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The impact of emergency department crowding on admission decisions and patient outcomes

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ABSTRACT

Objectives: The objective of this study is to evaluate the impact of emergency department (ED) crowding levels on patient admission decisions and outcomes.
Methods: A retrospective study was performed based on 2-year electronic health record data from a tertiary care hospital ED in Alberta, Canada. Using modified Poisson regression models, we studied the association of patient admission decisions and 7-day revisit probability with ED crowding levels measured by: 1) the total number of patients waiting and in treatment (*ED census*), 2) the number of boarding patients (*boarder census*), and 3) the average physician workload, calculated by the total number of ED patients divided by the number of physicians on duty (*physician workload census*). The control variables included age, gender, treatment area, triage level, and chief complaint. A subgroup analysis was performed to evaluate the heterogeneous effects among patients of different acuity levels.
Results: Our dataset included 141,035 patient visit records after cleaning from August 2013 to July 2015. The patient admission probability was positively correlated with ED census (relative risk [RR] = 1.006, 95% confidence interval [CI] = 1.005 to 1.007) and physician workload census (RR = 1.029, 95% CI = 1.027 to 1.032), but inversely correlated with boarder census (RR = 0.991, 95% CI = 0.989 to 0.993). We further found that the 7-day revisit probability of discharged patients was positively associated with boarder census (RR = 1.009, 95% CI = 1.004 to 1.014).
Conclusions: Patient admission probability was found to be directly associated with ED census and physician workload census, but inversely associated with the boarder census. The effects of boarder census and physician workload census were stronger for patients of triage levels 3–5. Our results suggested that (i) insufficient physician staffing may lead to unnecessary patient admissions; (ii) too many boarding patients in ED leads to an increase in unsafe discharges, and as a result, an increase in 7-day revisit probability.

1. Introduction

Emergency department (ED) crowding, defined as a situation in which the demand for emergency services exceeds the ability of ED to provide quality care within a reasonable time [1], has become a widely recognized public health problem [2,3]. As a result, ED patients often face long waiting times to be treated, which has been associated with prolonged length of stay (LOS), increased morbidity and mortality rates, decreased patient satisfaction [4-6], etc.

ED serves as the gate of hospitals and admits a significant portion of hospital inpatients. In general, the decision on whether a patient should be admitted from ED to hospital is clinical. However, recent studies have associated the admission decisions with ED crowding level, quantified by various measures [7-11]. For example, the admission decision for patients with transient ischemic attack or minor stroke was found to be positively associated with the ED LOS [7]. Similar relationship was found for discharged patients during their revisits to the ED in 7 days [8]. Both the number of patients in the waiting room and physician workload at time of patient initial assessment were found to be positively associated with the admission decision [9,11]. Increased ED census at triage was found to be associated with more patients being classified as high acuity [10]. These studies hypothesized that the increased admission probability might be attributed to physicians

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admitting more grey-zone patients, i.e., patients whose disposition decisions were ambiguous and required significant resources for a safe discharge plan, due to the pressure and information overload brought by ED crowding.

The impact of crowding on decision making has been identified in other healthcare settings. For example, one study found a correlation between the discharge rate and occupancy level in the intensive care units [12]. Another study found that higher number of boarding patients led to a change in the patient prioritization behaviors of ED decision makers [13]. Furthermore, recent studies have found that the availability of observational stays may also impact patient admission decisions due to administrative or financial incentives [14,15].

Using the input-throughput-output conceptual framework, the admission decision is critical as it lies at the interface between ED throughput and output [16]. Our work complements the previous studies by providing further evidence on how ED crowding level impacts the admission probability using data from an urban tertiary hospital in Calgary, Alberta, Canada. Our study differs from the existing work in the literature in how the ED crowding levels are measured. Specifically, we decompose the total number of patients in the ED at any given time into ED census (which counts patients waiting or in treatment) and boarder census (which counts boarding patients), so as to study their effects on the admission decisions in a more granular level for patients of different acuity levels. By including physician average workload, we investigate the impact of ED staffing level on physicians' disposition decision making when controlling the overall ED census level. We found that patients were more likely to be discharged when too many ED beds were occupied by boarders, which had a negative effect on the quality of care measured by the 7-day ED revisit probability. To the best of our knowledge, our study is among the first to separately investigate the effects of ED census, boarder census, and physician workload.

2. Methods

2.1. Study design and setting

This study was approved by the institutional review board with reference number of REB16–0441. We performed a retrospective study on patient visit data collected from an urban tertiary care hospital in Alberta, Canada with 146,743 visit records during a 2-year time period from August 1, 2013 to July 31, 2015. During the study period, the triage protocol in use was the Canadian Triage and Acuity Scale (CTAS), which classifies patients into five severity levels from 1 (most urgent) to 5 (least urgent). The ED is divided into the main ED area and a fast-track line. The main area receives urgent patients and fast-track sees non-urgent patients. At the time of the study, the main ED had 50 beds and operated 24 h per day and 7 days per week, and the fast-track area had 8 beds and was open 14 h per day from 10 AM to midnight.

2.2. Data analysis

Each observation in our data contains a patient's triage information, triage time, initial assessment time (time at which the patient is first seen by a physician), bed request time for admit patients (start time of boarding), last contact time (time at which the patient leaves the ED), and disposition. We removed the first 600 observations to avoid censored estimates.

Patients whose dispositions were not “admit” or “discharge” (including “left without being seen”, “left against medical advice”, “transfer”, etc.) were excluded. Furthermore, observations with incomplete or wrong entries, such as a negative age or negative waiting time, were dropped. There were 141,035 observations after cleaning, among which, there were 32,477 admissions and 108,558 discharges. Fig. 1 provides a detailed illustration of the data cleaning process. All visit records were de-identified to protect the privacy of the patients and medical personnel.

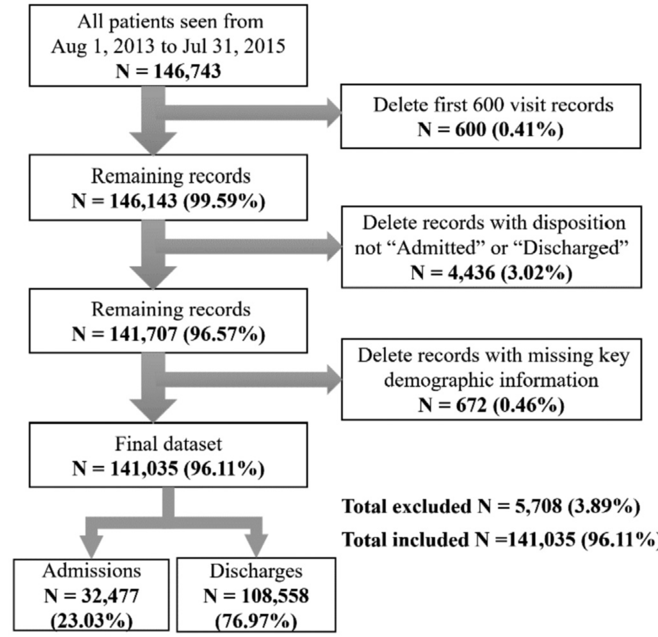

Fig. 1. A flowchart for the data selection process.

The binary response variable is a patient's disposition (admit = 1, discharge = 0). The explanatory variables of interests in our study include patients' age, gender (male or female), arrival mode (walk-in or by ambulance), treatment area (main area or fast-track), triage level, and chief complaint code. To capture the potential nonlinear effect of a patient's age on the admission probability, we classified age into 5 groups (in years): 0 to 18, 18 to 40, 40 to 55, 55 to 70, and over 70, and included age group in the model as a categorical variable. The chief complaint codes of patients have 170 categories. In the model, we kept the 50 most frequent categories and classified the remaining into a single category “Others.”

ED crowding level is of primary interest. We define three variables to measure the ED crowding level: ED census, boarder census and physician workload census. At time of a patient's disposition decision, ED census is the total number of patients waiting to be seen and patients whose treatment are in process, boarder census is the number of boarding patients, and physician workload census is calculated by the total number of patients in the ED divided by the number of physicians on duty. Table 1 shows the summary statistics of all variables except for the chief complaint codes, which is provided in Table S1 in the supplement material.

2.3. Statistical modelling

Prior to model fitting, we applied the AIC-based forward variable selection, and the results showed that all control variables discussed above should be included in the final model. The generalized variance-inflation factors (GVIFs) for all control variables were computed and no significant multicollinearity was found [17]. Detailed analysis results can be found in Tables S2 and S3 in the supplement material.

To study the impact of ED census, boarder census, and physician workload on patient admission probability, we fitted a multivariable modified Poisson regression model using all patient visit records data with R (version 3.6) [18]. We chose the modified Poisson model over the popular logistic regression model due to that the odds ratio reported by the logistic regression model is often misinterpreted as a relative risk, which leads to potential exaggeration [19,20]. In contrast, modified

Table 1
Characteristics of study sample stratified by triage level (CTAS). ED census, boarder census, and physician workload census were measured at the time of admission decisions.

Variable	All patients	CTAS 1&2	CTAS 3	CTAS 4&5
Observations	141,035	53,233	54,910	32,892
ED Census				
Mean (SD)	44.52 (12.10)	44.14 (12.38)	44.71 (12.03)	44.84 (11.76)
Median & Range	45 & (1, 84)	45 & (2, 82)	46 & (1, 84)	46 & (5, 81)
Boarder Census				
Mean (SD)	8.99 (4.51)	9.07 (4.54)	9.07 (4.51)	8.73 (4.45)
Median & Range	8 & (0, 34)	8 & (0, 34)	8 & (0, 33)	8 & (0, 33)
Physician Workload Census				
Mean (SD)	11.64 (3.70)	12.04 (3.92)	11.61 (3.64)	11.04 (3.35)
Median & Range	10.8 & (0.3, 34.5)	11.0 & (0.3, 34.5)	10.8 & (0.4, 34.5)	10.33 & (3.5, 34.5)
Age Groups (%)				
0–18 years	1.66%	1.53%	1.51%	2.13%
18–40 years	38.15%	32.65%	38.66%	46.21%
40–55 years	21.56%	22.26%	20.93%	21.48%
55–70 years	19.32%	21.99%	18.60%	16.18%
Over 70 years	19.31%	21.57%	20.30%	14.00%
Disposition (Admit %)	23.03%	35.79%	19.88%	7.63%
Gender (Female %)	51.79%	48.40%	54.85%	52.17%
Arrival Mode (%)				
Ambulance	28.96%	41.46%	26.02%	13.62%
Walk-in	71.04%	58.54%	73.98%	86.38%
Treatment Area (Main %)	82.34%	93.71%	82.42%	63.79%

Note. CTAS = Canadian Triage and Acuity Scale; ED = emergency department; SD = standard deviation.

Poisson models can directly estimate the relative risk. We then used the same modified Poisson regression model with the 7-day revisit probability as the response variable to study the impact of ED crowding on patient outcomes. To further study the heterogeneity among patients of different acuity levels, we performed a subgroup analysis by classifying patients into three groups: the high-acuity group (CTAS 1&2), the middle-acuity group (CTAS 3), and the low-acuity group (CTAS 4&5).

3. Results

The regression results on all patient visit records show that all three censuses of ED crowding level were significantly associated with patient admission probability (see the first column in Table 2). Specifically, the relative risk (RR) for admission per patient increase in ED census was 1.006 (95% CI = 1.005 to 1.007), the RR for physician workload census was 1.029 (95% CI = 1.027 to 1.032), and the RR per patient increase in boarder census was 0.991 (95% CI = 0.989 to 0.993). Putting the results in a practical context, a patient is 0.6% and 2.9% more likely to be admitted when the ED census and physician workload census increase by one, respectively; the patient is 0.9% less likely to be admitted when there is one more boarding patient in the ED, while controlling for other variables.

Table 2
The RRs for admission probability and 7-day revisit probability with 95% confidence intervals. The RRs for chief complaint codes were provided in Table S4 in the supplement materials for the sake of space.

Variables	RR for admission probability	RR for 7-day revisit probability
Intercept	0.045 (0.041,0.048)	0.079 (0.067,0.092)
ED Census	1.006 (1.005,1.007)	0.999 (0.997,1.001)
Physician Workload Census	1.029 (1.027,1.032)	0.987 (0.981,0.994)
Boarder Census	0.991 (0.989,0.993)	1.009 (1.004,1.014)
Age Groups (Base = 18–40 years)		
0–18 years	1.172 (1.071,1.283)	0.531 (0.422,0.669)
40–55 years	1.429 (1.385,1.473)	0.975 (0.923,1.029)
55–70 years	1.923 (1.869,1.979)	0.934 (0.879,0.992)
Over 70 years	2.301 (2.237,2.367)	0.944 (0.880,1.013)
Gender (Base = Female)	1.172 (1.152,1.192)	1.057 (1.012,1.103)
Triage Level (Base = CTAS 1&2)		
CTAS 3	0.650 (0.636,0.663)	1.029 (0.969,1.093)
CTAS 4&5	0.354 (0.340,0.368)	1.277 (1.198,1.361)
Arrival Mode (Base = Walk-in)	1.758 (1.722,1.795)	0.879 (0.821,0.942)
Treatment Area (Base = Fast-Track)	2.650 (2.500,2.810)	1.079 (1.014,1.149)

Note. CTAS = Canadian Triage and Acuity Scale; ED = emergency department; RR = relative risk.

The results for the 7-day revisit probability are presented in the second column of Table 2. ED census was not significantly associated with the 7-day revisit (RR = 0.999, 95% CI = 0.997 to 1.001). The RR for boarder census was 1.009 (95% CI = 1.004 to 1.014), suggesting that boarder census was positively associated with the 7-day revisit probability. The RR for physician workload census was 0.987 (95% CI = 0.981 to 0.994), suggesting that physician workload census was reversely associated with the 7-day revisit probability.

The results from the subgroup analysis (Table 3) show that the effects of all three ED censuses are significant for each subgroup, indicating the admission probability for patients of different acuity levels are all affected by ED crowding censuses. However, we also observed that the effects of physician workload census and boarder census are stronger for patients of middle-to-low acuity levels than that of high acuity levels: the RR per patient increase of physician workload census was greater for middle (RR = 1.038, 95% CI = 1.034 to 1.042) and low acuity group (RR = 1.053, 95% CI = 1.043 to 1.063) than for high acuity group (RR = 1.022, 95% CI = 1.019 to 1.024), and the RR per patient increase of boarder census was lower for middle (RR = 0.987, 95% CI = 0.983 to 0.990) and low acuity group (RR = 0.976, 95% CI = 0.968 to 0.985) than for high acuity group (RR = 0.995, 95% CI = 0.993 to 0.998).

We further investigate the heterogeneous effects of the various measures of ED crowding on the admission probability for patients of different acuity levels. For illustration purpose, we consider a typical patient: a walk-in female with a chief complaint of abdominal pain, aged between 18 and 40, and treated in the main area. The admission probability of this patient was predicted and illustrated in Fig. 2(a)–(d) for different acuity levels when we varied the ED census, the boarder census, the physician workload census, and the ED staffing level, respectively, with all other variables fixed at their corresponding medians.

Table 3
The RRs for admission probability with 95% confidence intervals for acuity-level based subgroup analysis. The RRs for chief complaint codes were provided in Table S5 in the supplement materials for the sake of space.

Variables	CTAS 1&2	CTAS 3	CTAS 4&5
Intercept	0.040 (0.035,0.046)	0.032 (0.028,0.036)	0.013 (0.010,0.017)
ED Census	1.006 (1.005,1.006)	1.006 (1.005,1.007)	1.007 (1.004,1.010)
Physician Workload Census	1.022 (1.019,1.024)	1.038 (1.034,1.042)	1.053 (1.043,1.063)
Boarder Census	0.995 (0.993,0.998)	0.987 (0.983,0.990)	0.976 (0.968,0.985)
Age Groups (Base = 18–40 years)			
0–18 years	1.245 (1.119,1.386)	1.047 (0.872,1.256)	0.969 (0.668,1.404)
40–55 years	1.345 (1.295,1.397)	1.497 (1.415,1.584)	1.522 (1.339,1.729)
55–70 years	1.747 (1.687,1.809)	2.036 (1.932,2.146)	2.392 (2.125,2.692)
Over 70 years	1.963 (1.896,2.033)	2.511 (2.387,2.642)	3.585 (3.201,4.016)
Gender (Base = Female)	1.173 (1.149,1.198)	1.181 (1.144,1.218)	1.142 (1.064,1.227)
Arrival Mode (Base = Walk-in)	1.574 (1.535,1.615)	1.822 (1.758,1.888)	2.658 (2.440,2.894)
Treatment Area (Base = Fast-Track)	3.317 (2.955,3.723)	2.197 (2.026,2.383)	2.305 (2.027,2.621)

Note. CTAS = Canadian Triage and Acuity Scale; ED = emergency department; RR = relative risk.

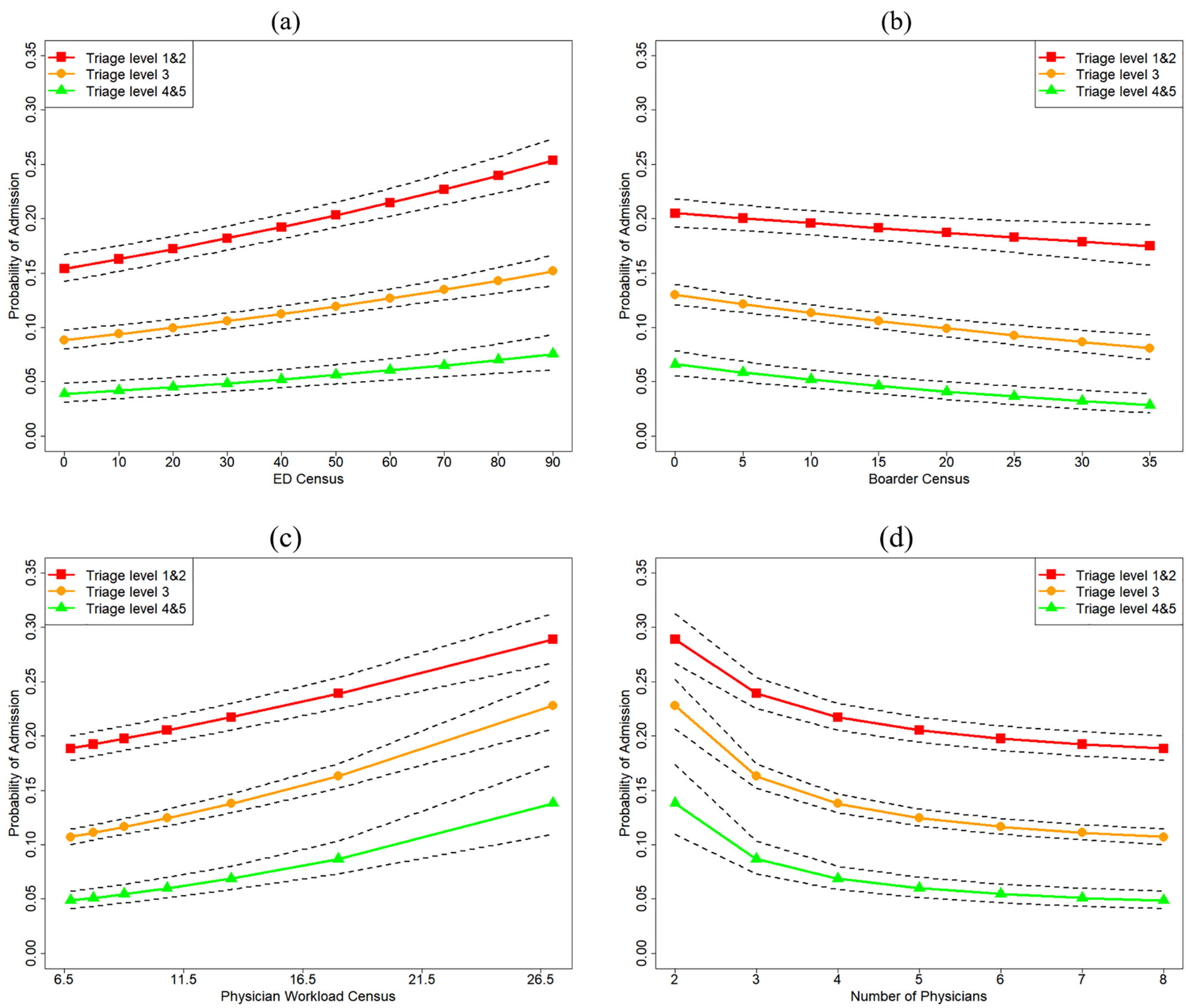

Fig. 2. Predicted probability of admission versus ED census (a), boarder census (b), physician workload census (c), and ED staffing level (d), with 95% confidence intervals in subgroup analysis, for a female patient with a chief complaint of abdominal pain, aged between18 and 40, treated in the main area.

From Fig. 2(a), we observe that the ED census has a stronger impact on high-acuity patients. Specifically, as the ED census increases from 10 to 80 patients, the probability of a high-acuity patient being admitted increases by around 7.70%, whereas the increases for middle- and low-acuity patients are 4.90% and 2.82%, respectively. In contrast, we can see from Fig. 2(b) that the boarder census has a stronger impact on middle-to-low acuity patients. As the boarder census increases from 5 to 30 patients, the decreases in admission probability for high-, middle-, and low-acuity patients are 2.15%, 3.47%, and 2.63%, respectively. Fig. 2(c) and (d) show that higher physician workload (or lower physician staffing level) leads to higher admission probability.

4. Discussion

Existing studies in the literature have found that ED crowding level affects the admission decisions [7-11]. However, by decomposing the total number of patients into patients in waiting/treatment and boarding patients, we were able to differentiate their impacts on the admission decisions and patient outcomes. Furthermore, including physician workload census in the model enabled us to explore the relationship between ED staffing level and the admission decisions.

We found that a patient was more likely to be admitted if there were more patients in ED waiting for or in treatment, or if the average physician workload is higher. When more patients are waiting or in treatment in the ED, or the average number of patients assigned to each physician increases, the physicians may be information-overloaded and tend to simplify the disposition decision making by choosing “safe-admission,” i.e., admitting more “grey-zone” patients since safe discharge of such patients requires further assessment, which takes time and resources. When the ED census level is controlled, high physician workload implies insufficient staffing. Hence, we conclude that insufficient physician staffing may lead to unnecessary admissions.

On the other hand, a patient was less likely to be admitted if there were many patients waiting in ED beds to be transferred to inpatient units (i.e., boarders). As the number of boarders increases, physicians tend to discharge more patients, because boarding patients occupy ED beds for a prolonged period of time, which creates bed block and slows down ED patient flow. However, patients may be discharged inappropriately, which could have adverse effect on the patient outcome. We then studied the association between 7-day revisit probability of discharged patients and the boarder census. The RR per patient increase in boarder census 1.009 (95% CI = 1.004 to 1.014), suggesting that a discharged patient is more likely to make a revisit within 7 days when the number of boarders at the time of discharge was higher. Hence, we conclude that high number of boarders may lead to inappropriate discharge decisions.

4.1. Limitations

There were several limitations to this study. Our study was based on data from a single hospital ED in the Calgary Zone of Alberta, Canada. Hence, the findings may not apply to hospitals of different sizes or in other countries/areas. However, as shown on the website of the Canadian Institute for Health Information (CIHI) that all Canadian EDs struggle with delays to physician assessment and prolonged LOS for admitted patients [21]. Hence, we believe that the problem is arguably as great in any other ED. Our collaborating physician works in multiple EDs in the Calgary Zone, and his experiences also confirm this insight. Nevertheless, it would be helpful to conduct further analysis using data from other hospitals.

We mainly used patient counts to measure the ED crowding level. Other measures, such as patient length of stay, waiting time from triage to initial physician assessment, and time from bed request to bed assignment should be explored [22]. Physicians may exhibit heterogeneous behaviors in their disposition decision making. Hence, it would be of interest to control physician characteristics in the model. We used the 7-day revisit probability as a measure of the patient outcome. Other measures on quality of care, such as 48- or 72-h revisit probability, can be further explored.

Recently, interviews with emergency physicians in the United States and England found that the availability of observational stays impacts a patient's admission probability, potentially due to administrative and financial considerations [14,15]. Observational Units (or Clinical Decision Units) existed in some Canadian hospitals [23]. However, we believe that patient admission decisions were not affected in Canadian hospitals since the government is the single payer of healthcare costs and no one benefits financially from extra admissions. But it would be of interest to investigate the impact of observational stays using data so as to provide direct evidence.

5. Conclusions

In this study, we found that patient admission probability was positively associated with the average physician workload, suggesting that insufficient staffing level may lead to unnecessary admissions. We also found that the number of boarding patients was reversely associated with patient admission probability and was positively associated with the 7-day revisit probability, suggesting that too many boarding patients occupying ED beds may lead to inappropriate patient discharge. Our study provides further evidence that ED crowding may have impact on the disposition decisions by physicians and thus on patient outcomes.

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Prior presentations

None.

Author contributions

Dr. Ouyang conceptualized the study, obtained funding, and critically reviewed and revised the original draft. Junyan Wang performed data analysis and drafted the initial manuscript. Dr. Sun conceptualized the study, obtained funding, oversaw data curation, formal analysis as well as manuscript preparation. Dr. Lang conceptualized the study, supervised data curation, and reviewed and revised the original draft. All authors helped edit and approved the final version of the manuscript.

Declaration of Competing Interest

HO, JW, ZS, and EL report no conflict of interest.

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None.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajem.2021.10.049.

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