IMPACT OF EMERGENCY DEPARTMENT OVERCROWDING ON PATIENT OUTCOMES AT A TERTIARY CARE TEACHING HOSPITAL

Rahul Nayyar[1*], Bipul Kumar Singh[2], Himanshu Prusty[3], Surbhi Gaur[4], Pramod Kumar[5]

[1*]Department of Hospital Administration, Mahatma Gandhi Medical College and Hospital, Jaipur.
[2]Department of Hospital Administration, Army Hospital Referral & Research, Delhi.
[3]Military Hospital, Jaipur.
[4]Department of Hospital Administration, Mahatma Gandhi Medical College and Hospital, Jaipur.
[5]Department of Hospital Administration, Mahatma Gandhi Medical College and Hospital, Jaipur.

Corresponding Author: Rahul Nayyar
Department of Hospital Administration, Mahatma Gandhi Medical College and Hospital Jaipur.

ABSTRACT

Background: Emergency department (ED) overcrowding may delay care and adversely affect patient outcomes, particularly in high-volume tertiary hospitals.

Objective: To evaluate the association between ED overcrowding, care-process delays, and adverse patient outcomes at a tertiary care centre.

Methods: This prospective observational cohort study included 600 consecutive ED patients. Overcrowding was defined as an occupancy ratio >100% at arrival. Outcomes included time to physician assessment, time to treatment, ED length of stay, premature departure, ICU transfer, in-hospital death, 72-hour revisit, and a composite adverse outcome. Multivariable models adjusted for demographic characteristics, triage category, comorbidity, arrival mode, shift, and NEWS2 score.

Results: Overcrowding occurred in 340 patients (56.7%). It was associated with adjusted median delays of 20.5 minutes to physician assessment, 25.6 minutes to treatment, and 53.5 minutes in ED length of stay (all p<0.001). The composite adverse outcome was more frequent during overcrowding (25.3% vs 15.4%; risk ratio 1.64, 95% CI 1.17–2.31). Overcrowding remained independently associated with the composite outcome (adjusted odds ratio 1.91, 95% CI 1.20–3.03) and doubled the risk of leaving early.

Conclusion: ED overcrowding was associated with delayed care, prolonged stay, premature departure, and increased overall adverse outcomes.

Keywords: Emergency Department Overcrowding, Patient Outcomes, Occupancy Ratio, Treatment Delay, Tertiary Care.

INTRODUCTION

Emergency department (ED) overcrowding occurs when the demand for emergency care exceeds the available clinical space, staffing, diagnostic capacity, or access to inpatient beds. It is increasingly recognised as a system-level failure rather than simply a consequence of high patient attendance, reflecting interacting problems in patient inflow, internal processing, boarding, and hospital discharge. Across diverse healthcare settings, ED overcrowding has been associated with delayed care, reduced operational efficiency, and poorer patient outcomes [1,2].

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Crowding may be particularly pronounced in tertiary-care hospitals because of high referral volumes, greater clinical complexity, limited inpatient bed availability, and prolonged boarding of patients awaiting admission. Operational bottlenecks after the initial ED assessment can further impede patient flow. These may include delayed responses to specialty or subspecialty consultation requests, sequential cross-referrals among multiple departments, and uncertainty regarding which service should assume responsibility for admission. In institutions where resident physicians require approval from senior specialists before making definitive admission decisions, additional delays may occur. Admission decisions may also be deferred until laboratory or imaging results become available. Collectively, these consultation, diagnostic, and decision-making delays may prolong ED length of stay, increase boarding, and perpetuate overcrowding [1,2].

Several operational measures have been used to quantify ED crowding, including waiting-patient counts, boarding time, ED length of stay, and composite crowding scores. The ED occupancy ratio is particularly practical because it relates the number of patients physically present in the ED to the number of available treatment spaces and can be calculated in real time [3].

ED overcrowding has important clinical implications. It has been associated with delayed antibiotic administration in patients with pneumonia [4], delayed or inadequate analgesia for severe pain [5], and delays in diagnostic and therapeutic procedures. Such delays may be particularly harmful in time-sensitive conditions, including sepsis, acute coronary syndromes, stroke, trauma, and respiratory failure.

Crowding has also been associated with increased mortality, longer hospitalisation, and greater healthcare expenditure. Richardson reported increased 10-day mortality during periods of ED overcrowding [6], whereas Sun et al. found higher inpatient mortality, longer hospital stays, and greater costs among patients admitted during highly crowded periods [7]. Higher ED occupancy ratios have also been associated with increased early mortality [8]. In addition, crowding may increase the likelihood of patients leaving without being seen or before treatment is completed, prolong ED stay, and contribute to unplanned return visits [9].

Despite substantial international evidence, the causes and consequences of ED overcrowding may vary according to local staffing structures, consultation pathways, diagnostic capacity, referral practices, admission governance, and inpatient bed availability. Evidence from tertiary-care centres in resource-limited settings remains limited. Therefore, the present study aimed to evaluate the association between ED overcrowding and patient outcomes at a tertiary-care centre. Specifically, it assessed crowding using the ED occupancy ratio and other operational indicators, compared care-process and clinical outcomes between overcrowded and non-overcrowded periods, and identified independent predictors of adverse outcomes.

METHODS

Study design and setting

A prospective, single-centre, hospital-based observational cohort study was conducted in the emergency department (ED) of a tertiary care centre from 1 January to 31 December 2025. The ED had a nominal capacity of 48 treatment beds, with the number of functional beds recorded at each patient arrival. Consecutive eligible patients were enrolled until the target sample of 600 participants was reached. Exposure status was assigned according to ED operational conditions at the time of arrival. Participants were followed through hospital discharge and, where applicable, for 72 hours after ED discharge or premature departure.

Study population and data collection

The cohort comprised patients presenting for emergency care across all age groups and triage categories during the recruitment period. Each enrolled patient was assigned a unique study identifier and linked to the hourly ED operational snapshot corresponding to the time of arrival. Patient-level variables recorded at presentation included age, sex, Emergency Severity Index (ESI) triage category, arrival mode, arrival date and shift, National Early Warning Score 2 (NEWS2), and comorbidity burden measured using the Charlson Comorbidity Index. Shifts were defined as day (08:00-15:59), evening (16:00-23:59), and night (00:00-07:59).

Operational variables recorded at arrival included the number of functional ED beds, number of patients physically present, waiting-patient count, boarding-patient count, inpatient bed occupancy, and National Emergency Department Overcrowding Scale (NEDOCS) score. Time stamps for arrival, initial physician assessment, treatment initiation, and physical departure from the ED were used to derive care-process intervals. Disposition, intensive care unit (ICU) transfer, in-hospital death, and 72-hour ED revisit were ascertained from the hospital record.

Exposure assessment

The primary exposure was the ED occupancy ratio at the time of patient arrival, calculated as:

ED occupancy ratio (%) = patients physically present in the ED / functional ED beds × 100

An occupancy ratio of 100% or less was classified as non-overcrowded, whereas a ratio greater than 100% was classified as overcrowded. The binary classification was used for the primary analyses. The occupancy ratio was also analysed as a continuous measure in a prespecified sensitivity analysis. Waiting-patient count, boarding-patient count, boarding burden, inpatient bed occupancy, and NEDOCS score were examined as secondary operational indicators. Boarding burden was calculated as the number of boarding patients divided by the number of functional ED beds, multiplied by 100.

Outcome definitions

The primary outcome was a composite adverse patient outcome, defined as the occurrence of at least one of the following: in-hospital death, direct ICU admission or ICU transfer within 24 hours of ED arrival, an unplanned ED revisit within 72 hours, or premature departure from the ED. Premature departure included leaving without being seen and leaving before completion of treatment.

Secondary clinical outcomes were hospital admission and the individual components of the primary composite. Unplanned 72-hour revisit was evaluated among patients discharged from the ED or leaving prematurely. Care-process outcomes were time from ED arrival to initial physician assessment, time from arrival to initiation of treatment, and ED length of stay, defined as the interval from arrival to physical departure from the ED.

Sample size

The sample size was based on comparison of two independent proportions. Assuming a composite adverse outcome rate of 15% during non-overcrowded periods and 25% during overcrowded periods, a two-sided α of 0.05, 80% power, and equal allocation, approximately 250 patients were required in each exposure group. Allowing 10% for incomplete records or unavailable outcome data yielded a minimum target of 550. A final recruitment target of 600 consecutive patients was selected to provide adequate precision and support multivariable adjustment.

Statistical analysis

Categorical variables were summarised as n (%) and continuous variables as mean (SD) or median (IQR), as appropriate. Welch's t test, Mann-Whitney U test, Pearson's chi-square test, or Fisher's exact test were used to compare overcrowded and non-overcrowded groups. Risk ratios with 95% confidence intervals (CIs) were presented for binary outcomes, and the primary composite outcome was also presented as absolute risk difference. Median regression was used to analyze care-process times and multivariable logistic regression was used to analyze the composite adverse outcome, after adjusting for the associations. The models comprised age, sex, Emergency Severity Index category, Charlson Comorbidity Index, mode of arrival, shift and NEWS2 score. The occupancy ratio was used in a sensitivity analysis, which was modelled continuously per 10 percentage points increase. The 72-hour revisit analysis was limited to patients who were discharged or left early. Tests were two-tailed and $p<0.05$ was deemed statistically significant. The data were analyzed in SPSS version 26 and R. The study protocol was approved by the Institutional Ethics Committee of the participating tertiary care centre and the study was carried out in compliance with the Declaration of Helsinki. All participants or their legally authorised representatives gave written informed consent prior to participation.

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RESULTS

Study cohort and overcrowding exposure

All 600 enrolled patients were included in the analysis, and 72-hour outcome ascertainment was complete for all participants. The median emergency department (ED) occupancy ratio at arrival was 104.2% (IQR 95.8%-112.5%); 340 (56.7%) patients presented during overcrowded periods and 260 (43.3%) during non-overcrowded periods. Age, sex, triage category, arrival mode, comorbidity burden, and NEWS2 score were comparable between exposure groups. Arrival-shift distribution differed, with evening presentations accounting for 186 (54.7%) overcrowded arrivals compared with 71 (27.3%) non-overcrowded arrivals ($\chi^2(2)=82.35$, $p<0.001$) (Table 1).

Operational burden and care-process outcomes

Overcrowded presentations occurred under substantially greater waiting, boarding, inpatient bed-occupancy, and NEDOCS burdens (Table 2). Physician-assessment and treatment times were available for 572 (95.3%) patients. After adjustment for age, sex, triage category, Charlson Comorbidity Index, arrival mode, shift, and NEWS2 score, overcrowding was associated with a 20.5-minute longer median time to physician assessment (95% CI 17.4-23.7), a 25.6-minute longer median time to treatment (95% CI 21.9-29.2), and a 53.5-minute longer median ED length of stay (95% CI 29.0-78.0); all $p<0.001$ (Figure 1).

Clinical outcomes

The composite adverse outcome occurred in 86 (25.3%) patients presenting during overcrowded periods and 40 (15.4%) presenting during non-overcrowded periods, corresponding to a risk ratio of 1.64 (95% CI 1.17-2.31), an absolute risk difference of 9.9 percentage points (95% CI 3.5-16.3), and $p=0.003$. Leaving early was also more frequent during overcrowding [30 (8.8%) vs 11 (4.2%); risk ratio 2.09, 95% CI 1.07-4.08; $p=0.027$]. Hospital admission, ICU transfer within 24 hours, in-hospital death, and unplanned 72-hour ED revisit did not differ significantly between exposure groups (Table 3; Figure 2).

Multivariable analysis

In the adjusted logistic regression model, presentation during an overcrowded period remained independently associated with the composite adverse outcome (adjusted odds ratio 1.91, 95% CI 1.20-3.03; $p=0.006$) (Table 4). No other prespecified covariate was independently associated with the composite outcome at the 0.05 significance level. In a sensitivity model replacing the binary overcrowding indicator with the continuous occupancy ratio, each 10-percentage-point increase in occupancy was associated with higher odds of the composite outcome (adjusted odds ratio 1.25, 95% CI 1.05-1.49; $p=0.014$).

Table 1. Baseline characteristics according to ED overcrowding exposure

Characteristic	Overall (n=600)	Non-overcrowded (n=260)	Overcrowded (n=340)	Test statistic	p value
Age, years, mean (SD)	49.2 (20.9)	49.4 (20.1)	49.1 (21.4)	t(573.8)=0.16	0.875
Sex				$\chi^2(1)=0.20$	0.656
Female	312 (52.0)	132 (50.8)	180 (52.9)		
Male	288 (48.0)	128 (49.2)	160 (47.1)		
ESI triage category				$\chi^2(4)=3.54$	0.472
ESI 1	21 (3.5)	11 (4.2)	10 (2.9)		
ESI 2	125 (20.8)	55 (21.2)	70 (20.6)		
ESI 3	271 (45.2)	119 (45.8)	152 (44.7)		
ESI 4	124 (20.7)	46 (17.7)	78 (22.9)		
ESI 5	59 (9.8)	29 (11.2)	30 (8.8)		
Arrival mode				$\chi^2(2)=2.03$	0.362
Walk-in	346 (57.7)	150 (57.7)	196 (57.6)		
Ambulance	175 (29.2)	81 (31.2)	94 (27.6)		
Referred	79 (13.2)	29 (11.2)	50 (14.7)		
Arrival shift				$\chi^2(2)=82.35$	<0.001
Day	226 (37.7)	98 (37.7)	128 (37.6)		
Evening	257 (42.8)	71 (27.3)	186 (54.7)		
Night	117 (19.5)	91 (35.0)	26 (7.6)		
Weekend arrival	183 (30.5)	80 (30.8)	103 (30.3)	$\chi^2(1)=0.00$	0.971
NEWS2 score, median (IQR)	3.0 (1.0–5.0)	3.0 (2.0–5.0)	3.0 (1.0–5.0)	U=44356.5	0.940
Charlson Comorbidity Index, median (IQR)	1.0 (0.0–3.0)	1.0 (0.0–3.0)	1.0 (0.0–3.0)	U=43869.5	0.871

Note. Values are n (%), mean (SD), or median (IQR). Percentages are column percentages. p values were obtained using Welch's t test, Pearson's χ^2 test, or the Mann-Whitney U test, as appropriate. ED, emergency department; ESI, Emergency Severity Index; NEWS2, National Early Warning Score 2.

Table 2. Operational conditions and care-process outcomes according to ED overcrowding exposure

Measure	Non-overcrowded	Overcrowded	U statistic	p value	Adjusted median difference (95% CI); p value
Functional ED beds, median (IQR)	48 (48–48)	48 (48–48)	43364.0	0.102	—
Patients physically present, median (IQR)	45 (43–47)	54 (51–57)	21.5	<0.001	—
ED occupancy ratio, %, median (IQR)	93.8 (90.9–97.9)	112.5 (106.3–118.8)	0.0	<0.001	—
Waiting-patient count, median (IQR)	6 (4–8)	13 (10–15)	4861.0	<0.001	—
Boarding-patient count, median (IQR)	3 (1–5)	8 (6–10)	10028.5	<0.001	—
Boarding burden, %, median (IQR)	6.3 (2.1–10.4)	16.7 (12.5–20.8)	10072.5	<0.001	—
Inpatient bed occupancy, %, median (IQR)	82.8 (81.4–84.4)	85.4 (83.7–87.4)	19757.5	<0.001	—
NEDOCS score, median (IQR)	35.6 (24.9–45.4)	73.0 (61.7–85.4)	2742.5	<0.001	—
Time to physician assessment, min, median (IQR) [n=253/319]	36 (25–50)	59 (44–78)	19436.5	<0.001	20.5 (17.4–23.7); <0.001
Time to treatment, min, median (IQR) [n=253/319]	55.0 (38.0–76.0)	82.0 (62.5–105.0)	20248.0	<0.001	25.6 (21.9–29.2); <0.001
ED length of stay, min, median (IQR)	297.0 (207.5–403.2)	326.5 (233.8–516.0)	37018.5	<0.001	53.5 (29.0–78.0); <0.001

Note. Values are median (IQR). Unadjusted comparisons used the Mann-Whitney U test. Adjusted median differences were estimated by median regression with adjustment for age, sex, ESI triage category, Charlson Comorbidity Index, arrival mode, shift, and NEWS2 score; positive values indicate longer times during overcrowding. Time-to-physician and time-to-treatment analyses included 253 non-overcrowded and 319 overcrowded patients. NEDOCS, National Emergency Department Overcrowding Scale.

Table 3. Primary and secondary clinical outcomes according to ED overcrowding exposure

Outcome	**Non-overcrowded n (%)**	**Overcrowded n (%)**	**Risk ratio (95% CI)**	**Test statistic**	**p value**
Composite adverse outcome	40 (15.4)	86 (25.3)	1.64 (1.17–2.31)	$\chi^2(1)=8.72$	0.003
Hospital admission	106 (40.8)	120 (35.3)	0.87 (0.70–1.06)	$\chi^2(1)=1.88$	0.170
ICU transfer within 24 h	12 (4.6)	23 (6.8)	1.47 (0.74–2.89)	$\chi^2(1)=1.24$	0.266
In-hospital death	3 (1.2)	6 (1.8)	1.53 (0.39–6.06)	Fisher OR=1.54	0.738
Leaving early	11 (4.2)	30 (8.8)	2.09 (1.07–4.08)	$\chi^2(1)=4.88$	0.027
Left without being seen	7 (2.7)	21 (6.2)	2.29 (0.99–5.31)	Fisher OR=2.38	0.051
Left before treatment completion	4 (1.5)	9 (2.6)	1.72 (0.54–5.53)	Fisher OR=1.74	0.410
Unplanned 72-h ED revisit	14 (9.1)	29 (13.2)	1.45 (0.79–2.65)	$\chi^2(1)=1.49$	0.222

Note. Risk ratios compare overcrowded with non-overcrowded presentations. Pearson's χ^2 test was used except for in-hospital death, leaving without being seen, and leaving before treatment completion, for which Fisher's exact test was used. The 72-hour revisit analysis was restricted to patients discharged from the ED or leaving early (154 non-overcrowded and 220 overcrowded). CI, confidence interval; ICU, intensive care unit; OR, odds ratio.

Table 4. Multivariable logistic regression for the composite adverse outcome

Variable	**Adjusted odds ratio**	**95% CI**	**Wald z**	**p value**
Overcrowded (>100% vs ≤100%)	1.91	1.20-3.03	2.74	0.006
Age (per 10 years)	0.95	0.81-1.11	-0.67	0.501
Male sex (vs female)	0.67	0.44-1.01	-1.90	0.057
ESI 1 (vs 3)	2.14	0.58-7.83	1.14	0.252
ESI 2 (vs 3)	0.78	0.38-1.59	-0.69	0.490
ESI 4 (vs 3)	1.41	0.82-2.43	1.25	0.212
ESI 5 (vs 3)	1.41	0.69-2.87	0.94	0.348
Charlson index (per point)	1.09	0.96-1.25	1.30	0.193
Ambulance arrival (vs walk-in)	1.24	0.76-2.04	0.86	0.391
Referred arrival (vs walk-in)	0.73	0.37-1.41	-0.94	0.345
Evening shift (vs day)	1.30	0.82-2.06	1.12	0.261
Night shift (vs day)	1.31	0.72-2.41	0.88	0.378
NEWS2 (per point)	0.98	0.86-1.11	-0.36	0.716

Note. The model included 600 patients and 126 composite-outcome events. Reference categories were non-overcrowded, female sex, ESI 3, walk-in arrival, and day shift. Overall likelihood-ratio $\chi^2(13)=25.71$, $p=0.019$. In a separate sensitivity model, each 10-percentage-point increase in ED occupancy ratio was associated with an adjusted odds ratio of 1.25 (95% CI 1.05-1.49; $p=0.014$). CI, confidence interval; ED, emergency department; ESI, Emergency Severity Index; NEWS2, National Early Warning Score 2.

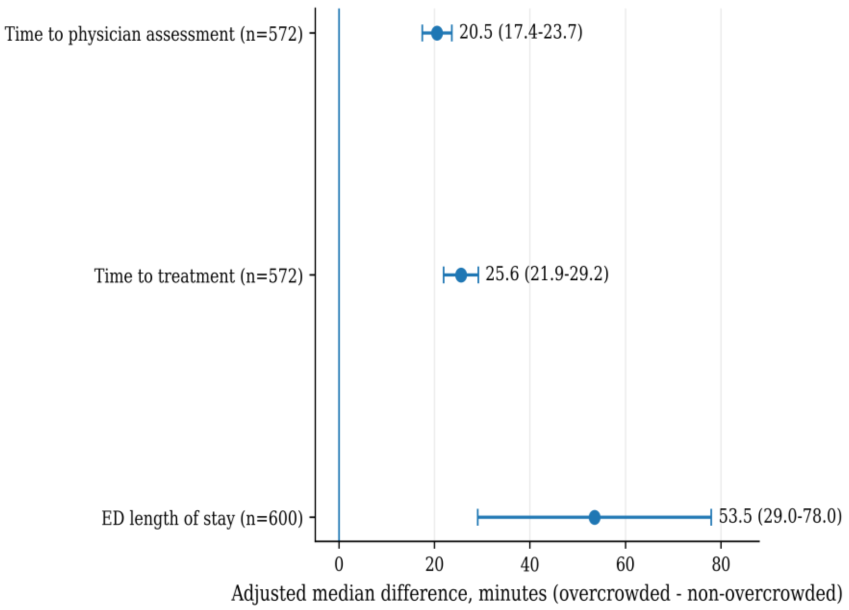

Figure 1. Adjusted differences in median care-process times associated with ED overcrowding. Points represent median-regression coefficients and bars represent 95% confidence intervals. Models were adjusted for age, sex, ESI triage category, Charlson Comorbidity Index, arrival mode, shift, and NEWS2 score. Positive estimates indicate longer times during overcrowding.

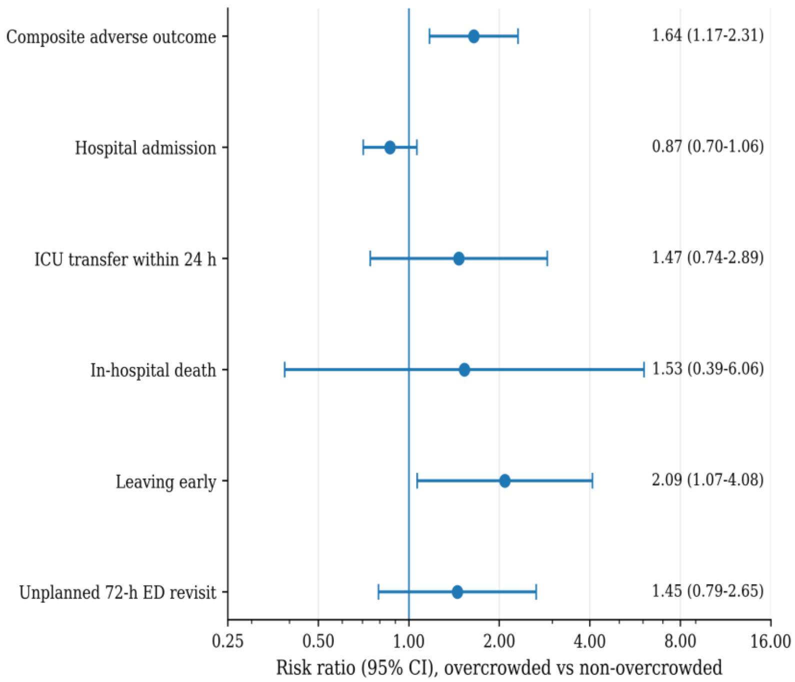

Figure 2. Risk ratios for the primary and secondary clinical outcomes among patients presenting during overcrowded versus non-overcrowded periods. Points represent risk ratios and bars represent 95% confidence intervals. The 72-hour revisit analysis was restricted to patients discharged from the ED or leaving early. CI, confidence interval; ED, emergency department; ICU, intensive care unit.

DISCUSSION

This prospective cohort study found that emergency department (ED) overcrowding was associated with clinically important care-process delays and poorer overall outcomes at a tertiary-care centre. Compared with non-overcrowded periods, overcrowding prolonged the adjusted median time to physician assessment by 20.5 minutes, time to treatment by 25.6 minutes, and ED length of stay by 53.5 minutes. The composite adverse outcome increased from 15.4% to 25.3%, and overcrowding remained independently associated with this outcome after adjustment for age, sex, triage category, comorbidity, arrival mode, shift, and NEWS2 score.

Each 10-percentage-point increase in occupancy was associated with a 25% increase in the adjusted odds of the composite outcome. Premature departure was also approximately twice as frequent during overcrowded periods.

These findings are consistent with evidence that crowding and boarding adversely affect ED flow and downstream hospital care. Singer et al. reported that mortality increased from 2.5% among patients boarded for less than 2 hours to 4.5% among those boarded for 12 hours or longer. Mean inpatient length of stay also increased from 5.6 to 8.7 days across these boarding-duration categories [10]. In the present study, overcrowded presentations were characterised by higher boarding-patient counts, boarding burden, inpatient bed occupancy, and NEDOCS scores. This pattern is compatible with exit block contributing to prolonged ED stays, although the observational design does not establish a causal direction between these operational indicators and overcrowding.

Derose et al. similarly reported that ED crowding predicted longer inpatient length of stay but was not independently associated with mortality after case-mix adjustment [11]. This finding is pertinent to the present results, in which process delays and the composite adverse outcome were significantly associated with overcrowding, whereas in-hospital mortality was not. Only nine deaths occurred in the present cohort, limiting the statistical power to identify an independent difference in this relatively rare outcome.

Mortality effects have been more apparent in substantially larger studies. Af Ugglas et al., using data from 14 Swedish EDs, found that increased crowding was associated with higher short-term mortality after adjustment for patient and operational characteristics [12]. In a national cohort of more than five million admitted patients, Jones et al. found that 30-day mortality began to increase when the interval from ED arrival to inpatient admission exceeded approximately 5 hours, with greater increases among patients waiting for 6–8 hours [13]. Although the present study did not demonstrate a statistically significant mortality difference, the dose–response association between occupancy and the composite adverse outcome supports the possibility that increasing operational strain progressively delays assessment, treatment, and disposition.

Crowding may also affect clinical decision-making and resource utilisation. Chiu et al. reported that overcrowding was associated with longer physician decision times, prolonged ED length of stay, increased laboratory testing and computed tomography use, and greater use of observation or admission [14]. In the current study, overcrowding was similarly associated with increased waiting-patient numbers, boarding burden, and care-process intervals. However, the hospital-admission rate did not differ significantly between overcrowded and non-overcrowded periods. This suggests that the principal local effect of overcrowding was impaired movement of patients through existing assessment and disposition pathways rather than an increase in the absolute volume of admissions.

Consultation and admission processes may represent additional bottlenecks within these pathways. Brick et al. found that consultation decision time accounted for a substantial proportion of total ED length of stay and that longer latency before the first consultation request and multiple consultations were independently associated with prolonged stay [17]. Geskey et al. reported that implementing a 90-minute institutional standard for completion of consultation and admission disposition reduced consultation-response time from 121 to 100 minutes and enabled patients to leave the ED approximately 18 minutes earlier [18]. These findings support the importance of prompt specialty responses and avoiding unnecessary sequential consultations.

Admission ownership and the authority to make definitive disposition decisions may also influence ED flow. Choi et al. reported that permitting emergency physicians to arrange selected medical admissions without mandatory specialty consultation reduced median ED length of stay from 673 to 237 minutes, without significant differences in interdepartmental transfer or in-hospital mortality [19]. This evidence suggests that clearly defined admission pathways and appropriately delegated decision-making authority may shorten disposition time. Nevertheless, the applicability of such arrangements depends on institutional policy, clinical complexity, specialty availability, and patient-safety safeguards.

Dependence on diagnostic results before admission may create a further delay. Li et al. demonstrated that laboratory turnaround time, testing volume, and repeated testing episodes were independently associated with longer ED stays. Each 30-minute increase in laboratory turnaround time was associated with an average 17-minute increase in ED length of stay [20]. These findings support workflows in which necessary investigations, consultations, and admission planning proceed in parallel whenever clinically appropriate, rather than requiring the sequential completion of every diagnostic step before a disposition decision is initiated.

Taken together, the available evidence indicates that delayed specialty or subspecialty consultation, multiple sequential cross-referrals, unclear responsibility for admission, dependence on senior approval, and waiting for diagnostic results are plausible mechanisms through which ED stays may become prolonged. However, consultation-request and response times, the number and sequence of specialty referrals, the seniority or decision-making authority of the assessing clinician, admitting-service ownership, and diagnostic turnaround times were not recorded in the present study. These factors should therefore be regarded as plausible operational explanations and priorities for future investigation, rather than as causes demonstrated by the current data.

Premature departure was one of the clearest individual outcomes. Fayyaz et al. reported that approximately 13% of patients in a tertiary-care ED left without being seen and that prolonged waiting was strongly associated with this outcome [15]. In the present cohort, premature departure increased from 4.2% during non-overcrowded periods to 8.8% during overcrowded periods. Although the absolute rates were lower than those reported by Fayyaz et al., the direction and magnitude of the association were similar, indicating that demand–capacity mismatch can translate directly into incomplete care. Li et al. further demonstrated that patients who leave without being seen remain clinically vulnerable: 24.8% returned to an ED within 7 days, and 11.5% of those who returned required hospital admission [16]. In the present study, the 72-hour revisit rate was numerically higher during overcrowded periods, although the difference did not reach statistical significance. These findings support treating premature departure as a patient-safety outcome rather than merely an operational performance measure.

The concentration of overcrowding during the evening shift is also important. More than half of overcrowded presentations occurred during the evening, compared with approximately one-quarter of non-overcrowded presentations. However, evening arrival was not independently associated with the composite adverse outcome after occupancy and patient characteristics were included in the multivariable model. This suggests that operational burden, rather than time of day alone, was the more relevant exposure. Nevertheless, evening staffing, availability of senior decision-makers, specialty consultation coverage, diagnostic capacity, and inpatient bed turnover may represent practical targets for intervention.

The composite outcome requires cautious interpretation. Its increase was partly driven by premature departure, whereas ICU transfer, mortality, hospital admission, and 72-hour revisit did not differ significantly when analysed individually. Composite outcomes improve statistical efficiency but combine events of differing frequency and clinical importance. Accordingly, the adjusted odds ratio of 1.91 should be interpreted as evidence of increased overall risk rather than as evidence that overcrowding doubled the risk of every individual component.

This study has several strengths. Patients were prospectively matched to the operational conditions present at the time of arrival, avoiding reliance on daily averages that may obscure shorter periods of crowding. Exposure was assessed using the occupancy ratio together with waiting-patient counts, boarding-patient counts, boarding burden, inpatient bed occupancy, and NEDOCS scores. Baseline acuity, comorbidity burden, and NEWS2 scores were comparable between exposure groups, and adjusted analyses accounted for relevant patient and presentation characteristics. Complete 72-hour outcome ascertainment and the continuous-occupancy sensitivity analysis further strengthened the consistency of the findings.

Several limitations should be acknowledged. As a single-centre observational study, the findings may not be fully generalisable and causality cannot be inferred. Some operational factors, including consultation delays, referral sequencing, admission ownership, staffing, and diagnostic turnaround times, were not measured, and process-time data were unavailable for 28 patients. The study was also not powered to assess rare outcomes such as mortality, and crowding status was based on conditions at arrival. Nevertheless, the prospective design, real-time operational measurements, complete outcome follow-up, and adjusted analyses strengthen the reliability of the findings.

CONCLUSION

ED overcrowding was independently associated with delayed assessment and treatment, prolonged ED stay, increased premature departure, and a higher composite risk of adverse outcomes. The continuous analysis suggested a dose-related relationship, supporting real-time monitoring of occupancy rather than reliance on a simple crowded/non-crowded classification. Practical responses should prioritize evening surge capacity, rapid initial assessment, active boarding management, and hospital-wide bed-flow interventions.

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