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The Impact of Hospital Bed Occupancy on Patient Flow and Emergency Department Access: A 25-Hospital Cohort Study

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ABSTRACT

Objectives: To evaluate the effect of hospital occupancy levels on inpatient and emergency department (ED) flow rates, ED length of stay (ED) and access block, and identify critical occupancy thresholds above which patient flow deteriorates.
Design: Retrospective cohort study using routinely collected administrative data.
Setting: Twenty-five public hospitals in Queensland, Australia, over a 5.5-year period (1 April 2017 to 31 August 2022).
Main Outcome Measures: ED presentation and discharge rates, inpatient admission and discharge rates, hospital occupancy levels, length of stay, access block and 4-h rule compliance.
Results: The analysis reveals a significant performance shift as hospital occupancy levels increase and identifies site-specific critical 'choke points' where patient flow deteriorates. Notably, as occupancy rises, we observed a growing divergence between ED presentations and discharge rates, and between inpatient admissions and discharges, indicating system congestion. Additionally, when assessing flow across the 25 hospitals, the data demonstrates that a 10% increase in bed occupancy rate correlates with a 0.32-h (19-min) extension in ED length of stay (or 33 min for patients admitted from the ED). Also, significant disparities in hospital operations were observed between weekends and weekdays, with weekday admissions and discharges up to three times higher than weekends, highlighting the increased operational pressure during the work week.
Conclusions: The investigation challenges the traditional 85% occupancy target, demonstrating that optimal occupancy levels vary by hospital. The study also underscores the strong correlation between hospital bed occupancy and ED access performance, with higher hospital occupancy correlating with longer ED stays and decreased adherence to performance indicators. As hospitals approach full capacity, the pressure on ED resources intensifies, resulting in longer wait times and delays in care.
JEL Classification: Emergency medicine, Health occupations, Health services administration, Statistics, epidemiology and research design

1 | Introduction

Hospital overcrowding has been recognised as a driver of access block, the unavailability of inpatient beds for emergency department (ED) patients [1]. Hospital bed occupancy is a key measure used to indicate overcrowding and health system efficiency [2], as high levels of occupancy have been linked to compromised safety and service delays [3]. Bed occupancy

Plain Language Summary

The known: Hospital overcrowding is inefficient and is associated with mortality. Traditionally, a target figure of 85% has been suggested as an optimal occupancy level to achieve good flow.

The new: Occupancy targets can be customised locally instead of adopting a one-size-fits-all target that does not account for differences in size, patient case-mix or operational characteristics of the hospital. Analysing hourly occupancy can identify the points where flow begins to degrade. Access block, length of stay and compliance with the 4-h rule worsen as occupancy increases.

The implications: Data-driven evidence can be used to identify when hospitals need to implement additional patient flow and capacity management strategies.

influences critical policy decisions, including the allocation of nursing resources [4], and raises concerns about maintaining care standards under high occupancy [5, 6].

Defined as the percentage of occupied inpatient beds, hospital bed occupancy is a vital metric for hospital administrators to balance patient care with operational efficiency. Optimal occupancy supports inpatient care and has downstream effects on other departments, notably the ED. Economic and performance pressures often drive hospitals to maintain high occupancy, often favouring high-margin treatments (i.e., services that generate greater revenue per bed-day) which can lead to ED congestion and risks to patient safety and staff well-being [7]. Traditionally, an occupancy target of 85% is commonly suggested as an optimal level to achieve good flow [8–11]. However, reliance on a single figure is an oversimplification, and there have been calls for new approaches to monitor service use and align demand with capacity [12].

Sprivulis and colleagues [13] examined the link between hospital and ED overcrowding and increased mortality rates across three hospitals in Western Australia (2000–2003) and found a significant correlation between overcrowding and mortality. Conversely, a study in Sweden (2012–2016) across six hospitals found no significant association between bed occupancy and mortality, although it noted longer ED stays and a slight rise in 7-day revisits [14]. In England (2010–2018), higher bed occupancy was positively correlated with increased overall and surgical mortality and was negatively associated with patient-reported health gains [2], while a Danish study (1995–2012) found that high occupancy rates led to a 9% rise in in-hospital and 30-day mortality [15], with off-hours admissions showing higher mortality (i.e., nights and weekends, outside routine daytime operating periods). A 2012 study of 23 public hospitals in Queensland, Australia, highlighted early discharge as a key factor in reducing occupancy and improving patient flow [16].

We conducted a comprehensive analytical study using retrospective data from emergency and inpatient encounters across 25 of Queensland's largest public hospitals. Our aim was to identify the critical occupancy threshold, or choke point, and examine its effects on key ED metrics such as length of stay, access block and the rate of inpatient admissions and discharges.

2 | Methods

2.1 | Data

The ED and inpatient data for this study were sourced from Queensland Health's Statistical Services Branch. All wards were included in occupancy calculations, except virtual wards, Hospital in the Home and wards categorised as Awaiting Ward Admission. Hospital bed capacity data were obtained from the Australian Institute of Health and Welfare (AIHW), using the counts of available beds reported for each hospital on 30 June of each year [17].

The analysis covered from 1 April 2017 to 31 August 2022 (1979 days), with trimming at both ends to exclude incomplete or unreliable data. The study included 25 Queensland public hospitals with bed capacities ranging from 83 to 1066, classified into small (< 300 beds; 10 hospitals), medium (300–800 beds; 11 hospitals) and large (> 800 beds; 4 hospitals) groups based on AIHW classifications [18]. All ED presentations and inpatient admissions during this period were included. Records with incomplete timestamps were excluded, and missing data for key flow parameters were minimal.

2.2 | Data Preparation

We created a combined dataset by linking ED presentations to subsequent inpatient admissions at the patient level using unique identifiers and timestamped transitions. Key steps in data preparation included:

- assigning arrival and departure events to hourly slots based on the year, month, day and hour of arrival/departure timestamps;
- aggregating data by hourly interval and segmenting by hospital; and
- calculating flow parameters including:
  - hourly rates of inpatient admissions and discharges
  - ED presentations and discharges
  - access block cases (the number of patients admitted from ED who were delayed from leaving the ED for more than 8 h [19])
  - mean ED length of stay (measured from time of presentation to time of discharge or admission)
  - mean ED length of stay (admitted patients) (specifically for patients later admitted as inpatients)
  - 4-h rule compliance (percentage of ED patients discharged or admitted within 4 h of arrival, formerly referred to as the National Emergency Access Target).

Access block and ED length of stay values were assigned to the hour of patient ED presentation, allowing system performance to be assessed at hourly intervals. Hourly occupancy was derived by aggregating ward-level census data and updating it using a cumulative admission–discharge model, then dividing by AIHW-reported bed capacity for each hospital.

2.3 | Analysis and Ethics

Flow parameters were aggregated across 1% occupancy bands, and mean values were visualised using smoothed line plots, typically showing rates (e.g., admissions/h) or performance measures (e.g., ED length of stay). Figures were generated using R, version 4.4.0 [20]. To quantify associations between occupancy and ED metrics, we used simple linear regression models with ED length of stay, access block incidence and 4-h rule compliance as the response variables. No multivariable models were used, as the analysis was descriptive. Models were applied across all hospitals and selected individual sites.

To support effective flow and capacity, we identified choke points (occupancy levels where inflow and outflow rates began to diverge) such as ED presentations versus ED discharges or inpatient admissions versus inpatient discharges. These were detected by visually inspecting plots of hourly flow against occupancy to locate consistent, sustained divergence. Choke points were determined for the full cohort and by hospital size (small, medium, large). Although this approach involved interpretative judgement, it was not arbitrary: initial identification was performed by one author (VR) and independently verified by several others (JB, SK, JY, HH, ID) to ensure consistency and minimise subjectivity. Programmatic approaches may be explored in future work to formalise choke point detection.

We also analysed flow parameters by weekdays (Monday–Friday) versus weekends (Saturday–Sunday), and by shift: day (08:00 AM–03:59 PM), evening (04:00 PM–11:59 PM) and night (12:00 AM–07:59 AM), to assess temporal trends. To examine the impact of the coronavirus disease 2019 (COVID-19) pandemic, we compared occupancy patterns across three periods: pre-COVID-19 (2017–2019), during the first wave of COVID-19 (2020–2021) and post-COVID-19 (2022), stratified by hospital size.

An ethics exemption for the study was granted by Metro South Human Research Ethics Committee (EX/2022/QMS/89905) as this is a quality improvement study with the intent to publish the findings.

3 | Results

At inpatient occupancy levels below 86%, the hourly rates of ED discharges closely matched the rate of ED presentations, and inpatient discharge rates were generally aligned with inpatient admissions. Above this threshold, divergence was observed between inflow and outflow rates. This inflection point was observed in the aggregate data across all 25 hospitals (Figure S1).

Hourly flow patterns varied by hospital size, with choke points occurring at different occupancy thresholds. Divergence between admissions and discharges emerged at approximately 117% in small hospitals, 91% in medium hospitals and 86% occupancy in large hospitals (Figure S2). Larger hospitals therefore showed earlier and more pronounced divergence, while smaller hospitals maintained alignment at higher occupancy. Some small and medium hospitals sustained efficient flow above 85% occupancy.

Occupancy levels and patient flow parameters differed between weekdays and weekends. Weekday inpatient admissions and discharges peaked at approximately 390 and 340 patients/h, compared with 130 and 135 on weekends, and a larger gap was observed between admission and discharge rates on weekdays (Figure S3). These differences indicate substantial variation in operational activity by day of the week.

Inpatient activity was lower during weekends than weekdays, particularly during evening and night shifts. On weekdays, admissions were approximately 350 patients/h during the day shift (08:00 AM–03:59 PM), compared with 200 patients/h in the evening shift (04:00 PM–11:59 PM) and 100 patients/h in the night shift (12:00 AM–07:59 AM) (Figure 1). ED presentations during the evening shift were associated with the longest length of stay and highest access block rates (Figure 2).

Hourly occupancy data from a medium-sized hospital showed that weekend occupancy typically stayed below 90% in 95% of hourly intervals, while 21% of hourly intervals in weekdays exceeded this level. After March 2020, the proportion of intervals below 90% dropped from 88% to 77% on weekdays, indicating increased occupancy following the first COVID-19 wave (Figure S4). Hourly occupancy distributions by hospital size and pandemic periods revealed a modest decrease during the COVID-19 period and a rebound post-pandemic. Post-COVID-19, small hospitals had the largest increase in occupancy, with higher median and upper-quartile values compared with earlier periods (Figure S5).

Hourly occupancy trends reflected the timing and volume of inpatient admissions and discharges. Admissions exceeded discharges in the morning, peaking at about 10:00 AM and increasing occupancy to around 87%. Discharges then surpassed admissions in the afternoon, peaked at 03:00 PM, which led to a gradual decline in occupancy, falling to 78% around 07:00 PM, before rising slightly to approximately 79% at midnight (Figure S6).

Increased bed occupancy was associated with declines in ED length of stay, access block and 4-h rule compliance. While the inclusion of 25 hospitals introduced some variations, the overall trend remained consistent (Figure S7). In a small- and a medium-sized hospital (AIHW public acute group B), occupancy increases from 70% to over 100% were associated with a 2-h rise in ED length of stay for admitted patients and a 15%–20% drop in 4-h rule compliance. In the medium-sized hospital, each 10% occupancy increase corresponded to a 0.55-h (approximately 33 min) rise in ED length of stay for admitted patients (Figure S8, Table 1).

4 | Discussion

This 5.5-year analysis of patient flow across 25 hospitals provides insights into how inpatient occupancy affects the whole-of-hospital performance. Our findings indicate clear shifts in hospital flow performance as occupancy increases. Understanding critical occupancy thresholds, or choke points, where performance begins to decline, is essential.

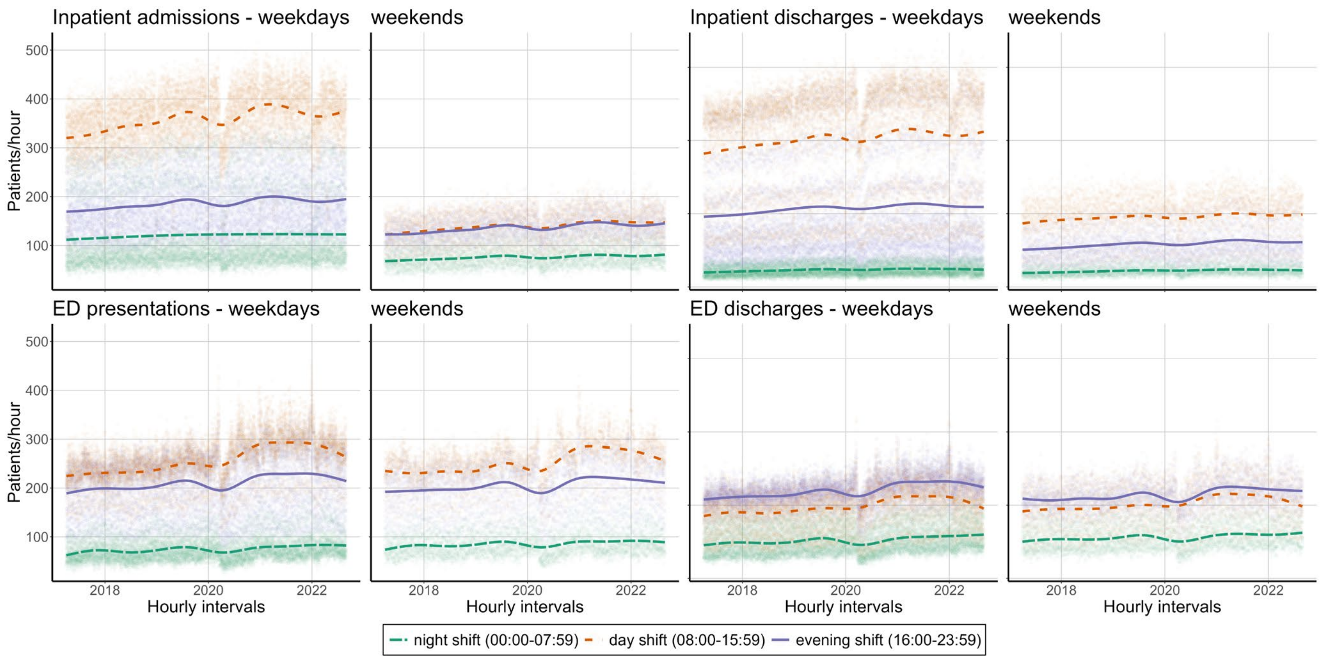

FIGURE 1 | Hourly count of inpatient admissions and discharges, and emergency department (ED) presentations and discharges for all 25 hospitals, separated by weekends versus weekdays and working shifts.

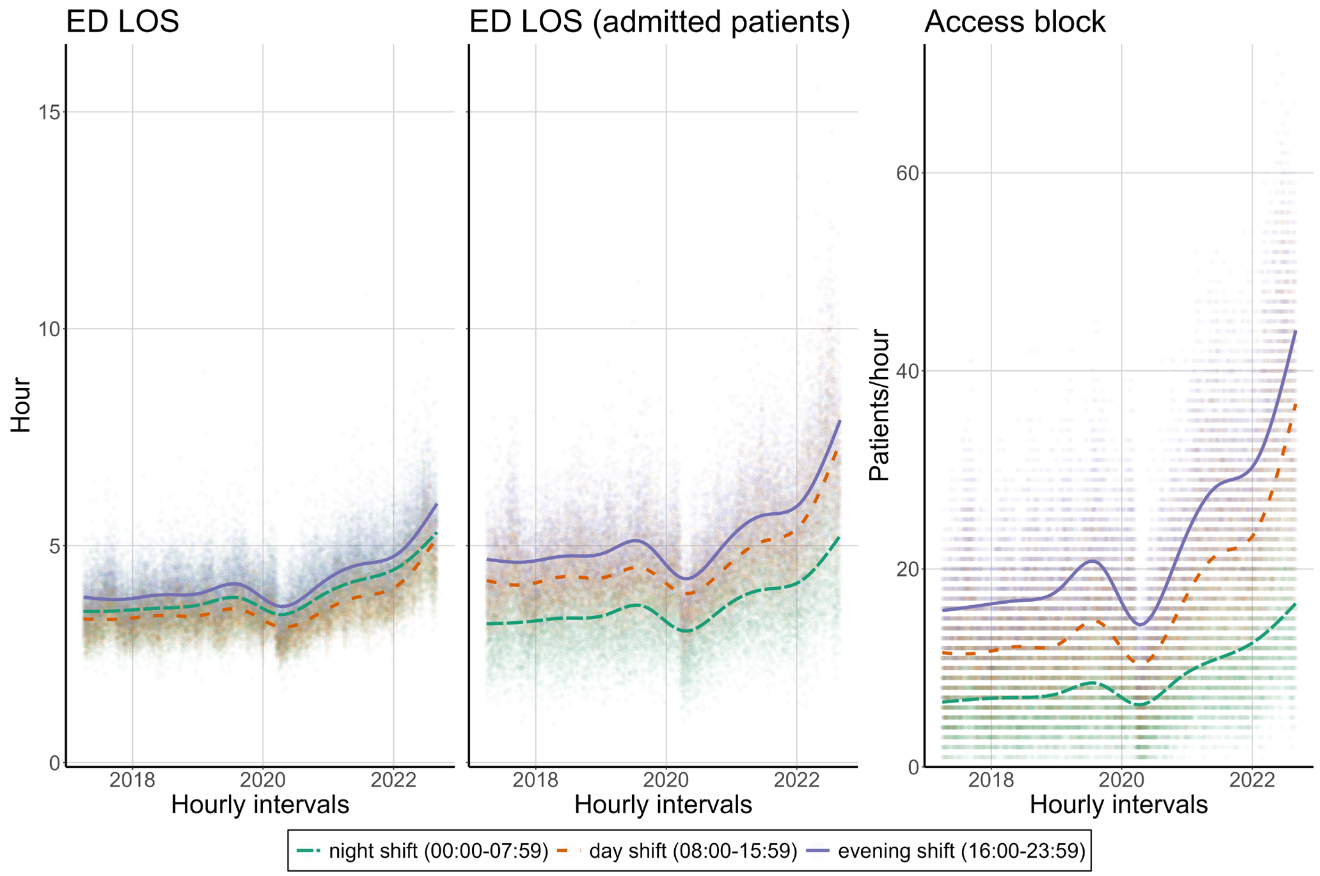

FIGURE 2 | Hourly emergency department (ED) length of stay (LOS) and access block for all 25 hospitals, separated by working shifts (based on ED presentation time).

TABLE 1 | Association between bed occupancy and emergency department length of stay, access block and 4-h rule compliance.

Outcome measures	Slope (95% confidence interval)	R^2 value
All 25 hospitals in study		
Access block	0.378 (0.288–0.467)	0.698
Four-hour rule compliance	−0.352 (−0.478 to −0.225)	0.498
Emergency department length of stay	0.032 (0.024–0.040)	0.663
Inpatient length of stay (from ED admission)	0.055 (0.044–0.065)	0.778
A small hospital		
Access block	0.007 (0.006–0.009)	0.553
Four-hour rule compliance	−0.240 (−0.294 to −0.185)	0.604
Emergency department length of stay	0.030 (0.022–0.034)	0.625
Inpatient length of stay (from ED admission)	0.052 (0.043–0.061)	0.740
A medium hospital		
Access block	0.021 (0.019–0.023)	0.918
Four-hour rule compliance	−0.448 (−0.500 to −0.397)	0.869
Emergency department length of stay	0.033 (0.029–0.037)	0.848
Inpatient length of stay (from ED admission)	0.046 (0.039–0.052)	0.818

Abbreviation: ED, emergency department.

We observed that at high inpatient occupancy levels, divergence grows between ED presentation and ED discharge, as well as inpatient admissions and inpatient discharges. Separate choke point analyses by hospital size support the view that the 85% occupancy target [1, 8–10] is not an optimal one-size-fits-all measure. Different hospitals, depending on size, case-mix and operations, experience variable occupancy thresholds, after which flow degrades. While these local variations inform site-specific planning, the system-level choke point observed at 86% occupancy may still provide a useful system-level reference point when interpreted alongside complementary flow and access indicators, rather than as a standalone target, and serve as a valuable state-wide or national policy. This threshold could function as a pragmatic trigger for initiating capacity management strategies before conditions deteriorate. Pre-emptive action at or just below this level could help maintain flow and avoid escalation into access block, given delays in recognising and responding to system strain.

These findings align with a large-scale, hourly analysis conducted in 2012 [16], supporting the use of flow divergence patterns as a stable, evidence-based metric. While these insights can help manage capacity, sustained demand often makes it impractical to keep inpatient beds unoccupied. In some cases, admitting patients to a crowded ward may be safer than extended ED stays. Considering our findings, one solution may be to reduce occupancy by facilitating timely discharge of patients ready to leave but delayed by system blockages, including transport, diagnostics or post-discharge care arrangements [21].

A more effective strategy is to act pre-emptively by discharging patients as occupancy nears the choke point. These findings support developing data-driven early warning systems to anticipate flow degradation. As hour-by-hour operational adjustments may not be feasible, recognising predictable strain patterns enables early intervention. These discharge-driven actions can reduce occupancy before pressures escalate, helping preserve flow. The focus needs to be on increasing discharges to achieve good flow and this is inherently linked to the definition of occupancy assessed here. We recommend using this insight as data-driven evidence to identify when hospitals need to implement additional patient flow and capacity management strategies. Although hospitals may operate above these occupancy inflection points during peak demand, doing so sustainably requires additional system-level safeguards to avoid performance decline.

Our analysis reveals that hospitals face significant operational pressure on weekdays, with significantly higher inpatient admissions and discharges compared with weekends. Much of this weekday activity relates to scheduled or elective procedures, which are under hospital control and may be amenable to redistribution. One potential strategy to alleviate this pressure is the implementation of a 7-day hospital model, which could better balance flow, reduce weekday pressure and improve care across the week. Some weekend activity involves value-adding care, but reduced staffing over a weekend imposes a constraint on the care delivered. Over the whole final year of the study period, the weekend bed use across the 25 hospitals totalled 836,336 bed-days, one-third of which might be able to be prevented via additional weekend services. Based on the mean inpatient length of stay of 1.77 days for acute care episodes, this would translate to capacity for approximately 157,000 additional admissions per year (or 432 patients per day) across the system (refer to Table S1). Although our study does not include a cost analysis, these figures suggest that alternative scheduling models may be worth exploring as part of broader efforts to improve flow and capacity.

Bed occupancy is shaped by the timing of admissions and discharges, and mismatches between the two can cause capacity constraints. Discharge processes often begin in the morning, but many patients remain within the hospital until late afternoon, due to delays in post-discharge arrangements or test results. Admissions start early in the morning and peak in the afternoon, before most discharges are completed, pushing occupancy to 100% as early as 01:00 PM. These dynamics are often marked when relying solely on midnight census values, which typically reflect the lowest occupancy point of the 24-h cycle. This highlights the limitations of using midnight snapshots as a measure of overall daily occupancy, an approach that may underestimate daytime pressure and overlook critical fluctuations in hospital-wide capacity and flow performance.

The findings reinforce a strong relationship between hospital bed occupancy and ED performance, with higher occupancy associated with longer ED length of stay, more access block and lower 4-h rule compliance. This pattern holds across both large- and medium-sized hospitals, indicating that as hospitals approach capacity, the pressure on ED resources intensifies, resulting in longer patient wait times and delays in care. These results align with international studies reporting similar impacts, including prolonged ED length of stay, reduced throughput and increased risks for boarded patients [22–24].

Smaller hospitals showed lower access block rates and shorter ED lengths of stay, even at relatively high occupancy levels, suggesting that small hospitals may be more resilient to occupancy pressures. Several unmeasured factors may contribute to this apparent resilience. Smaller hospitals may also benefit from more flexible bed management practices and more predictable patient turnover, whereas larger hospitals face complex, high-acuity caseloads that make them more vulnerable to rising occupancy.

The COVID-19 pandemic disrupted hospital operations, including changes in service models, demand patterns and infection control protocols. Although hospitals implemented operational adjustments such as the deferral of elective procedures and the establishment of fever clinics, there were no changes to the system performance metrics in use (e.g., the 4-h rule), ensuring consistency in how access block and ED length of stay were measured throughout the study period. We observed a temporary reduction in hourly occupancy during the pandemic, followed by a rebound, most notably in small hospitals, where median and the upper quartile range occupancy rose. This likely reflects deferred care returning to the system, increased demand driven by population and service pressures or residual operational constraints. Although we did not explicitly model pandemic policies, our findings suggest lasting shifts in resource use and capacity strain, highlighting the need for adaptable operational planning in response to system shocks.

Our study builds on this evidence by providing high-resolution, hospital-wide data across a state-wide cohort, showing that a 10% increase in hospital occupancy is associated with a 35-min increase in ED length of stay for admitted patients. The inverse relationship between bed occupancy and ED performance measures underscores the critical importance of managing bed availability efficiently within healthcare facilities. Higher bed occupancy not only strains resources but also adversely affects operational efficiency and patient outcomes within the ED. From a policy standpoint, addressing the root causes of ED overcrowding may be more effective than focussing solely on managing ED demand.

4.1 | Limitations

This study focussed on timeliness and efficiency metrics and did not assess patient-centred outcomes, such as mortality, readmissions and care experience. Bed capacity was assumed to be constant throughout the year (based on AIHW data), although it fluctuates in practice due to staffing and operational factors. Inconsistencies in how hospitals include wards in occupancy calculations limit the ability to apply a standardised approach across sites.

We acknowledge that the use of basic linear regression inadequately disentangles the complex interdependencies inherent in hospital patient flow, and that system-wide differences across hospitals could cause these estimates to vary. Accordingly, our findings should be interpreted as indicative trends rather than precise predictive models.

5 | Conclusion

This study shows that rising hospital occupancy is associated with reduced patient flow and ED access, with clear choke points where performance declines. A 10% occupancy increase was correlated with a 0.32-h increase in ED length of stay, a 0.55-h increase in admitted patient length of stay and a 3.5% reduction in 4-h rule compliance. Although a universal occupancy target may not apply, observed choke points highlight opportunities for improvement or learning from better-performing hospitals. Weekday pressure and misaligned admission–discharge timing further compound flow issues. A 7-day hospital model and proactive discharge strategies may ease pressure and improve access. Inclusion of 25 public hospitals supports relevance to other Australian and similar health systems. Finally, future studies should examine ward-level staffing and patient acuity to explain performance variation.

Author Contributions

Vahid Riahi: conceptualisation, methodology, investigation, writing – original draft, visualisation, data curation, formal analysis, writing – review and editing, project administration. Justin Boyle, Sankalp Khanna, Andrew Staib and Clair Sullivan: conceptualisation, methodology, investigation, writing – original draft, visualisation, data curation, formal analysis, writing – review and editing, resources, supervision, funding acquisition, project administration. Hwan-Jin Yoon and Ibrahima Diouf: conceptualisation, methodology, investigation, writing – original draft, visualisation, data curation, formal analysis, writing – review and editing. Hamed Hassanzadeh: conceptualisation, methodology, investigation, writing – original draft, visualisation, data curation, formal analysis, writing – review and editing. Mahnaz Samadbeik: conceptualisation, methodology, investigation, writing – original draft, visualisation, data curation, formal analysis, writing – review and editing. Emma Bosley: conceptualisation, methodology, investigation, writing – original draft, visualisation, data curation, formal analysis, writing – review and editing, resources, supervision, funding acquisition. James F. Lind: resources, supervision, funding acquisition.

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Disclosure

Not commissioned; externally peer reviewed.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data relating to analysis of ambulance and hospital records is unable to be shared due to ethics and regulatory limitations.

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Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Data S1:** mja270143-sup-0001-Figures.pdf.