: time for interventions and policy evaluations. *Emerg Med Int*. 2012;2012:838610.
2. Health and Social Care Inspectorate. *Hur Står Det Till Med Våra Akutmottagingar (How Are Our Emergency Departments Doing)?* Stockholm, Sweden: Health and Social Care Inspectorate; 2015.
3. Kocher KE, Asplin BR. Emergency department crowding 2.0: coping with a dysfunctional system. *Ann Emerg Med*. 2012;60:687-691.
4. Chiu IM, Lin YR, Syue YJ, et al. The influence of crowding on clinical practice in the emergency department. *Am J Emerg Med*. 2018;36:56-60.
5. van der Linden N, van der Linden MC, Richards JR, et al. Effects of emergency department crowding on the delivery of timely care in an inner-city hospital in the Netherlands. *Eur J Emerg Med*. 2016;23:337-343.
6. McCarthy ML, Zeger SL, Ding R, et al. Crowding delays treatment and lengthens emergency department length of stay, even among high-acuity patients. *Ann Emerg Med*. 2009;54:492-503.e4.
7. Van Der Linden MC, Khursheed M, et al. Two emergency departments, 6000 km apart: Differences in patient flow and staff perceptions about crowding. *Int Emerg Nurs*. 2017;35:30-36.
8. Guttmann A, Schull MJ, Vermeulen MJ, et al. Association between waiting times and short term mortality and hospital admission after departure from emergency department: population based cohort study from Ontario, Canada. *BMJ*. 2011;342:d2983.
9. Jo S, Jeong T, Jin YH, et al. ED crowding is associated with inpatient mortality among critically ill patients admitted via the ED: post hoc analysis from a retrospective study. *Am J Emerg Med*. 2015;33:1725-1731.
10. Jo S, Jin YH, Lee JB, et al. Emergency department occupancy ratio is associated with increased early mortality. *J Emerg Med*. 2014;46:241-249.
11. Paton A, Mitra B, Considine J. Longer time to transfer from the emergency department after bed request is associated with worse outcomes. *Emerg Med Australas*. 2018;31:211-215.
12. Eriksson J, Gellerstedt L, Hilleras P, et al. Registered nurses' perceptions of safe care in overcrowded emergency departments. *J Clin Nurs*. 2017;27:e1061-e1067.
13. Sun BC, Hsia RY, Weiss RE, et al. Effect of emergency department crowding on outcomes of admitted patients. *Ann Emerg Med*. 2013;61:605-611.e6.
14. Asplin BR. Measuring crowding: time for a paradigm shift. *Acad Emerg Med*. 2006;13:459-461.
15. McCarthy ML, Aronsky D, Jones ID, et al. The emergency department occupancy rate: a simple measure of emergency department crowding? *Ann Emerg Med*. 2008;51:15-24, e1-2.
16. Nissen L, Kirkegaard H, Perez N, et al. Inter-rater agreement of the triage system RETTS-HEV. *Eur J Emerg Med*. 2014;21:37-41.
17. Perez N, Nissen L, Nielsen RF, et al. The predictive validity of RETTS-HEV as an acuity triage tool in the emergency department of a Danish regional hospital. *Eur J Emerg Med*. 2016;23:33-37.
18. Wireklint SC, Elmqvist C, Parenti N, et al. A descriptive study of registered nurses' application of the triage scale RETTS(c); a Swedish reliability study. *Int Emerg Nurs*. 2018;38:21-28.
19. Bullard MJ, Musgrave E, Warren D, et al. Revisions to the Canadian Emergency Department Triage and Acuity Scale (CTAS) guidelines 2016. *CJEM*. 2017;19:S18-S27.
20. Agency for Healthcare Research and Quality. *Emergency Severity Index (ESI): A Triage Tool for Emergency Department Care*. 2012; Available at: https://www.ahrq.gov/professionals/systems/hospital/esi/index.html. Accessed June 4, 2019.
21. Kaji AH, Schriger D, Green S. Looking through the retrospectoscope: reducing bias in emergency medicine chart review studies. *Ann Emerg Med*. 2014;64:292-298.
22. Charlson ME, Pompei P, Ales KL, et al. A new method of classifying prognostic comorbidity in longitudinal studies: development and validation. *J Chronic Dis*. 1987;40:373-383.
23. Forster AJ, Rose NG, van Walraven C, et al. Adverse events following an emergency department visit. *Qual Saf Health Care*. 2007;16:17-22.
24. Verelst S, Wouters P, Gillet JB, et al. Emergency department crowding in relation to in-hospital adverse medical events: a large prospective observational cohort study. *J Emerg Med*. 2015;49:949-961.
25. Goulet H, Guerand V, Bloom B, et al. Unexpected death within 72 hours of emergency department visit: were those deaths preventable? *Crit Care*. 2015;19:154.
26. Mathews KS, Durst MS, Vargas-Torres C, et al. Effect of emergency department and ICU occupancy on admission decisions and outcomes for critically ill patients. *Crit Care Med*. 2018;46:720-727.
27. Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. *Med J Aust*. 2006;184:213-216.
28. Sprivulis PC, Da Silva JA, Jacobs IG, et al. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *Med J Aust*. 2006;184:208-212.
29. Obermeyer Z, Cohn B, Wilson M, et al. Early death after discharge from emergency departments: analysis of national US insurance claims data. *BMJ*. 2017;356:j239.