Abstract

Objective

Low acuity 'Fast Track' patients represent a large portion of Australian Emergency Departments' (ED) workload and must be managed efficiently to meet the National Emergency Access Target. The current study determined the relative importance and estimated marginal effects of patient and system-related variables in predicting ED Fast Track patients who stayed longer than four hours in the ED.

Methods

Data for ED presentations between 1 July 2014 and 30 June 2015 were collected from a large regional Australian public hospital. Only 'Fast Track' patients were included in the analysis. A gradient boosting machine was used to predict which persons would have an ED length of stay greater or less than four hours. The performance of the final model was tested using a validation dataset that was withheld from the initial analysis. Twenty-seven variables were analysed.

Results

The model's performance was very good (area under receiver operating curve (AUC) .89, where 1.0 is perfect prediction). The five most important variables for predicting length of stay were time-dependent and system-related (not patient-related); these were the amount of time taken from when the patient arrived at the ED to 1) order imaging, 2) order pathology, 3) request admission to hospital, 4) allocate a clinician to care for the patient, and 5) handover a patient between ED clinicians.

Conclusions

This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: [10.1111/1742-6723.12964](https://doi.org/10.1111/1742-6723.12964)

We identified the most important variables for predicting length of stay greater than four hours for Fast Track patients in our ED. Identifying factors that influence length of stay is a necessary step towards understanding ED patient flow and identifying improvement opportunities.

Keywords: National Emergency Access Target, Emergency Department, Fast Track, efficiency, length of stay

Introduction

Emergency Departments (ED) are under pressure to deliver safe, effective and efficient care. Demand for services has risen faster than population growth.¹ Presentations to Australian EDs increased by 21% between 2009-10 and 2013-14.² ED overcrowding has become a serious problem as the number of patients waiting to be assessed, treated and discharged exceeds the capacity of staff and the physical environment.³ To promote more efficient practice, the Australian National Emergency Access Target (NEAT) was introduced which defines the proportion of patients to be discharged within four hours.⁴ The original intention was to incrementally increase the target to 90%; the target for Victorian EDs is currently 81%.⁵

Low acuity patients, defined as Australasian Triage Scale category 4 and 5 patients,⁶ constitute approximately 50% of Australian ED presentations² and must be efficiently managed to meet the NEAT. To improve efficiency, Fast Track Units have been introduced in EDs to stream people with low-acuity conditions to functionally separate areas within the ED to prevent them queuing behind people with more urgent problems who are seen preferentially. Fast Track Units have reduced waiting times and length of stay (LOS), improved patient and staff satisfaction, and reduced the number of people leaving without treatment while not delaying care to higher acuity

patients.⁷⁻⁹ Despite these advances, NEAT compliance for low acuity patients remains challenging for some EDs. At our service, 24% of Fast Track patients had a LOS greater than four hours in 2014.

To achieve the NEAT, each hospital must investigate and understand factors that affect LOS and address modifiable factors to improve care efficiency.¹⁰ ED LOS is determined by multiple interdependent factors. Asplin's conceptual model of 'patient flow' includes three stages: input (the number, acuity, and complexity of patients seeking care), throughput (the processes of care within the ED) and output (the movement of patients out of the ED).¹¹ Patient care can be delayed in one or more stages. Commonly reported causes of delays include increased patient presentations, increased patient complexity, staff shortages, delays accessing diagnostic services, limited physical space and insufficient inpatient beds.¹² However, no study to our knowledge has specifically investigated factors that determine LOS for Fast Track patients. The determinants of Fast Track patients' LOS could be different to non-Fast Track patients' due to different care needs and Fast Track Units being a functionally distinct part of EDs.

The current study investigated factors associated with Fast Track patient LOS. Specifically, we investigated variables that are known or have occurred prior to four hours and whether they predict ED LOS greater than four hours. The study represents a necessary step towards implementing site-specific data-informed interventions to improve care efficiency and NEAT performance.

Method

Setting

Data were collected from the ED of a 432-bed regional Australian public hospital that provides tertiary level care to over 350,000 people in the region.¹³ At the time of study, the ED had 30 beds and an eight-bed Short Stay Unit where patients can stay up to 48 hours. In addition, the Fast Track Unit consisted of seven rooms including two procedure rooms used for tasks such as plastering and suturing. The Fast Track Unit was overseen by an Emergency Physician and staffed at different times by a junior medical officer (resident or registrar), nurse practitioner, physiotherapy practitioner and registered nurse. The Emergency Physician supervised the Fast Track Unit while concurrently overseeing other parts of the ED. Overnight, the Fast Track Unit was overseen by an ED registrar. Junior doctors assigned to the Fast Track Unit could see non-Fast Track patients at their discretion, if the workload in other areas was high. One nurse practitioner worked 13:00-21:30 on weekdays and 9:00-17:30 on weekends. One physiotherapy practitioner worked 8:00-16:30 on weekdays and 9:30-18:00 on weekends. The physiotherapy practitioner also received referrals to assess and treat patients being managed by ED medical staff in any part of the ED, including the Short Stay Unit. Referred patients typically required mobility assessments as part of discharge planning. The Planning and Referral Team (PART) provided care coordination and discharge planning services for patients that required additional home and community support on discharge. Patients' eligibility for Fast Track management was determined by the ED triage nurse on their arrival to the ED. Eligibility was broadly defined as people presenting with relatively simple illnesses and injuries that are amenable to rapid investigation, decision making, and management. In 2015, 64,926 people presented to the ED and 17,867 (28%) were categorised 'Fast Track'.

Data retrieval

Investigators inspected the organisation's electronic medical records and identified quantitative variables relevant to the study aims. To enable efficient extraction of data for thousands of patient presentations, included variables needed to be suitable for electronic, rather than manual extraction from hospital records and databases. Twenty-seven variables were identified and included in the analysis (see Appendix 1 for the variables). Data for ED presentations between 1 July 2014 and 30 June 2015 were retrieved retrospectively by the organisation's information services department and provided to the investigators for analysis.

Patient data were included irrespective of whether the patient was discharged to their usual place of residence or were admitted to the hospital. Only possible predictor events that occurred before four hours were included in the analysis (e.g. x-rays ordered after four hours were not included). Patients whose investigation/s occurred after 4 hours necessarily stayed in the ED more than four hours, hence they were redundant within the analysis. People who attended the ED and 'left without being seen' or 'left without treatment' were excluded from the analysis as they represent a unique group of people who were not the focus of the current study.

Data pre-processing and preliminary exploration

Some variables were reclassified or relabelled to assist with data analysis and interpretation (see Appendix 1 for details). For example, variables with several rarely occurring categories had these categories grouped into an 'other' category.

Univariable relationships between predictor variables and ED LOS greater than four hours (ED>4hrs) were examined with binned proportion plots for continuous variables and contingency

tables for categorical variables. Examination of these relationships (data not shown) suggested non-linearities which informed our analysis model (see 'Data analysis').

Data analysis

A gradient boosting machine (GBM)¹⁴ was used to predict which persons would have an ED LOS greater or less than four hours. The GBM was chosen to model the data because we had a large number of variables which might impact prediction and GBMs are well equipped to handle large numbers of predictors. GBMs also allow modelling of interactions and non-linearities within the data which do not need to be specified a priori.

We withheld 30% of the data as a validation set and chose to sample within each month of the data to limit any seasonal effects. To protect against overfitting, repeated ten-fold cross-validation (with ten repeats) was used on the training data to select the tuning parameters for the GBM. We selected the optimal tuning parameters (minimum cross-validation area under the receiver-operator curve, AUC) from a grid consisting of: interaction depth 1, ..., 5; number of trees/weak learners 1000, 1500, ..., 3000; and shrinkage factor $\in (0.01, 0.005, 0.001)$. Variable importance was defined as the relative influence a variable had on reducing the loss function used in the GBM. Importance was standardised so the sum of all estimated variable influences equalled 100.

After selecting the optimal tuning parameters, the model was refit on the whole training dataset. From the final model, we estimated marginal effects for variables of interest using the tree traversal method of Friedman.¹⁴ To gauge the performance of the GBM, we used the final model to predict the outcome of persons in the validation dataset which we then used to calculate AUC. An AUC of 1.0 would indicate perfect prediction, whilst an AUC of 0.5 would indicate prediction no better than tossing a coin.

All analysis was performed using R (Version 3.4.0).¹⁵ GBM fit used the `gbm` package.¹⁶

Ethical considerations

Barwon Health Human Research Ethics Committee approved the study (reference 14/155).

Results

Patient characteristics

Between 1 July 2014 and 30 June 2015 there were 62955 presentations to the ED of which 17644 were classified 'Fast Track'. People with investigations that occurred after ED>4hrs were removed from the analysis so that 16397 attendances were analysed of which 15.8% had ED>4hrs. The median age (Q1, Q3) was 28.0 (15.2, 46.6) years, 7171 (43.7%) were female, 13424 (81.9%) were Triage category 4 or 5, 1564 (9.5%) were admitted to hospital and 9636 (58.8%) had an "injury" diagnosis which included fractures, sprains, strains and lacerations.

Impact of modelled variables on predicting ED>4hrs

The GBM model identified the relative importance of each variable in contributing to ED>4hrs (see Figure 1). The GBM performance was very good, with the testing dataset AUC equalling 0.89.

Five variables reduced the estimate of the loss of function of the model by over 60% (i.e. contributed over 60% towards the model's performance), all of which were time-dependent:

- 1) Time to imaging request
- 2) Time to admission request
- 3) Time to pathology request

- 4) Time to clinician allocation
- 5) Time to intra-ED handover

Marginal effects of these variables indicated, as expected, that the probability of ED>4hrs increased the closer the event occurred to ED>4hrs (see Figure 2). The probability of ED>4hrs increased slowly when the event occurred in the first 60 to 100 minutes of a person arriving at the ED (probability ED>4hrs $\leq$ 0.2) and increased rapidly thereafter. For example, when imaging was ordered within 40minutes of the patient's arrival, the probability of ED>4hrs was very low (probability $\leq$.08) and then increased marginally up to approximately 100 minutes (probability $\leq$.15), but then more than doubled between 100 and 150 minutes (probability $\approx$.4). Forty-seven percent of admitted patients had ED>4hrs, including 29% of patients with an admission-request submitted within 30 minutes of the patient's arrival.

Considering the remaining variables, diagnosis group was the most important non-time dependent variable. 'Injury' was the most frequently represented diagnosis group accounting for 58.8% (n=9636) of diagnoses of which 13.6% (n=1310) exceeded four hours. 'Musculoskeletal' was the second largest diagnostic group of which 40.3% (n=488) were classed as lower back pain of which 26.2% stayed longer than four hours.

Month of arrival, type of imaging ordered and clinician-group seen were also important variables. The odds of ED>4hrs was less in November (OR .81, 95% CI 0.66 to 0.99, compared to January), which is the month, on average, with the least number of presentations to our ED. Ordering x-rays was associated with a small increase in proportion of people with ED>4hrs compared to no imaging (12.2% v 16.7%), but 57.6% of the 604 people requiring advanced imaging (such as CT, MRI, US) had ED>4hrs. Relative to Consultants, patients seen by Nurse Practitioners and

Physiotherapy Practitioners had lower odds of ED>4hrs (OR .31, 95% CI .25 to .38) with 6.3% of patients ED>4hrs; patients seen by Interns and Residents had higher odds (OR 1.48, 95% 1.27 to 1.72; OR 1.51, 95% 1.25 to 1.82 respectively) with 24.4% and 24.8% of patients ED>4hrs respectively.

Discussion

Site-specific analysis is recommended to identify factors influencing ED LOS.¹⁰ The current study identified factors predicting ED>4hrs for Fast Track patients in a large regional ED. The most important factors were system-dependent and time-dependent events: ordering imaging or pathology tests, requesting admission to hospital, allocating a clinician to care for the patient and intra-ED clinician handover.

Ordering appropriate investigations early in a patient's care experience is imperative for efficient ED care and discharge.¹⁷ Our results concur with others who found ordering pathology tests and imaging, particularly advanced imaging such as CT, were associated with increased ED LOS.¹⁸⁻²¹ In contrast, ordering investigations early, through initiatives such as nurse initiated x-rays, might decrease ED LOS.^{22, 23} Our results indicate that time to ordering imaging was the most important predictor of ED>4hrs. Given that almost 50% of Fast Track patients received imaging, detailed process-mapping of when and why clinicians order imaging could identify opportunities for service improvement and subsequent shorter LOS. Assessing the appropriateness of investigations was beyond the scope of our study, but other investigators found unnecessary imaging and laboratory investigations were common in EDs.^{24, 25} Reducing unnecessary investigations is possible. Stuart et al¹⁷ reduced laboratory and imaging investigations by 40% through staff education, implementing

protocols for ordering, and auditing performance. In addition, processing laboratory investigations in the ED can reduce time to results being available and reduce LOS compared to external processing.⁸

Our results are consistent with others who found waiting time to see a clinician is related to ED>4hrs.²⁶ Increased waiting time also reduces care quality and patient satisfaction.²⁶ Our data indicates that as long as clinician allocation occurred within the first hour of a patient's arrival, then the probability of ED>4hrs was very low ($\leq .08$) and remained modest up until approximately 90minutes ($\leq .15$).

NEAT compliance is more difficult for admitted patients, and in this respect, our data are consistent with others.¹⁰ Delays to admission affect NEAT performance and reduce care quality and patient outcomes.^{10, 27} Promptly commencing admission processes reduces the risk of ED>4hrs, but our data indicates 'exit block' from ED still exists regardless of when an inpatient bed was requested; 29% of admitted patients whose admission request occurred within 30 minutes of arrival still had ED>4hrs. Hospital occupancy was only marginally associated with ED>4hrs (OR 1.0, 95% CI 1.00-1.01), so other factors must influence admission efficiency after the request is made. Consistent with Asplin's model of 'patient flow' through ED,¹¹ improving NEAT performance for admitted patients requires a whole-system response.²⁸

Clinical handover is a high risk scenario and the National Safety and Quality Health Service Standards recognises its importance for high-quality care.²⁹ Our data indicates that time to intra-ED handover had a higher risk of ED>4hrs, but it is unknown whether handover contributed to delayed care and discharge or was a consequence of it. Ye et al³⁰ observed intra-ED handover and found that inadequate handover resulted in delays to patient care and confusion. Guidance for improving handover is provided by the Australian Commission on Safety and Quality in Health Care.³¹

Our ED was relatively efficient at managing “injuries”, the most common presentation type, but was less efficient with the second largest diagnostic group, low back pain (LBP). LBP is a common musculoskeletal disorder seen in EDs and these patients often stay longer than 4 hours.^{32, 33} Patients with severe LBP often find mobilising difficult or impossible, delaying discharge home. Our experience is that severe LBP often coincides with sciatica and effective treatment options for sciatica are limited. There is little empirical support for the effectiveness of NSAIDs, corticosteroids, anti-depressants or opioid analgesics compared with placebo treatments.³⁴ Patients with severe LBP remain a management challenge for EDs.

Clinician-group showed a modest influence on ED>4hrs. Similar to our study, others investigators demonstrated reduced waiting time and LOS for patients seen by Nurse Practitioners and Physiotherapy Practitioners compared to doctors.^{35, 36} Improved Nurse Practitioners and Physiotherapy Practitioner outcomes could reflect their specialty role in Fast Track, scope of practice including possible differences in the types of presenting conditions seen compared to doctors. Junior doctors had more patients with ED>4hrs, so timely supervision by senior staff might be necessary to improve care efficiency.³⁷

Limitations

We included variables that were collected and retrievable electronically. Other variables not included in our modelling could affect ED>4hrs. The number of staff working during a patient presentation is one potentially important variable that was not included in our model that other investigators have found to be associated with ED LOS.³⁸ Another potentially important variable is the time between ordering an investigation (e.g. pathology) and the results being available to ED clinicians. Some of our variables will be affected by measurement error. For example, ‘time to

handover' indicates when the handover was registered in the electronic patient record, which could be different to the time handover actually occurred. This study identified associations between variables and ED>4hrs. Further investigation is required to understand the mechanisms by which these variables affect ED>4hrs and more importantly, how these variables can be modified to reduce ED LOS. Our results cannot be generalised to other health services with different processes and patient presentations. However, it is recommended that EDs are assessed individually,^{10, 39} and our study provides a method for other health services to better understand their performance relative to the NEAT.

Conclusions

Discharging ED patients within four hours is a key performance indicator against which health services are assessed. The current study determined the relative importance and estimated marginal effects of patient and system-related variables towards predicting ED>4hrs in Fast Track patients. The most important variables were time-dependent events: ordering imaging and pathology tests, requesting admission to hospital, allocating a clinician to care for the patient, and intra-ED clinician handover. Identifying these variables as important to ED>4hrs is a necessary step towards understanding *how* these variables contribute to patient flow through the ED and *where* improvement opportunities exist.

Competing interests

None declared.

Appendix 1. Variables included in GBM analysis

1. Patient's age (grouped into 10-yearly increments, commencing 0 years old)
2. Patient's sex (male, female)
3. Patient's usual place of residence (private residence living with others, private residence living alone, all other types of residence (e.g. correctional facility, residential aged care, homeless))
4. Month of arrival
5. Day of arrival
6. Time of arrival (4-hourly intervals from 0:00 to 23:59)
7. Mode of arrival (ambulance, private car/walking, other (police, helicopter, plane, public transport))
8. Source of referral (self, other (General Practitioner, local health service or health provider, police or correctional officer))
9. Compensable status (Medicare patient, Traffic Accident Commission, Work Cover, other)
10. Australasian Triage Scale score assigned on arrival (1 to 5)
11. Number of Fast Track patients waiting to be seen on patient's arrival
12. Number of non-Fast Track patients waiting to be seen on patient's arrival
13. Total number of Fast Track patients in ED on patient's arrival
14. Total number on non-Fast Track patients in ED on patient's arrival
15. Number of Fast Track patients with a bed request on patient's arrival
16. Number of non-Fast Track patients with a bed request on patient's arrival

17. Hospital occupancy at time of patient's arrival
18. Clinician-group allocated to care for patient (doctor intern, doctor resident, doctor registrar
doctor consultant, nurse practitioner, physiotherapist)
19. Time to clinician being allocated to patient (minutes)
20. Time to imaging being requested (minutes)
21. Type of imaging requested (none, x-rays only, advanced imaging (CT, MRI, US))
22. Time to pathology being requested (minutes)
23. Discharge destination (admit to hospital, return to usual residence)
24. Time to hospital admission (bed) being requested from hospital bed-manager (if admitted,
minutes)
25. Time to intra-ED handover (if handover occurred, minutes)
26. Seen by Planning and Referral Team (PART) (yes, no)
27. Diagnosis group (Injury, Cancer, Cardiovascular, Dental, Endo-metabolic, ENT, Eye,
Gastroenterology, General Surgery, Haematology-Immunology, Infections, Miscellaneous,
Musculo-Skeletal, Neurology, O+G, Orthopaedics, Psych-Behavioural, Renal-Urology,
Respiratory, Skin and Soft tissues)

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Figure 1. Relative importance of each variable towards ED>4hrs

Note: 'Relative Importance' has been standardised so that the contribution of all variables sums to 100, FT = Fast Track, PART = Planning And Referral Team

Figure 2. Probability of ED > 4hrs for five most important variables in the GBM model

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Title:

Why do 'fast track' patients stay more than four hours in the emergency department? An investigation of factors that predict length of stay

Date:

2018-10-01

Citation:

Gill, S. D., Lane, S. E., Sheridan, M., Ellis, E., Smith, D. & Stella, J. (2018). Why do 'fast track' patients stay more than four hours in the emergency department? An investigation of factors that predict length of stay. EMERGENCY MEDICINE AUSTRALASIA, 30 (5), pp.641-647.
<https://doi.org/10.1111/1742-6723.12964>.

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