



# Access block and overcrowding in emergency departments: an empirical analysis

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## ABSTRACT

**Objective** To quantify the determinants of the duration of time spent in an emergency department (ED) for patients who need admission to hospital.

**Methods** A retrospective analysis of a year of administrative data on all patients presenting to 38 public hospital EDs in Victoria, Australia in 2005/2006.

Individual administrative data on patient care time, defined as the time in the ED from first being seen by a treating doctor to admission, were analysed using parametric survival analysis (generalised  $\gamma$  model). Patient times were regarded as censored if the patients died in the ED or were transferred to another hospital. The outcome measure was the elasticity of patient care time, calculated as the percentage change in time for a 1% change in continuous variables and a unit change in dichotomous variables.

**Results** The mean patient care time was 396 min (95% CI 395 to 398). Reduced time in ED was associated with the number of nurses (elasticity =  $-2.38\%$ ; 95% CI  $-2.31$  to  $-2.45$ ); the number of beds (elasticity =  $-2.99\%$ ; 95% CI,  $-2.89$  to  $-3.08$ ); the number of doctors (elasticity =  $-0.235\%$ ; 95% CI  $-0.232$  to  $-0.237$ ). There was significant variation in the time spent in the ED across hospitals after adjustment for observable differences in patient and hospital characteristics. Overall an increase in hospital resources, as measured by the number of nurses, doctors and physical beds, is associated with a significant reduction in patient care time in the ED.

**Conclusion** Increasing hospital capacity is likely to reduce overcrowding in the average ED, but factors that determine congestion in individual hospitals need to be further investigated.

## INTRODUCTION

Access block, the inability to access inpatient beds, has been identified as one of the major causes of overcrowding in hospital emergency departments in many countries, including Australia,<sup>1</sup> North America,<sup>2</sup> the UK<sup>3,4</sup> and Korea.<sup>5</sup> Such overcrowding impedes the delivery of good healthcare, causes delays in transport and treatment, causes frustration for patients and staff, resulting in patients leaving without being seen, and, most importantly, increases the risk of poor patient outcomes. Numerous studies have reported an association between overcrowding in emergency departments and excess inpatient length of stay,<sup>6,7</sup> with at least two reports of an association between overcrowding and inpatient mortality.<sup>6,8</sup> In this study we investigate the determinants of access block, estimating the relationship between the time spent in the Emergency Department (ED) by those

admitted to hospital and the hospital resources available relative to demand.

## METHODS

We measure the extent of access block across Victorian public hospitals by quantifying the relationship between time spent in ED and resources in hospitals, controlling for variation in the demand for hospital care. The hypothesis is that there is a relationship between duration of stay in the ED and factors that determine the demand and supply of available inpatient beds in a given hospital. Boarding time, measured as the time in ED after a bed request has been made, has been the standard measure of bed blockage in the literature.<sup>9</sup> Boarding time, however, may underestimate the effect of supply factors on waiting time for a patient in the ED if the length of treatment time or the decision to admit a patient is influenced by bed availability. This could occur either directly or indirectly, for example through the general level of hospital activity leading to delays in diagnostic results or long boarding times affecting resources available in the ED for the treatment of patients. Doctors may treat for a longer time and more aggressively if they know that there is a long wait for an inpatient bed. Observation within the ED can be an adjunct to formal inpatient admission,<sup>10</sup> and boarding time as a measure of access block will be biased to the extent that the duration of assessment, treatment and observation in the ED are influenced by resource constraints within the hospital. The size of this effect is unknown and in some Victorian hospitals, where there are specific purpose observational units close to the ED to admit patients for short stays, the effect is likely to be restricted to delays in diagnostics from outside the ED. In addition, overcrowding in the ED caused by bed blockage will make it increasingly difficult to find appropriate areas to treat new patients and lead to longer treatment and observation times.<sup>11</sup> An alternative measure less commonly used is total ED waiting time.<sup>11</sup> This measure is less efficient, as it includes time prior to being seen by a doctor, which is influenced more by what have been called input and throughput factors within the ED<sup>9,12,13</sup> than by what we are interested in here, hospital inpatient resources. The primary duration measure that we use here is patient care time in the ED, defined as the time between being seen by a doctor and being admitted to hospital. This measure captures the effect of inpatient resources on waiting, and has a potential advantage over the conventional measure of boarding time in that it allows for the direct and indirect influence of inpatient hospital resources on treatment and observation time. In

a secondary analysis we analyse the data using boarding time as the outcome variable.

The duration of individual patients' time in ED was analysed retrospectively in a parametric survival analysis that controlled for observable hospital and patient characteristics. Survival analysis is the natural way to analyse time to event data such as this, and has a number of advantages over other commonly used approaches. It does not, for example, assume that the duration is normally distributed, as a multiple linear regression approach would,<sup>14</sup> nor is it necessary to construct a binary variable on whether the patient exceeded an arbitrary threshold waiting time to define access blockage, as others have done.<sup>3</sup> Survival analysis also allows for incomplete spells in the ED prior to admission caused by death or transfer to another facility. The most flexible and robust approach is a semi-parametric statistical model, of which the best known is the Cox proportional hazard model. Other parametric models are more efficient, but need to assume a particular functional form for the hazard function  $h(t)$  (the probability of a patient being admitted at time  $t$ , given that he or she has been waiting until time  $t$ ) and as a consequence can be sensitive to misspecification. The data showed that the cumulative hazard function increased with time in the ED. This suggested that the Cox proportional hazard model, the Weibull model or the generalised  $\gamma$  model were potentially suitable. We therefore tested these three models. For the Cox proportional hazard model we use the rescaled Schoenfeld residuals and the global test of Grambsch and Therneau<sup>15</sup> to test for non-proportionality of the hazard. The test rejected the assumption of proportionality ( $p < 0.001$ ). The choice between Weibull and generalised  $\gamma$  distribution was made on the basis of the value of the likelihood function. The model is presented in an accelerated failure time format and, since all the continuous covariates are taken in natural logarithms, the coefficients can be interpreted directly as elasticities (ie, the percentage change in time in ED for a 1% change in the independent explanatory variables). All data were analysed using STATA10 (StataCorp, 2007).

## DATA

Data on individual patient waiting times were taken from the Victorian Emergency Minimum Dataset (VEMD) in the financial year 2005/2006.<sup>16</sup> This contains standardised routine reports on de-identified demographic, administrative and clinical data on presentations at all public hospitals in the State of Victoria, Australia with a 24 h ED. Data were selected to include those who were admitted or transferred to another hospital or died. Time waiting for admission to a ward was taken as the difference

between the time first seen by a doctor and the time transferred to a ward. Data were regarded as right censored if the patient died or was transferred to another hospital. Data on hospital resources (number of available beds, nurses and doctors) were provided by the Victorian Department of Human Services. These are based on annual averages reported by the hospitals. The size of the catchment population was used as a proxy for the demand for beds. Patient-flow data for each statistical local area is used to define hospital service areas or catchment area, based on the methods of Zwanziger and Melnick.<sup>17</sup> The square of continuous covariates was included to allow for non-linear effects. We chose explanatory variables that represent patient demand characteristics (triage category, demographics) and constraints on the supply of inpatient beds to ED patients (hospital staffing and bed capacity, hospital type and catchment area). Table 1 shows the data item definitions and sources.

As the information recorded in the VEMD is not all captured in real time, time first seen by doctor and time to admission or discharge may not always be accurate. It is also possible that the request for a bed may be made before the patient is ready for discharge, thus inflating the boarding time. In a busy ED there may be delays in data entry and a consequent inaccuracy in measuring patient care times.<sup>18</sup> Consequently a limitation of this study is that the VEMD waiting time data may not accurately reflect the time spent in ED associated with problems of access to inpatient beds, but we have no reason to believe that this inaccuracy is large or will lead to bias in the results.

## RESULTS

The mean time spent in the ED from seeing a doctor to being transferred to a ward across the 38 hospital campuses is 396 min (95% CI 395.13 to 397.63). The results of the generalised  $\gamma$  survival analysis are shown in table 2 and plotted in figure 1. Table 2 shows the elasticity of patient care time with respect to each of these variables (column 3) at their sample means (column 1). The elasticity is the predicted percentage change in patient care time associated with a 1% change in the variable. For example, a 1% change in the mean number of nurses (from 998 to 1008) is associated with a 2.38% fall in waiting time (from 396 to 387=9 min) assuming all other variables remain at their mean values. Similarly, an increase of 1% in the bed capacity is associated with a 2.99% fall in waiting time (from 278 to 281=12 min). The statistical model predicts that a combined 1% increase in the number of nurses, physical bed capacity and the number of doctors is associated with a reduction in the average waiting time of 22 min from the average of

**Table 1** Variable definitions and data sources

Variable name	Definition	Source
Waiting time	Minutes between being seen by a doctor and being admitted or transferred, or dying	VEMD
Catchment population	Calculated as population of health service area 18	VEMD
Day	Weekend/Weekday	VEMD
Hospital location	Metro/Rural	VEMD
Season	Summer/Autumn/Spring/Winter	VEMD
ED patient category	Resuscitation, Emergency, Urgent, Semi-urgent or Non-urgent	VEMD
Age	Age in years	VEMD
Social disadvantage	SEIFA index of disadvantage for postcode of patient	ABS Census of Population and Housing (2006)
Gender	Male/Female	VEMD
Country/Region of origin	Southern Europe, Eastern Europe, Western Europe, South-East Asia, UK, Other	VEMD
Indigenous	Aboriginal or Torres Strait Islander	VEMD
Doctors	Number of FTE doctors employed in the hospital campus	Data supplied by the Victorian DHS
Nurses	Number of FTE nurses employed in the hospital campus	Data supplied by the Victorian DHS

VEMD, Victorian Emergency Minimum Dataset.

396 min. The elasticity with respect to binary variables such as the category of patient, ethnicity, weekend/weekday, metro/rural, season, and hospital campus is interpreted as the percentage change in waiting time compared with the excluded category. For example, weekends are associated with a 1% fall in waiting time or 4 min (compared with weekdays), while patients wait for 7.8% less time in summer than in winter (31 min). It is interesting to note that there is considerable variation in waiting time across hospitals, which is significant even after adjustment for observable patient characteristics and hospital resources (not reported in table 2). Four hospitals have mean waiting times at least 69% (398 min) more and two hospitals have waiting times at least 46% less (265 min) than the comparison hospital campus. With boarding time rather than patient care time as the outcome variable, the best fitting models gave similar results for bed capacity, but the elasticity of boarding time with respect to the number of nurses was positive and for doctors it was insignificant.

## DISCUSSION

To the best of our knowledge this is the first study to quantify the duration in ED associated with bed access block factors controlling for observable patient and hospital-level characteristics. We find that available hospital resources are strongly associated with time spent waiting in ED for admission. For a given level of demand (as captured by the needs of the catchment population of a given level of disadvantage), overall resources available in the hospital are strong predictors of patient time spent in ED waiting for a bed. We have measured duration in ED continuously in minutes rather than using an indicator of access block, as this avoids the clinically arbitrary nature of such measures. The mean time spent in the ED from

seeing a doctor to being transferred to a ward across the 38 hospital campuses was over 6 h, and, as figure 1 shows, the predicted probability of staying in ED remains high for considerably longer than that. Twenty-seven per cent of people waited more than 8 h, the most commonly used threshold indicator of acceptable performance for an ED. It is interesting to note that there is considerable variation in access block across a set of tertiary hospitals of similar size even after controlling for catchment area and hospital staff resources. There are a number of possible explanations for this, including uncontrolled differences in clinical and administrative practice as well as differences in quality and efficiency between hospitals. If the causes of these differences could be established, targeted programs to reduce waiting might offer the potential for greater gains in patient access than general funding increases.

## LIMITATIONS OF THE STUDY

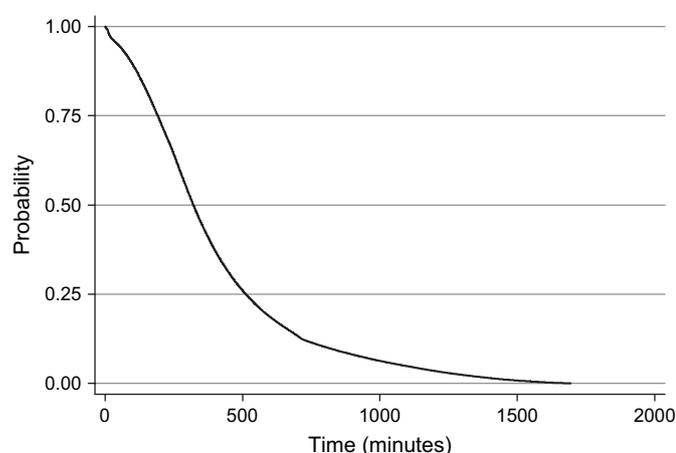
This is an observational study and we cannot be certain that an increase in hospital staffing or ward bed capacity will reduce overcrowding in an ED. It is possible that there are characteristics of patients that we have not been able to measure precisely (such as condition and severity) or the hospital (resource allocation or particular specialty capacity such as critical care beds) that might explain both ED waiting time and resource use for a particular patient. We did control for triage category as well as bed and staff availability in the individual hospital, and this, along with other patient characteristics, is likely to capture much of the variation in waiting time associated with patient and hospital heterogeneity. The accuracy of hospital resource variables is limited by the data, which are reported only as annual aggregates. There is considerable movement of staff around the hospital (including the ED) and the number of available beds may vary across the year. In addition, staffing levels at the ward level may vary by specialty, but the effect on admissions of overall level of bed availability is likely to be captured by total number of doctors, nurses and beds. Moreover, while there are no doubt differences between hospitals in capacity and efficiency, all hospitals in the sample are major tertiary hospitals with similar levels of recurrent funding per case mix adjusted patient. There is likely to be some measurement error in the time spent in the ED, since these data are not all recorded in real time and we cannot be certain that they are unrelated to resource use or how crowded the ED is at the time of recording. It seems likely that the data understate patient care time and may understate the impact of hospital resources on duration of stay in the ED.

We have chosen to use the time from being first seen by a doctor to the time of admission as our measure of access block duration. This is in contrast to most of the published literature, which uses the time from an inpatient bed request to the time of admission as a measure of the effect of bed access block on overcrowding in the ED. To the extent that treatment time is part of the wait that is related to inpatient demand and supply, its exclusion could potentially bias the results. Its inclusion might lead to some loss in precision, as part of the treatment and observation time is unrelated to inpatient factors, but it will not bias the results. We re-estimated the duration analysis using the more conventional measure of boarding time, but in our sample the overall statistical fit was not as strong, and, while bed capacity had the expected effect on access block, other variables were either not significant or had signs that were the opposite of those expected.

For these reasons, while we have some confidence in predicting a reduction in waiting time as a consequence of an increase in ward staff and bed capacity, given that parametric

**Table 2** Responsiveness of waiting time in ED associated with patient and hospital

Variable	Sample mean	SD	% change in duration ED stay for a 1% (or category) change	95% CI
Minutes waiting in ED	396	307.35		
Age	38	28.05	-0.04%	(-0.04%, -0.36%)
Disadvantage	995	70.90	0.16%	(0.11%, 0.21%)
Doctors	184	226.98	-0.24%	(-0.25%, -0.23%)
Nurses	998	714.81	-2.38%	(-2.45%, -2.31%)
Beds	278	161.04	-2.99%	(-3.09%, -2.89%)
Catchment population	35273	172278	0.62%	(0.60%, 0.64%)
Emergency	0.17	0.38	19%	(16.7%, 19.8%)
Urgent	0.46	0.50	20%	(17%, 20%)
Semi-urgent/non urgent	0.32	0.47	15%	(12%, 15%)
Male	0.49	0.50	2%	(1%, 2%)
Indigenous	0.01	0.09	10%	(6%, 13%)
S.Europe	0.09	0.28	2%	(1%, 3%)
East.Europe	0.01	0.01	5%	(2%, 8%)
West.Europe	0.02	0.13	-1%	(-3%, -1%)
SE.Asia	0.02	0.13	-5%	(-7%, -2%)
UK	0.06	0.24	-1%	(-2%, 0%)
Weekend	0.42	0.49	-1%	(-2%, -1%)
Metro	0.72	0.45	0%	(-2%, 2%)
Summer	0.24		-8%	(-9%, -7%)
Spring	0.25	0.43	2%	(1%, 3%)
Autumn	0.26	0.43	-6%	(-7%, -5%)



**Figure 1** Probability of remaining in ED prior to inpatient admission.

survival analysis can be sensitive to variable misspecification and measurement error, the actual magnitude of the effects predicted in table 2 should be treated with caution. A future study using linked ED and inpatient information on patients and resources at the ward level at the time of the patient episode might be able to improve the accuracy of these predictions.

## CONCLUSIONS

The results of the current study are consistent with other evidence<sup>4 5 14 19 20</sup> that the availability of fully staffed inpatient beds is a major determinant of ED overcrowding. The number of nurses, bed capacity and the number of doctors have a significant effect on waiting time for admission to a hospital from the ED. Given the limitations of the data, the sensitivity of parametric survival analysis to misspecification, and the differences across hospitals within this study, caution should be exercised in any generalisation of the magnitude of these results beyond the observed time and place of the Victorian hospital system and its scale of operations. Nevertheless, we are confident that the results are consistent with a significant effect of bed access block on patient time in the ED.

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**Competing interests** None.

**Ethics approval** This study was conducted with the approval of the Department of Human Services Victoria.

**Contributors** AH was responsible for the initial draft and final writing of the paper. AS was responsible for the statistical design and production of the empirical results.

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