

ORIGINAL RESEARCH

Feeling the HEAT: Using Hourly Emergency Activity Tracking to demonstrate a novel method of describing activity and patient flow

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Abstract

Objective: The objective of the present study is to demonstrate a novel method of mapping ED activity to analyse patterns presentations, occupancy and performance trends.

Methods: This was a retrospective, descriptive analysis of de-identified and linked ED presentations across NSW, Australia, over five calendar years, 2010–2014. It was undertaken as part of the Demand for Emergency Services Trend in Years 2010–2014 (DESTINY) study. The DESTINY project analysed 10.8 million presentations during 2010–2014. Hourly Emergency Activity Tracking (HEAT) maps were generated to visually represent and analyse the number of emergency arrivals to ED occupancy and proportion of patients leaving the ED within 4 h per hour of day across consecutive months of the year.

Results: HEAT maps provided a means of visually representing ED activity to demonstrate hour-to-hour trends in presentations, occupancy and performance between 2010 and 2014. This analysis has shown that the most marked increase in

presentations per hour has occurred during the 10.00–14.00 hour period, associated with an improvement in ED performance during the same period.

Conclusion: HEAT maps may be used to facilitate further analyses of ED demand, patterns of patient presentations and patient flow and future health system redesign.

Key words: activity, emergency department, performance.

Introduction

Although the rise in ED demand and the impact of time-based targets on overall ED performance and quality of care are well documented,^{1–5} the underlying cause of these changes remain less well characterised. Several studies have pointed to increasing ED utilisation by specific patient groups such as the aged and those with higher acuity.^{5–7} However, few studies have examined hour-by-hour trends in ED patient numbers and occupancy, which may provide better understanding of patterns of presentation and demand. Such information

Key findings

- Demand for EDs is growing around the world, but the patterns of this demand remain poorly understood.
- This study tracked average ED presentations on an hour-by-hour basis and found that the increases were mainly during the 10.00 to 14.00 hour period.
- Despite the increase, the proportion of patients leaving ED within 4 h appears to be increasing.

can be valuable in assisting clinicians, clinical managers and hospital administrators on a day-to-day level, so that workforce and other resources more closely align with changes in ED activity. Surveillance of external and internal factors that influence operational efficiency can potentially be analysed.⁶ External factors include ambulance presentations and case-mix such as injury, infectious disease and mental health. Information relating to hourly ED demand may also facilitate identification of variances in patient flow and presentations that result from internal factors such as access block and ward bed allocation practices. Information of such granularity requires presentation in a manner that facilitates visualisation and interpretation of large quantities of data so that its implications are readily discerned.

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We sought to demonstrate ED activity on an hour-by-hour basis using a novel visual aid to demonstrate changes in activity in NSW EDs during the time of the National Emergency Access Target policy implementation. This method of visual representation is intended to facilitate further understanding of ED activity, including types of ED presentations and patterns of patient flow.

Methods

Design and setting

This was a retrospective, descriptive analysis of de-identified and linked ED presentations across NSW over five calendar years, 2010–2014. It was undertaken as part of the Demand for Emergency Services Trend in Years 2010–2014 (DESTINY) study. NSW is the most populous state in Australia with a population of around 7.5 million people and a land area of 809 000 km².⁸

Data sources

The NSW Emergency Department Data Collection Registry contains routinely collected administrative and clinical data for patient-level presentations across all public hospital EDs in NSW. Data obtained for DESTINY included arrival mode, patient registration, type of visit, triage category, mode of separation and the ED diagnosis entered made at the time of discharge. Presentations classified as planned presentations, dead on arrival or transfers from other facilities were excluded. EDs that did not submit data during the study period were also excluded. A full description of data variables and classifications were published in an earlier report.⁹

Outcomes

The outcomes of interest were the number of ED arrivals, total number of patients within ED and proportion of total patients within ED patients leaving within 4 h and therefore meeting performance (National Emergency Access Target [NEAT] or Emergency

Performance Target) criteria (admitted to an in-patient ward, transferred to another institution or discharged from ED after treatment within 4 h of arrival time). All outcomes were calculated and reported as a monthly average for each hour of the day.

Computation and statistical analyses

Computations were performed on a standard PC desktop workstation (Hewlett Packard Z230) using Microsoft Excel using Visual Basic-A macros and SAS Enterprise Guide version 6.1. Owing to the large data set (11.8 million separate presentations) and limitations in Excel data processing capacity, the data set was divided into 19 day, overlapping blocks of 2 weeks with 5 days of overlap per block (a total of 132 blocks). Each of these blocks was further analysed based on diagnostic groups, age groups, triage groups, hospital designation level and mode of arrival.⁹ Analysis consisted of calculating the number of patients presenting to ED, leaving ED or present in ED on an hour-by-hour basis. Calculations assumed no patient would remain in ED for more than 3 days and mapped patient-encounter by patient-encounter rather than by sum of inputs and outputs. This ensured that any errors in calculated length of stay in the database would be removed after 3 days rather than accumulating across the 5 year period. Mean patient arrivals and mean number of patients in ED at a given hour of the day were calculated based on the date and time of arrival and departure from ED. These mean values over a given month were assigned a colour on a red to green scale, relative to the maximum or minimum hourly number of patients observed during the study period (and reversed for NEAT proportions). Intuitively, we chose red to reflect more intense activity, through to a cooler green to represent lower numbers and blue to represent absolute zero. Colours were chosen based on investigating team consensus. These were presented in tables showing average presentations or

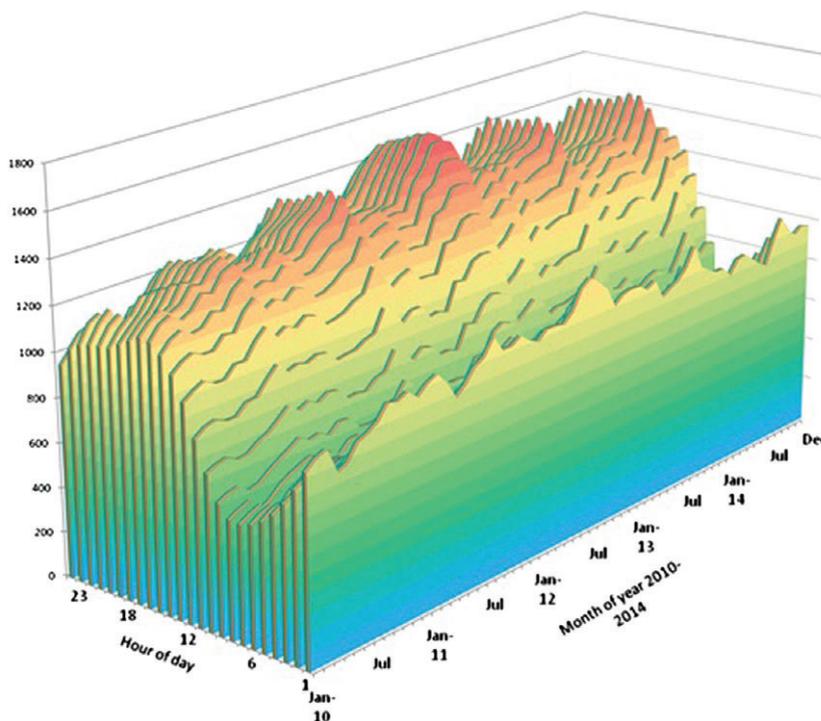


Figure 1. Three-dimensional representation of total number of patients within NSW EDs by hour and month of year from 2010 to 2014.

occupancy by hour of day for each month of the 5 year period. Each table was assigned a separate red-green scale based the minimum and maximum values within a given table, to highlight trends within the table. The final graphical presentations were termed Hourly Emergency Activity Tracking (HEAT) maps.

Ethics

Access to the de-identified linked data set was granted by the NSW Population Health Services Research Ethics Review Committee.

Results

There were 11.8 million ED presentations identified between January 2010 and December 2014. After exclusions, 10.8 million presentations were analysed. Figure 1 is presented to assist with the conceptualisation of the data contained in the HEAT maps and is a three-dimensional (3D) representation of the total number of patients in ED by hour of day and month of the year. HEAT maps generated (Figs 2–4) were aerial views of the corresponding 3D charts using the colour of the peaks on the graphs to colour the cells in the HEAT map (e.g. Fig. 3 is an aerial view of Fig. 1).

Emergency arrivals and occupancy per hour

Figure 2 shows the HEAT map for the monthly average number of ED arrivals per hour, and demonstrates

the gradual increase in presentation rates between 08.00 and 22.00 hours with stable presentation rates during night periods. The peak in presentation rates occurred between 10.00 and 14.00 hours, and this peak has increased from around 300 patients per hour (yellow) to around 400 patients per hour (red) between 2010 and 2014. When total numbers of patients within ED per hour were analysed (Fig. 3), a seasonal pattern emerges with increased total number patients within ED during winter months, particularly 2012, with no discernible increase afterwards.

Proportion of patients leaving ED within 4 h

With respect to proportion of patients meeting NEAT criteria, the increased depth of green in Figure 4 demonstrates a clear trend towards improvement in NEAT performance after January 2012, mainly during daytime hours. This translated to an average daily NEAT performance increase from around 30% to over 50% during 11.00–12.00 and 17.00–18.00 hours after January 2012.

Discussion

This method of data presentation allowed changes in activity that occurred over both months of year and hour of day to be presented and analysed simultaneously. Several studies have already reported improvements in ED performance as a result of time-based targets.^{2–5} We have found comparable results, with

respect to ED performance and utilised a novel tool to visually represent the pattern of these changes. The study demonstrates a steady climb in presentations with predictable seasonal and time of day peaks, occurring in summer from 08.00 to 22.00 hours and occupancy that peaks in winter. Despite the steady increase in total numbers of ED presentations since 2010, the ED occupancy appears to have remained stable, with the proportion of patients staying in EDs <4 h increasing after 2012. This implies that patient flow within EDs has improved and has mitigated the impact of ED overcrowding since the implementation of ED treatment targets in 2012.

There are several aspects of ED activity reporting that are unique to this analysis. First, it allowed visualisation of hour-by-hour changes in ED activity, plotted over many months so that trends and patterns can be readily identified. For example, the increase in ED presentation numbers from 2010 to 2014 occurred primarily during business hours (09.00–18.00 hours) with peak presentation rates occurring around 10.00–14.00 hours, with little change during night shift hours. These findings have implications around future ED workforce planning. The analysis also presents information on occupancy or the total number of patients in the ED at any given time. Occupancy requires calculation not only of presentation rates at a given hour but also their length of stay. Both presentation rates and occupancy have implications for day-to-day resource allocation and workforce and models of care planning that aims to match clinical staffing with periods of higher activity. Model of care interventions that have improved ED performance in previous studies include senior early assessment, streaming and team-based care.^{8–12} These could be deployed on a more targeted basis with real-time knowledge of activity and patient flow demonstrated here. In a study using discrete event data simulation, Khanna *et al.* showed that optimising ward discharges by 11.00 hours alone resulted in improved NEAT performance by around 16%.¹⁴ The present study suggests that a possible explanation for this may be the predictable surge in

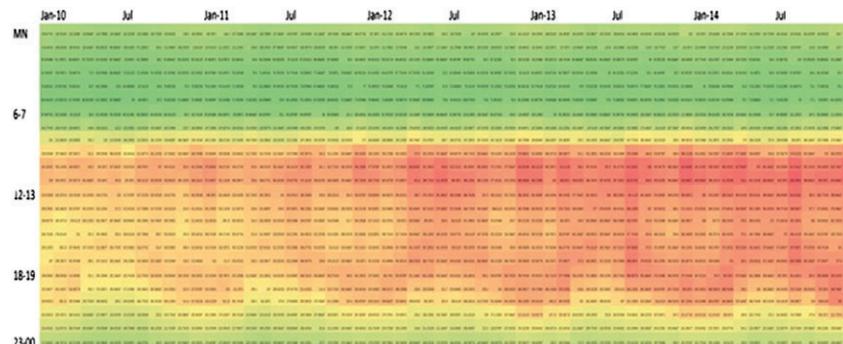


Figure 2. Mean number of NSW ED presentations per hour from 2010 to 2014 (green denoting smaller numbers and red denoting larger numbers).

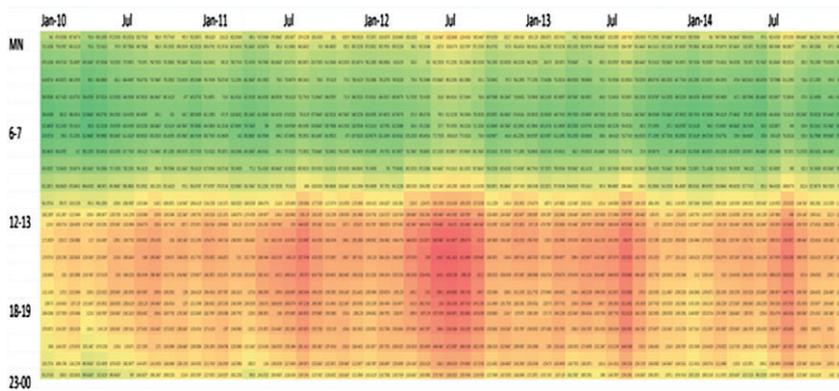


Figure 3. Total number of patients within NSW EDs per hour from 2010 to 2014 (green denoting smaller numbers and red denoting larger numbers).

daytime ED activity that seems to occur after 11.00 hours. Another important observation relates to seasonal variations in presentations and occupancy. Summer months appear to be associated with peaks in average presentations per hour, whereas winter months appear to be associated with peaks in number of patients within ED per hour. This may be because of increased access block and higher acuity of presentations during winter months. ED overcrowding appears to be more prominent during the 2012 winter period, which may have been associated with the introduction of NEAT and overcrowding because of lack of hospital acute in-patient beds (access block). Given the number of patients presenting per hour remained relatively stable during the same period, it would appear that the access block was the more likely explanation.

Second, the same method reported here can be used to further disaggregate the data into specific presenting problem types, in any given region or facility. This may assist with syndromic surveillance of various presenting problem types of public health importance such as influenza, injury or mental illness.^{13,14} Last, given the availability of mode of separation and length of stay data, these HEAT maps may also be used to describe, in near real time, patterns of patient flow within ED and the effects internal and external pressures such as ambulance presentations access block and surges in presentations. The total analysis reported here involved over 132 separate blocks of data requiring around 28 days of continuous processing time to generate 232 HEAT maps using a normal desktop computer. It was estimated that an individual HEAT map

required around 1–2 days of processing time to generate, suggesting that analyses of ED demand could be made in a timely manner.

Limitations

The study has several important limitations. Although the data were routinely used by government agencies to report ED activity, completeness and accuracy of the data as entered by administrative staff and ED clinicians were not evaluated in this study. Unlike recent published studies,¹⁴ we have not sought to relate changes in activity and ED performance with improvements in patient outcomes. This was only a descriptive representation of ED activity. The study did not include several ($n = 15$) small rural and remote EDs that did not submit data to the NSW Emergency Department Data Collection Registry during the study period. Individual HEAT maps presented in this study were not designed to be compared with other HEAT maps, as each table of values underlying the HEAT map was represented by a single red-green scale, based on minimum and maximum values, and designed to demonstrate trends within a given HEAT map. Given this, the appearance of a given HEAT map will change if different time periods are analysed. Further spatial analyses across regions or hospitals are possible by disaggregating the data and applying a uniform set of red-green scales. This would be helpful for analysing presentation patterns for particular types of presentations. Such analyses looking specifically into mental health presentations to ED are currently under way.

Conclusion

HEAT maps may be used to track ED activity with respect to presentation rates, occupancy and ED performance. These may facilitate more granular analyses of patient flow and syndromic surveillance of ED presentations, thereby enabling future health system redesign.

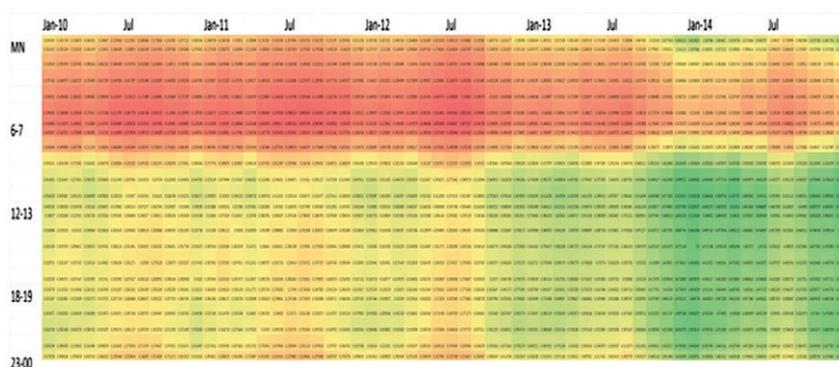


Figure 4. Proportion of total patients within NSW EDs per hour who met National Emergency Access Target criteria (admitted to ward or discharged from ED within 4 h of arrival time) (green denoting higher proportion).

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Competing interests

None declared.

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