Evidence driven strategies for meeting hospital performance targets

The value of patient flow modelling

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Introduction

Pressure on our hospital system seems to be on an ever-increasing upward spiral. Hospital executives and department directors are balancing a range of competing priorities on a daily basis. These include patients with increasingly complex needs, staffing shortages, delayed throughput, system bottlenecks, advances in technology and data management systems, emergency preparedness and facility maintenance. The most visible effect of these challenges is overcrowding in hospitals, which has been labelled an ‘international crisis’ [1], and has a significant impact on the quality of patient care and patient experience.

Hospital emergency departments (EDs) are at the forefront of these challenges facing our health care system. Emergency presentation rates are escalating, due to both our ageing population, and an increased prevalence of chronic diseases. Many public EDs are plagued by slow throughput times, long perceived waiting periods, limited surge capacity, technology integration challenges, and efficiency bottlenecks.

Impeded patient flow through the ED has been estimated to increase patient mortality by 20-30% [2], driving government health policy reform, that is focussed on improving access to ED, elective surgery and subacute care services.

The National Partnership Agreement on Improving Public Hospital Services (National Health Reform Act 2011) has introduced a National Emergency Access Target (NEAT) that requires 90% of all patients arriving at EDs to be seen and admitted or discharged within four hours by 2015. The National Health Performance Authority (NHPA) was also established in 2011 to monitor, report and compare performance of local healthcare organisations, including local hospital networks, public and private hospitals [3].

In 2012, the NHPA published baseline figure for patients moving through EDs within four hours ranged from 55% to 71% [4]. Having already adopted a four-hour target, Western Australian hospitals achieved the best results. The report indicated some progress nationally, but also highlighted a wide variation between hospitals. In general, we have a long way to go.

Capacity management practices vary widely between hospitals, and guidelines informing on efficient management of inpatient bed occupancy are limited. It is difficult to inform these strategies without system evaluation. Experts advocate that while investments in capital and the workforce are important to improving capacity, the greatest efficiencies will be found in system evaluation and redesign [5]. Meeting performance targets such as the NEAT is not solely the responsibility of emergency or surgery departments. Instead, whole-of-hospital engagement is essential in ensuring obstacles to effective patient flow are removed.

Within the Digital Productivity and Services Flagship, CSIRO’s Health Services research is contributing to the effort of solving the hospital overcrowding challenge and helping hospitals to provide their services in more efficient ways. Working with our hospital partners, CSIROs analyses of hospital datasets are leading to evidence-driven strategies that ease bottlenecks, optimisation of bed numbers for patient specialty groups, and improvements in capacity management strategies and care outcomes.

This report gives an overview of the different aspects of patient flow where we have applied analytics, optimisation, and operational decision support tools to improve the management of hospital resources.
The current focus of the National Health Reform Act is to set targets for hospital performance and then have the NHPA collate the data and measure performance in regular reports, including on the MyHospitals website. As well as NEAT, the targets also include the National Elective Surgery Target (NEST), around waiting times for public elective surgery procedures.

Meeting these targets will require hospitals to understand multiple aspects of patient interaction with their different service delivery areas. The areas where we have conducted key activities around patient flow are depicted in Figure 1. However, we have also found that different areas of the hospital are deeply and subtly interconnected, and so a holistic understanding of patient flow through the hospital and beyond will enable further performance improvements.

The collaborative analyses here have modelled patient flow based on retrospective analysis of hospital inpatient and ED data from reporting public hospitals in Australia, across time-spans of up to 10 years. Generally, we aggregated this data into hourly time intervals, as our work has provided evidence that daily measurement of patient flow parameters may be good for general planning tasks, but hourly measurement is more useful for the critical task of managing patient flow in crowded hospitals [6].
Linking ambulance, ED and admissions data

Approximately 20-25% of patients start their journey through the health system by arriving at an Emergency Department in an ambulance. Ambulance services often maintain separate databases from hospital admissions services, and identify patients in different ways. Linking patient information across these data systems provides an important understanding of their overall journey.

To enable the data in these different systems to be used for patient flow research, CSIRO developed a data integration tool [7] that produced a linked dataset of clinical and administrative data, without identifying information such as names and addresses. A research project was undertaken in a large regional teaching hospital ED over a two-month period involving 3469 ambulance records, 10,835 ED records, and 3431 hospital admission records [8]. The data set was able to provide hospital leadership with a complete view of the patients’ journeys from arrival by ambulance through to discharge [9]. This gave a detailed view of hospital workload before and after the opening of a new hospital ED (with no extra hospital beds). Such projects are crucial in setting expectations for building new EDs and the flow-on effect to hospital admissions, and patient wellbeing.
The length of time a patient spends in the emergency department (termed “Length of Stay” or LOS) is the key measurement used to determine hospital NEAT performance, with the requirement that all hospitals will discharge 90% of patients from the Emergency Department within 4 hours by 2015. This follows international best practice, with other countries introducing four-hour rules or more complex quality indicators. CSIRO has reviewed historical ED LOS performance for a major Australian tertiary hospital across seven years. The analysis covered performance by unit and medical specialty, and investigated other factors that influence ED LOS performance such as patient arrival rates and the complexity of patient cases (referred to as case-mix). Our analysis found a significant difference in ED LOS between patients who were admitted to determine and address the source of the disease.

Influenza outbreaks are the most common – generally occurring annually and causing a large burden on the health system. CSIRO has used a variety of models to identify these outbreaks as early as possible. Models include adaptive cumulative sum (CUSUM) plans applied to ED presentation data to signal unusual outbreaks of influenza-like illnesses; influenza presentation forecasts based on historical ED data; and outbreak notification using internet search data.

Using these models, we studied the incidence, characteristics and outcomes of patients with influenza-like symptoms presenting to 27 public hospital EDs in Queensland, Australia, over five years [10], and also used surveillance and forecasting models to predict and track epidemics of influenza [11]. These models are now used in Queensland as part of planning for the winter influenza outbreak, and also have potential in continual monitoring for unexpected outbreaks.

ED Length of Stay (LOS) performance

The length of time a patient spends in the emergency department (termed “Length of Stay” or LOS) is the key measurement used to determine hospital NEAT performance, with the requirement that all hospitals will discharge 90% of patients from the Emergency Department within 4 hours by 2015. This follows international best practice, with other countries introducing four-hour rules or more complex quality indicators. CSIRO has reviewed historical ED LOS performance for a major Australian tertiary hospital across seven years. The analysis covered performance by unit and medical specialty, and investigated other factors that influence ED LOS performance such as patient arrival rates and the complexity of patient cases (referred to as case-mix). Our analysis found a significant difference in ED LOS between patients who were admitted following their presentation and those who were not, as well as strong differences among specialties and units. These findings are consistent with NHPA reporting across Australia in [4]. In addition, one of the more striking factors we found to influence ED LOS was the time of day the patient arrived. We have since extended this work by assessing the impact of arrival time and inpatient occupancy on ED LOS based on 30 major reporting facilities in Queensland. Through this additional work, we uncovered some important differences between NEAT (which applies to all ED presentations) and the previous long standing metric used to measure ED flow performance, Access Block (which applies to ED patients waiting for an inpatient bed).

Our analysis suggests that hospitals aiming to improve NEAT performance will need to examine potential improvements in individual specialties, such as direct admission to a coronary unit for patients complaining of chest pain. We also learnt that unlike Access Block, a high proportion of discharged ED patients fail the NEAT four hour target during the early hours of the morning, and during periods of low ED occupancy. Such studies make excellent cases for compelling hospitals to understand their four-hour ED discharge performance and underlying bottlenecks, before embarking on the journey of ED process redesign to improve NEAT compliance.
The ED LOS performance analysis discussed above showed that patients admitted to wards from the ED spent consistently longer in the ED than those who were discharged from the hospital, and represent much more than 10% of arrivals. Therefore, meeting the performance goal of discharging 90% from ED in four hours will necessarily require hospital staff to be able to admit a patient to the right bed at the right time. To do this, the hospital needs to have an idea of the likely numbers of beds required to meet demand from ED, as well as the types of bed that will likely be needed.

The Patient Admission Prediction Tool (PAPT) is a CSIRO tool that has been developed, validated and implemented to predict ED presentations and subsequent hospital admissions and discharges across time of day, and day of the year [12-14]. Initial model development and validation was based on five years of historical data from two dissimilar hospitals, followed by validation on 27 hospitals representing around 95% of the ED presentations across Queensland.

Our analysis and validation demonstrated that presentations to the ED and subsequent admissions are far from random, and can be predicted with sufficient accuracy to be practically useful. As part of the project, we consulted with ED and bed management staff to identify the information they needed to have, and how they wanted to view it [15]. Implementing the predictive technology in ways that provided this information in a useful format has led to demand forecasting tools that enable better bed management and planning, leading to improved hospital performance. The tool is now being used by hospital staff to change various aspects of their planning and clinical processes [16].
The health sector has long recognised the value of information, and now collects large volumes of rich patient data. However, in many cases there are limited tools to effectively interrogate these data. Visual analytics can help staff and management to see and understand complex trends within these large datasets, providing direct support for planning and decision making, and an effective means to realise the value in patient flow analysis.

CSIRO has created a user-friendly support tool for bed administrators, to support their decision-making through viewing and analysing routinely collected hospital data [18]. The tool displays key inpatient and emergency department patient flow trends over selectable time periods; a day, a week, a month or a year. The selectable parameters include occupancy, ED and inpatient arrival and discharge rates (patients per hour/day/week etc) and lengths of stay, which can be filtered by all available fields in the data (e.g. by age, elective status, primary diagnosis, etc).

Visual patient flow tools transform routinely collected hospital data into valuable evidence for decision making, and are going to form an increasingly important component in the hospital bed manager’s tool kit. CSIRO is assisting in this transformation through understanding how these tools can be used for greatest effect.
One topic of much recent controversy is “optimum occupancy,” or how close to 100% occupancy a hospital can operate at before service efficiency decreases. While increasing inpatient occupancy levels are expected to have an impact on patient flow, a widely cited optimum occupancy level of 85% has been criticised for being both inappropriate [19] and too generalised [20] to be useful.

To help improve understanding of the effects of high occupancy levels on inpatient and ED patient flow, we investigated 30 months of historical records from 23 reporting public hospitals in Queensland [21]. The analysis identified three stages of system performance decline, or choke points, as hospital occupancy increased. These choke points were found to be dependent on hospital size, and reflected a system change from ‘business-as-usual’ to ‘crisis’. The results indicate that modern hospital systems can operate efficiently above the often-prescribed 85% occupancy level, with optimal levels dependent on the size of the hospital.

With this information, hospitals can characterise their individual choke points and determine their optimal occupancy. They are then able to design strategies to better cope when the hospital reaches that occupancy.

Figure 3. Inpatient and ED admissions and discharges across 23 reporting hospitals in Queensland. Vertical lines A, B and C represent performance change associated with patient flow.
Bed configuration

Having the right mix of beds is critical for hospitals in maximising efficient service delivery and patient care. In many hospitals, each specialty unit and ward has a fixed number of beds assigned, for example, there may be eight beds for cardiac patients, 12 for paediatric patients etc. The demographics of the local area that the hospital serves are rarely static, and the ‘winter bed demand’ is a well-known seasonal demand pressure. Hospitals can respond to these demand changes by seasonal or longer-term reviews of bed usage and allocations. Any additional bed capacity should be allocated based on the evidence from patient flow modelling, to optimise hospital performance, and ensure that patients have the best possible access to the right bed at the right time.

CSIRO has developed simulation models for patients admitted to inpatient beds from ED. These models can be used to assess how changing the numbers of beds in different specialities affects the waiting times for inpatient beds. The models have been used to determine the percentage of patients discharged within four hours from ED, for a fixed number of beds assigned to specialities in different combinations. The model can also automatically adjust allocation of beds between specialities to find the overall minimum number of beds needed in the hospital to achieve a specified NEAT performance.

The CSIRO models showed that dynamically altering the allocation of beds to suit incoming flow can improve the utilisation of beds. Other strategies such as clustering bed allocations to an appropriate group of specialties, can also be used to reduce waiting times. As an example one cluster might contain Cardiology, Cardiac Surgery, Respiratory and Sleep Medicine. Our modelling showed that both of these strategies result in improved bed utilisation, and reduced overall bed requirements to meet access targets.
A balancing argument in the face of pressures to fill hospitals to capacity to improve bed utilisation, is that the safety of patients may be compromised through increased staff workload and stress. There is much supposition and guesswork in understanding how hospital occupancy relates to patient safety and minimal hard evidence to date that higher inpatient occupancy equates to a higher likelihood of adverse events.

CSIRO has explored this important issue through examining the relationship between daily hospital occupancy rates and the occurrence of reported adverse events. Safety incident count data was modelled using Poisson regression and negative binomial regression techniques, and multinomial logistic regression and ordered logistic regression were used to determine probabilities of safety incidents. The study across 12 months of historical data from a large quaternary metropolitan hospital in Australia focused on preventable adverse events: medication administration, falls, and clinical management (as opposed to events such as post-operative acute myocardial infarction, wound sepsis or hospital-acquired pneumonia).

Hospital records of midnight occupancy and reported safety incidents were matched by date, to identify the nature and number of adverse events at different occupancy levels.

The study confirmed that increased hospital occupancy does increase the reported rate of adverse events; in general, for a 10% increase in hospital occupancy, the percentage increase in the incident rate of all reported adverse events was around 20%. This is an important factor to consider in developing capacity management strategies.

**Adverse event analysis**
Early discharge strategies

Patient arrivals at a hospital typically peak earlier in the day than the discharge peak, leading to a shortage of beds and overcrowding. A widely recommended strategy for improving patient flow in acute hospitals is to schedule patient discharges for earlier in the day. In the face of little evidence to support this suggestion, some clinicians have questioned whether this strategy makes a difference to patient flow and inpatient occupancy.

We have investigated the effects of varying inpatient discharge timing on ED length of stay and hospital occupancy, to determine the ‘whole of hospital’ response to discharge timing [22,23]. Analysing 30 months of historical data across 23 hospitals, we observed significantly higher levels of occupancy and length of stay when the discharge peak occurs after the peak in admissions. This trend was seen across hospitals of all sizes. We also constructed simulations to model the impact on occupancy levels of shifting all discharges earlier or later, providing a tool for hospital staff to see the effect of early discharge.

With the models clearly demonstrating that early discharge of patients significantly impacts overcrowding and improves patient flow, hospital staff can now use the model to see how much effort needs to be placed on early discharge each day to ensure that occupancy is maintained at a reasonable level.
CSIRO is developing models that use patient data to understand the characteristics of these so-called ‘frequent flyers’ and how they utilise the health system. This model can be used to identify inpatients pending discharge who have high risk of readmission to hospital. Our initial study has focussed on 10 years of data for chronic disease patients in a lower socio-economic urban area, and has integrated data from many sources to build a holistic picture for each patient that encompasses ED, inpatient, outpatient, community health, and pharmacy usage patterns.

CSIRO is working with a Health and Hospital Service (HHS) in Brisbane to provide a model for the identification of these frequent flyer patients. The HHS is then developing strategies to provide additional support to the patient in the community on discharge, with the goal of reducing the probability of re-presentation at the hospital.

Readmission prediction

The World Health Organisation (WHO) describes care for chronic disease (long-term, non-contagious health conditions), as ‘the health care challenge of this century’. These conditions are currently responsible for 60% of the global burden of disease, and are forecast to become the leading cause of disability by 2020 [24]. Improving the management of chronic disease, particularly for patients who frequently need ED or inpatient care, is increasingly seen as an important strategy for improving health outcomes and controlling healthcare expenditure [25].
Partnering to improve hospital performance

CSIRO is addressing Australia’s national challenges through National Research Flagships. The Digital Productivity and Services Flagship is specifically aimed at the challenges of harnessing communication technology and digital information to improve national productivity – including in Australia’s health system.

We understand that many health agencies are facing rising costs, and without productivity improvements (e.g., doing more with fewer resources), the essential services they provide will be significantly strained. We also understand that health professionals are already working very hard under stressful conditions, and that productivity improvements need to come from evidence driven insights and strategies. Rising to meet the NEAT challenge makes it imperative to find sustainable ways to improve productivity through better understanding and management of the multiple factors that affect patient flow and bed availability in hospitals.

This report details a number of the analyses that CSIRO has undertaken together with our hospital partners, and which are providing evidence based solutions to problems of overcrowding and bed capacity in hospitals. Bed demand may seem chaotic, but we have shown that hospital admissions are predictable when data techniques are applied properly to this complex system. Our models have provided information to hospitals to quantify the effect of early discharge on reducing peak occupancy, to show how having the right mix of speciality beds can reduce length of stay in emergency departments, and to show how understanding a hospital’s “choke point” can inform hospitals as to when to trigger “high occupancy” strategies, to provide a better degree of control.

Through the successful partnership initiatives and technological innovations presented in this report, we have demonstrated the potential of powerful modelling tools to improve health outcomes with improved productivity and better use of acute hospital beds. Such analyses can contribute substantially to the formation of evidence driven strategies and policy achievement.

CSIRO Health Services comprises a multidisciplinary team of experts, focussed on developing proven technologies to revitalise the way Australia’s health services are delivered. Harnessing world-class science, deep research skills, and partnering excellence with government and industry, we are advancing health service delivery.

To tackle the complex issues in health service delivery, we are developing strategic partnerships with state and federal government health departments and agencies, international health agencies, hospitals and health care providers, global health technology companies, and universities and research institutes.

We continue to grow our range of health partnerships and seek to foster strategic alliances for future projects. You can contact our business development team (contact details below) to find out more about our work in Health Services. If you are an emergency department bed manager, hospital manager or you represent a state government health department, we look forward to hearing from you, to develop evidence driven strategies to help you improve hospital performance.
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References
