The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments

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ABSTRACT

Objective: To examine the relationship between hospital and emergency department (ED) occupancy, as indicators of hospital overcrowding, and mortality after emergency admission.

Design: Retrospective analysis of 62 495 probabilistically linked emergency hospital admissions and death records.

Setting: Three tertiary metropolitan hospitals between July 2000 and June 2003.

Participants: All patients 18 years or older whose first ED attendance resulted in hospital admission during the study period.

Main outcome measures: Deaths on days 2, 7 and 30 were evaluated against an Overcrowding Hazard Scale based on hospital and ED occupancy, after adjusting for age, diagnosis, referral source, urgency and mode of transport to hospital.

Results: There was a linear relationship between the Overcrowding Hazard Scale and deaths on Day 7 ($r = 0.98$; 95% CI, 0.79–1.00). An Overcrowding Hazard Scale > 2 was associated with an increased Day 2, Day 7 and Day 30 hazard ratio for death of 1.3 (95% CI, 1.1–1.6), 1.3 (95% CI, 1.2–1.5) and 1.2 (95% CI, 1.1–1.3), respectively. Deaths at 30 days associated with an Overcrowding Hazard Scale > 2 compared with one of < 3 were undifferentiated with respect to age, diagnosis, urgency, transport mode, referral source or hospital length of stay, but had longer ED durations of stay (risk ratio per hour of ED stay, 1.1; 95% CI, 1.1–1.1; $P < 0.001$) and longer physician waiting times (risk ratio per hour of ED wait, 1.2; 95% CI, 1.1–1.3; $P = 0.01$).

Conclusions: Hospital and ED overcrowding is associated with increased mortality. The Overcrowding Hazard Scale may be used to assess the hazard associated with hospital and ED overcrowding. Reducing overcrowding may improve outcomes for patients requiring emergency hospital admission.

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Emergency department (ED) overcrowding is common in North America, the United Kingdom and Australasia.[1-3] Overcrowding results in ambulance diversion and impaired ED responsiveness.[2,4,5]

Inpatient bed "access block" is the principal cause of ED overcrowding.[1,4,6] Access block is defined as the proportion of ED patients requiring admission whose total time within the ED exceeds 8 hours.[7] Access block is correlated with total hospital inpatient bed occupancy of 90% or more, as measured by a midnight bed census.[7-9] A target occupancy of 85% has been suggested as a balance between unused bed capacity and efficient inpatient flow.[8,10]

Some studies have identified a relationship between high occupancy, access block and adverse patient outcomes, as measured by inpatient length of stay, hospital readmission or reattendance for emergency care.[11-13]

Our study examines whether high hospital occupancy and ED access block is also associated with increased patient mortality.

METHODS

The Emergency Care, Hospitalisation and Outcome Study (ECHO)

Western Australia's population at 30 June 2001 was 1.9 million, with 1.4 million people (77%) residing in metropolitan Perth.[14] Perth has seven public and three private hospitals with EDs. The Emergency Care, Hospitalisation and Outcome Study Project (ECHO) links all metropolitan Perth's emergency care records, with sufficient information to allow linkage, to metropolitan prehospital care records and hospitalisation and mortality records for the whole state.

Data from the three 400- to 550-bed tertiary hospitals in metropolitan Perth accepting adult referrals were used. These hospitals accepted 81% of all metropolitan ambulance attendances, 67% of emergency inpatient admissions and were responsible for 74% of episodes of ambulance diversion during the study period. For the study, we used the emergency admission record of the first ED attendance during the study period at any of the hospitals' EDs that resulted in the patient being formally admitted to the hospital.

FOR EDITORIAL COMMENT, SEE PAGE 203. SEE ALSO PAGE 213.

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Data sources

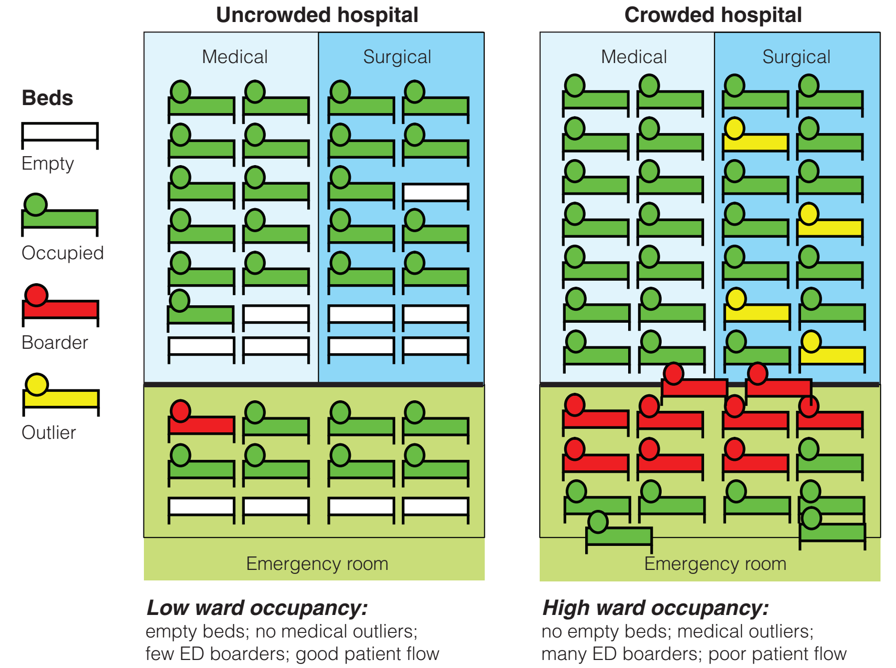
EDIS

EDIS (Emergency Department Information Systems, Version 10.0, Health Administration Solutions, Sydney) is the primary data source for ECHO. It is a patient tracking system, containing patient demographics, admissions, transfers, discharges, timetracking information and clinical information entered by clinical staff in real time.

Hospital Morbidity Data System

Information on length of stay was obtained from the Western Australian Hospital Morbidity Data System, which contains patient information for all hospital inpatient care episodes in Western Australia.

1 Hospital crowding states



ED = emergency department. Boarders = patients waiting for an inpatient bed. Outliers = patients unable to be admitted to the "correct" ward (eg, medical patients on surgical wards). ◆

Mortality Database

Death records were obtained from the Western Australian Mortality Database. The records contain death certificate information, including date of death and principal and secondary causes of death.[15]

Patient-based data linkage

EDIS, the Hospital Morbidity Data System, and the Mortality Database records were linked by the Western Australian Data Linkage Unit using probabilistic matching.[15,16] EDIS records for the period 1 July 2000 to 30 June 2003 were linked to morbidity and mortality records until 31 March 2004. A minimum of 42 000 records were needed to identify a 30-day mortality hazard ratio of 1.2 with a power of 0.9.

Statistical analysis

The Statistical Package for the Social Sciences (SPSS, Version 12.0, Chicago, Ill, USA) was used for the analysis.

Overcrowding and mortality analysis

Our analysis examined the effect on mortality of overcrowding, as indicated by high hospital occupancy and high ED occupancy of patients waiting for an inpatient bed. Box 1 illustrates the difference between uncrowded and overcrowded conditions.

Hospital occupancy was calculated from the admitted patient census at 23:59 on the day of attendance, divided by the 99th centile 23:59 patient census for the hospital during the first 6 months of the calendar year (eg, 400/500 = 80%). Access block occupancy was calculated as the percentage of ED cubicles occupied by patients experiencing access block (ie, waiting 8 hours or more for an inpatient bed) at the time of emergency attendance. The relationship between hospital occupancy, access block occupancy and other risk factors hypothesised as likely to influence mortality by Day 2 (Day 1 = day of attendance), Day 7 and Day 30 were evaluated using Cox regression analysis. Risk factors other than those indicative of hospital or ED occupancy or flow were chosen on the basis of a known relationship with emergency admission deaths, cost or hospital length of stay.[11,17] The model for the effect of overcrowding on mortality was developed manually. Deaths associated with overcrowding were calculated as the excess deaths in the exposed population.

Interaction between hospital occupancy and access block: the Overcrowding Hazard Scale

We developed an Overcrowding Hazard Scale to test the combined effects of hospital and ED overcrowding. Hospital occupancy was scored 1, 2 or 3 corresponding to occupancy levels < 90%, 90%–99% and ⩾ 100%, levels known to affect ED function (90%) or to indicate absolute hospital overcrowding (100%). Access block occupancy was scored 1, 2 or 3 corresponding to < 10%, 10%–19% and ⩾ 20% occupancy. The Overcrowding Hazard Scale score was calculated by multiplying the hospital occupancy score and the ED access block occupancy score, resulting in values ranging from 1 to 9 (eg, hospital occupancy 90%–99% and access block occupancy 10%–19% = 2 × 2 = 4). A second model for the effect of overcrowding on mortality was developed using the Overcrowding Hazard Scale instead of either hospital occupancy or access block.

Tests for confounding

Two potential confounders were tested.

- Confounding due to increased respiratory and cardiovascular diagnoses in winter was tested by removing admissions in the four peak respiratory/influenza months (June–September) of each year from the models.
- Confounding caused by admission selection (ie, hospitals operating at high occupancy may be less likely to admit patients at lower risk of death, resulting in a spurious association between overcrowding and mortality) was tested by assessing the relationship between overcrowding and the probability of admission for all adult index emergency attendances to the hospitals using binary logistic regression.

Clinical characteristics of overcrowding-associated deaths

Binary logistic regression was also used to evaluate differences in demographic, clinical and attendance characteristics of patients who died by Day 30 after experiencing an Overcrowding Hazard Scale score < 3, in comparision with those who experienced a score > 2.

Ethics approval

Ethical and record linkage approvals were obtained from the Human Research Ethics Committee at the University of Western Australia and the Confidentiality of Health Information Committee of Western Australia.

RESULTS

Sample characteristics

There were 62 495 first emergency admissions and 3084 deaths by the Day 30 censoring date. The admission characteristics, grouped by hospital occupancy, are summarised in Box 2. Higher hospital occupancy was associated with a slightly higher proportion of elderly, female, illness admissions, and was more likely during weekdays and during winter. However, the hospital occupancy groupings were undifferentiated with respect to the proportion of physician-referred admissions, ambulance-transported admissions, triage urgency, or length of hospital stay.[18]

Hospital occupancy and mortality

Box 2 shows a positive relationship between level of hospital occupancy and death by days 2, 7 and 30 after index ED attendance, with a relative increase in mortality by Day 7 of 18% (95% CI, 0.5%–38%) for hospital occupancy of 90%–99% and 46% (95% CI, 14%–85%) for hospital occupancy of 100% or more.

Box 3 illustrates the 7-day survival stratified by hospital occupancy, adjusted for age, mode of transport, diagnosis (ICD-10-CM), triage urgency and referral source. In comparison with < 90% occupancy, the 7-day hazard ratio for 90%–99% hospital occupancy was 1.2 (95% CI, 1.1–1.3; $P = 0.02$), and for ⩾ 100% hospital occupancy it was 1.3 (95% CI, 1.1–1.6; $P = 0.001$). Initially significant univariate associations between mortality and winter season, month of year, individual day of week and time of day were rendered non-significant after adjustment for the above variables. Adjustment for hospital attended (including use of an interaction term "hospital × occupancy") or length of hospital stay did not significantly change the hazard associated with hospital occupancy.

Relationship of hospital occupancy to access block

Mean ED access block occupancy at the time of ED attendance was 4.6% (95% CI, 4.5%–4.7%) for patients attending when hospital occupancy was < 90% and increased to 6.8% (95% CI, 6.7%–6.9%) for 90%–99% hospital occupancy and 9.7% (95% CI, 9.5%–10%) for ⩾ 100% hospital occupancy.

The Overcrowding Hazard Scale and mortality

Box 4 presents the 7-day hazard ratios associated with the Overcrowding Hazard Scale, using an identical model to that used for Box 3, but with the Overcrowding Hazard Scale substituted for hospital occupancy. A linear relationship between the Overcrowding Hazard Scale and 7-day mortality hazard was demonstrated ($r = 0.98$; 95% CI, 0.79–1.00; $P = 0.001$), indicating that an Overcrowding Hazard Scale score > 2 (defining "overcrowded conditions") is associated with increased patient mortality.

Box 5 presents the hazard ratios associated with overcrowded conditions and the other factors associated with Day 7 deaths, and Box 6 presents the deaths associated with overcrowded conditions, censoring survival at 2, 7 and 30 days: 2.3 deaths per 1000 emergency admissions were associated with overcrowded conditions by Day 30 (95% CI, 1.2–3.2), or an estimated 120 deaths (95% CI, 60–170) among the 53 025 tertiary hospital emergency admissions (including non-index admissions) in Perth in 2003.

Tests for confounding

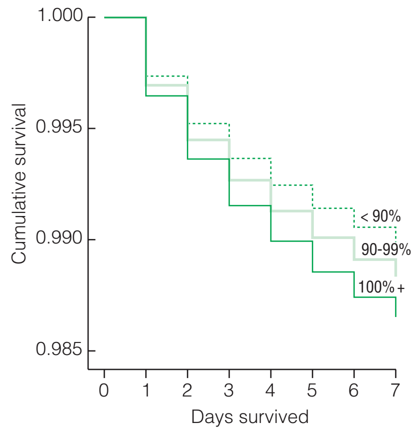
Testing for winter seasonal confounding revealed no significant effect. The Day 7 hazard ratio for overcrowded conditions after exclusion of 22 582 June to September

2 Characteristics of emergency hospital admissions grouped by hospital occupancy

	Occupancy < 90%		Occupancy 90%–99%		Occupancy ⩾ 100%		
Sample characteristic	*n* (%) or mean	95% CI	*n* (%) or mean	95% CI	*n* (%) or mean	95% CI	*P*
Sex (% female)	7 464 (45.0%)	44.3%–45.8%	19 023 (47.5%)	47.0%–48.0%	2 959 (50.6%)	49.3%–51.9%	0.05
Age (% ⩾ 50 years)	9 969 (60.1%)	59.4%–60.9%	25 805 (64.4%)	63.9%–64.9%	4 220 (72.1%)	71.0%–73.3%	< 0.001
Diagnosis (% injury)	4 130 (24.9%)	24.3%–25.6%	9 453 (23.6%)	23.2%–24.0%	1 343 (23.0%)	21.9%–24.0%	< 0.001
Shift (% 08:00–15:59 hours)	7 148 (43.1%)	42.4%–43.9%	18 123 (45.2%)	44.7%–45.7%	2 902 (49.6%)	48.3%–50.9%	0.12
Day (% Mon–Fri)	10 287 (62.0%)	61.3%–62.8%	30 043 (75.0%)	74.6%–75.4%	5 110 (87.4%)	86.5%–88.2%	< 0.001
Winter attendance (% Jun–Sep)	1 776 (10.7%)	10.2%–11.2%	16 192 (40.4%)	39.9%–40.9%	4 614 (78.9%)	77.8%–79.9%	< 0.001
Referral source (% physician-referred)	5 543 (33.4%)	32.7%–34.2%	13 603 (34.0%)	33.5%–34.4%	2 129 (36.4%)	35.2%–37.6%	0.36
Transport to emergency (% ambulance)	8 141 (49.1%)	48.3%–49.9%	20 653 (51.5%)	51.1%–52.0%	3 212 (54.9%)	53.6%–56.2%	0.09
Triage urgency (% resuscitation cases)	662 (4.0%)	3.7%–4.3%	1 546 (3.9%)	3.7%–4.0%	251 (4.3%)	3.8%–4.8%	0.27
Mean length of stay	6.60	6.44–6.76	6.72	6.61–6.83	6.76	6.49–7.04	> 0.2*
Mean length of stay, weighted for deaths	6.84	6.67–7.00	6.99	6.88–7.10	7.09	6.82–7.36	> 0.1*
Day 2 deaths (%)	179 (1.1%)	0.9%–1.2%	532 (1.3%)	1.2%–1.4%	91 (1.6%)	1.2%–1.9%	0.06
Day 7 deaths (%)	375 (2.3%)	2.0%–2.5%	1 065 (2.7%)	2.5%–2.8%	193 (3.3%)	2.8%–3.8%	0.002
Day 30 deaths (%)	725 (4.4%)	4.1%–4.7%	2 001 (5.0%)	4.8%–5.2%	358 (6.1%)	5.5%–6.7%	0.001
Total (% of 62 495 admissions)	**16 579 (26.5%)**		**40 067 (64.1%)**		5 849 (9.4%)		

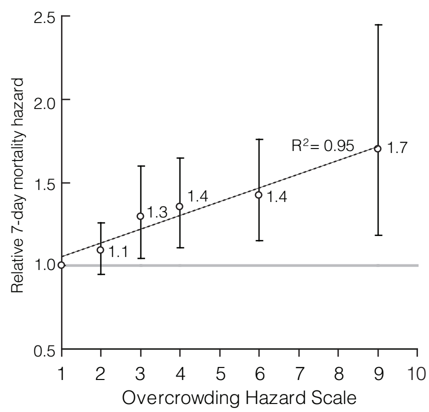
* For all between-group tests. ◆

3 Seven-day survival* after emergency admission stratified by hospital occupancy on the day of admission



* Adjusted for age, mode of transport, diagnosis (ICD-10-CM), triage urgency, and referral source. ◆

4 Relationship between the Overcrowding Hazard Scale and the 7-day mortality hazard for emergency admissions



admissions (36.1%) (hazard ratio, 1.3; 95% CI, 1.1–1.5; $P = 0.002$) was essentially identical to the Day 7 hazard ratio for the total study population in overcrowded conditions reported in Box 5.

In testing confounding caused by admission selection, neither hospital occupancy (risk ratio of admission when there was a 10% increase in occupancy: 1.0; 95% CI, 1.0–1.1) nor the presence of overcrowded conditions (risk ratio of admission with an Overcrowding Hazard Scale > 2: 1.0; 95% CI, 1.0–1.1) was associated with a reduction in the probability of admission among 194 362 ED attendees when adjusted for age, mode of transport, diagnosis, triage urgency, referral source and hospital attended.

5 Hazard ratios for variables used in 7-day mortality Overcrowding Hazard Scale model

Variable	Hazard ratio	95% CI	*P*
Age 50 years or older	3.3	2.8–4.0	< 0.001
Mode of transport (ambulance v not ambulance)	3.4	2.9–4.0	< 0.001
Diagnosis (illness v injury)	2.2	1.8–2.6	< 0.001
Australasian Triage Scale urgency Category 1 (resuscitation v less urgent categories 3, 4, 5)[18]	14.0	12.0–16.0	< 0.001
Australasian Triage Scale Category 2 (emergency v less urgent categories 3, 4, 5)[18]	1.6	1.4–1.8	< 0.001
Overcrowding Hazard Scale > 2	1.3	1.2–1.5	< 0.001
Referral source (physician v non-medical)	1.2	1.1–1.3	0.001

6 Cumulative deaths per 1000 new emergency hospital admissions associated with an Overcrowding Hazard Scale > 2

Censoring date	Hazard ratio (95% CI)	Deaths per 1000 emergency hospital admissions (95% CI)	*P*
Day 2	1.3 (1.1–1.6)	1.0 (0.4–1.4)	0.001
Day 7	1.3 (1.2–1.5)	1.9 (0.7–2.5)	< 0.001
Day 30	1.2 (1.1–1.3)	2.3 (1.2–3.2)	< 0.001

Deaths associated with overcrowding

Deaths by Day 30 associated with overcrowded conditions were undifferentiated with respect to age, diagnosis, urgency, mode of transport, referral source or hospital length of stay compared with uncrowded conditions. However, patients dying who experienced overcrowded conditions were more likely to be male (risk ratio, 1.3; 95% CI, 1.1–1.5; $P = 0.007$) and to have attended during winter (risk ratio, 2.9; 95% CI, 2.4–3.5; $P < 0.001$), between Monday and Friday (risk ratio, 2.1; 95% CI, 1.7–2.6; $P < 0.001$) and between 08:00 and 15:59 (risk ratio, 1.7; 95% CI, 1.3–2.2; $P < 0.001$), consistent with the known weekly and seasonal variation in hospital overcrowding and ambulance diversion in metropolitan Perth (see Box 2). Patients dying who experienced overcrowded conditions had longer total durations of stay in the ED (risk ratio per hour of ED stay, 1.1; 95% CI, 1.1–1.1; $P < 0.001$) and slightly longer physician waiting times (risk ratio per hour of ED wait, 1.2; 95% CI, 1.1–1.3; $P = 0.01$).

DISCUSSION

Overcrowding is associated with increased mortality

Our study showed that hospital and ED overcrowding is associated with a 30% relative increase in mortality by Day 2 and Day 7 for patients requiring admission via the ED to an inpatient bed. This increase in mortality appears to be independent of patient age, season, diagnosis or urgency. The estimate of 120 deaths per annum associated with overcrowding in metropolitan Perth hospitals suggests that overcrowding should be regarded as a patient safety issue rather than simply an issue of hospital workflow.

The finding of increased mortality associated with overcrowding is consistent with the known effects of overcrowding on emergency hospital admissions. Hospital occupancy above 90% has been demonstrated in our study to be closely associated with ED access block and is associated with an increased duration of ED stay.[9] The duration of stay in the ED was longer for patients who experienced overcrowded conditions and died.

The positive relationship between overcrowding and mortality is not explained by seasonal or admission selection confounding. For admission selection confounding, this counterintuitive finding may reflect the fact that hospital occupancy was measured at 23:59 each day and represents an outcome of all admission decisions made during the preceding 24 hours rather than perceived occupancy at the time of decision making about admission.

Understanding the relationship between overcrowding and patient harm

Our study did not examine the mechanisms by which overcrowding is associated with increased mortality. Examination of delays in the initiation of time-critical care, such as the administration of antibiotics in sepsis, may be a fruitful line of enquiry.[19] The longer physician waiting times and ED durations of stay among patients in our study who experienced overcrowded conditions and died may be acting as proxies for delays in the initiation of care. The presence of patients experiencing access block is strongly correlated with longer physician waiting times in EDs in both metropolitan Perth ($r = 0.86$) and internationally.[4,6]

Human error theory predicts that errors occur more often when systems are stressed by constraining resources; such as when a hospital is overcrowded.[20] Overcrowding is often associated with placing inpatients on an incorrect ward (eg, medical patients placed on surgical wards) where staff may be less familiar with standard service guidelines for care of the patient's condition or the clinical cues associated with potential adverse events. Such patient "outlying" may be a mediator of the association between overcrowding and increased mortality.

Given the association between the Overcrowding Hazard Scale and increased mortality, we suggest that the scale could be used to monitor the hazard associated with overcrowding in real-time. An Overcrowding Hazard Scale score >2 may be considered prima facie evidence of an increased Day 7 mortality hazard.[8]

Solutions to overcrowding

Hospital overcrowding is a complex phenomenon. The prevalence of overcrowding may rise in health services in developed economies as age-related demand for hospital services grows over the next 10–15 years.[21] In addition, economic incentives tend to favour high occupancy.[21] Solutions may include the realignment of incentives that favour high levels of hospital occupancy at the expense of emergency access. Other solutions may include strategies that reduce waste, misuse and overuse of health services, and improved chronic disease management to reduce hospital bed demand.[22] In addition, better matching of bed supply with predictable emergency demand and optimisation of hospital inpatient flow are required.[22-24]

Limitations

This study used data from only one health system. Confirmation of a relationship between overcrowding and mortality and validation of the Overcrowding Hazard Scale requires replication of the findings of our study in other health care systems.

The estimate of the 7-day hazard ratio, and particularly the 30-day hazard ratio, should be considered conservative. The study methods only allowed a patient to enter the dataset once, at the first (index) hospital ED attendance. The mortality hazard associated with overcrowding could increase with repeated exposure. In addition, no estimate has been made of the mortality hazard associated with overcrowding among patients discharged from EDs.

Finally, despite showing an association between overcrowding and mortality, further studies are needed to examine the mediators of the relationship of hospital overcrowding and patient mortality. Research is required that examines specifically the impact of delays in care associated with overcrowding on patient outcomes; and the impact on adverse event rates and patient outcomes of placing patients in wards or corridor locations inappropriate for their care during overcrowded conditions.

CONCLUSION

Hospital and ED overcrowding is associated with increased mortality. The Overcrowding Hazard Scale may be used to assess the mortality hazard to patients associated with hospital and ED overcrowding. Reducing overcrowding may improve outcomes for patients requiring emergency hospital admission.

COMPETING INTERESTS

None identified.

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