

TRANSFORMING EMERGENCY CARE: THE IMPACT OF REAL-TIME AND PREDICTIVE ANALYTICS ON ED OPERATIONS

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ABSTRACT

Emergency department (ED) overcrowding is a persistent global issue driven by growing patient volumes, limited hospital bed availability, and inefficient resource allocation. At Sir Charles Gairdner Hospital (SCGH), a 600-bed quaternary centre treating over 75,000 high-acuity patients annually, these pressures have been compounded by reduced access to transitional care. In response, SCGH developed a real-time and predictive analytics system to optimise patient flow and improve operational efficiency.

This study presents the ED BRAG Capacity Escalation System, a data-driven solution integrating real-time monitoring and artificial intelligence (AI) to enhance clinical decision-making. The model is built on three core metrics i.e. presentation numbers, admitted patient count, and waiting room occupancy, used to generate a BRAG (Black-Red-Amber-Green) status to objectively assess ED capacity. By utilising Microsoft Azure AI services, the system forecasts ED trends up to 10 hours in advance and processes over 40 supplementary risk indicators, such as ambulance ramping and mental health presentations.

Post-implementation data indicate notable improvements in performance, including more efficient ambulance transfers, timely triage, and reduced departure delays compared to other tertiary hospitals. These results underscore the transformative potential of real-time and predictive analytics in enhancing emergency care [6]. Future research should explore broader deployment to assess adaptability and long-term impact.

KEYWORDS

Emergency Care, transitional care, predictive analytics

INTRODUCTION

Ovidendantur, nesto qui officid modi offic tes debis volore laut viducid erumquam voluptaeprea et est, simolor epernatia Sir Charles Gairdner Hospital (SCGH) operates a large emergency department with a high-acuity patient population, including many elderly individuals, leading to an admission rate of nearly 45%. Annual ED presentations have increased by over 6% in recent years, while hospital bed availability has decreased, intensifying pressures on emergency services. A reduction in effective hospital capacity, combined with inadequate access to residential aged care, has led to access block and critical ED overcrowding. During peak periods, hospital occupancy exceeds 100%, and the ED often lacks the ability to absorb even baseline demand.

Traditional resource allocation strategies rely on manual systems that are time-consuming and dependent on subjective input from experienced clinicians. In highly dynamic environments, this approach is neither scalable nor efficient. In response, the SCGH team developed a real-time and predictive escalation tool based on fundamental ED metrics that allow standardised, automated monitoring of patient flow and operational risk.

The system was designed to provide universal applicability across health networks while retaining the flexibility to incorporate department-specific data. Central to its success was the integration of real-time location data, standardised definitions of ED capacity, and predictive analytics to anticipate patient surges. Predictive analytics significantly enhance operational efficiency by optimising resource allocation, streamlining patient prioritisation, and enabling timely clinical interventions [1]. A core innovation was the replacement of manual alert systems with automated, data-driven notifications, empowering clinical teams to make timely and informed decisions based on real-time and forecasted demand.

OPERATIONAL CHALLENGES IN EMERGENCY DEPARTMENTS

EDs in tertiary hospitals function as complex networks, moving patients through triage, clinical assessment, diagnostics, treatment, and eventually discharge or admission. However, a series of systemic problems hinder flow efficiency and introduce significant patient safety risks [2].

One major issue is the fragmentation of clinical data across siloed systems. Clinicians must consult multiple platforms to build a complete picture of patient progress, increasing administrative workload and risk of error. The lack of a unified real-time overview obstructs coordination with inpatient wards, impeding timely patient transfers and contributing to ED congestion. These delays can compromise the timeliness of care for acutely ill patients, heightening the risk of adverse clinical outcomes.

Additionally, functional ED capacity is often misrepresented. In theory, ED beds are intended for short-term emergency care; in practice, many are occupied by admitted patients awaiting transfer, reducing availability for new emergencies and prolonging wait times. Existing systems lack visibility into overburdened zones within the ED and do not provide actionable insights for reallocating resources efficiently.

Another core challenge is the limited awareness by other departments of ED operational pressures. Without clear communication and shared data, hospital services may inadvertently undermine ED performance. Manual processes such as headcounts remain common for workload assessment, consuming senior staff time and delaying critical interventions.

Moreover, the inability to transfer patients into inpatient or mental health services when these downstream facilities are at full capacity exacerbates ED congestion. This not only prolongs ED stays but also creates backlogs across the care continuum, preventing timely admission of new patients and straining the entire hospital system [4, 5, 7].

STUDY OBJECTIVE AND DESIGN OF THE ED BRAG SYSTEM

SCGH sought to address these issues by developing an automated escalation system capable of assessing ED capacity and forecasting future demand. The tool focuses on three key metrics: the total number of ED presentations, the number of admitted patients, and the volume of individuals waiting to be seen. These indicators were selected for their broad applicability and ability to reflect real-time pressure on ED resources.

The patient journey is typically divided into three stages: arrival and triage, clinical assessment and treatment, and a disposition decision that determines whether the patient is discharged, transferred, or admitted. The BRAG system was designed to monitor and support decisions at each stage. It incorporates a dynamic classification model that continuously evaluates operational thresholds and calculates the ED's capacity status accordingly.

The innovation lies not just in real-time monitoring, but in forecasting stress points. By applying AI algorithms to historical and live data, the system predicts surges in presentations and potential bottlenecks in waiting areas or assessment zones. It enables staff to plan resource allocation proactively rather than respond reactively once strain is already visible.

REAL-TIME MONITORING AND PREDICTIVE FORECASTING

The BRAG system integrates with existing hospital applications to extract over 40 key data indicators that shape the real-time status of ED operations. These include waiting room occupancy, ambulance offload delays, prolonged patient stays, mental health case load, and the availability of observation or resuscitation beds.

Data are visualised through a dashboard updated every 15 minutes, providing up-to-date insights to clinicians, managers, and executives. The colour-coded BRAG system reflects the ED's current capacity and anticipated strain levels, ensuring that all stakeholders are aligned to operational status and can act accordingly.

To forecast future demand, the system uses Azure-based machine learning models trained on extensive historical data. These models estimate hourly ED presentations, likely admissions, and anticipated waiting room congestion up to 10 hours in advance. The visualisation presents these trends on a timeline graph, clearly marking projected volumes and critical risk periods.

This level of foresight allows hospital teams to pre-emptively manage high-demand periods. For example, if a predicted surge in ambulance arrivals is identified, staff can reassign resources, prioritise discharges, or activate overflow protocols in advance. This proactive capacity management marks a shift from traditional, reactive models of emergency care.

COLLABORATIVE IMPLEMENTATION AND SYSTEM INTEGRATION

The BRAG system was developed through cross-disciplinary collaboration involving clinicians, data analysts, operational leaders, and IT professionals. This ensured that the tool addressed real-world challenges and could be smoothly integrated with existing infrastructure.

Rather than replacing current systems, BRAG complements them by acting as a centralised layer of intelligence. It provides continuous updates and automated alerts, reducing reliance

on manual tracking and freeing up senior clinical staff for direct patient care. It also standardises decision-making by replacing subjective assessments with objective, data-driven metrics.

EVALUATION AND KEY RESULTS

The project has been live in a production environment since June 2024, with an ongoing evaluation assessing its impact on ED performance and efficiency metrics. As emergency department (ED) demand continues to rise across Western Australia, where monthly ED presentations have increased by at least 4% compared to the same period in the previous

year—teaching and tertiary hospitals are facing growing challenges in managing patient flow. However, a comparison of ED key performance indicators (KPIs) before and after the implementation of ED BRAG shows that SCGH has achieved notable improvements relative to two comparable metropolitan hospitals, represented as FSH and RPH in this study. Table 1 KPIs illustrate SCGH's efficiency gains, comparing performance across the reporting periods before and after the ED BRAG rollout, considering both the adoption phase and its full operational integration.

TABLE 1: WESTERN AUSTRALIA HOSPITAL SERVICE PERFORMANCE REPORTING (HSPR) FRAMEWORK KPIS

Teaching & tertiary public hospitals in metro	Sir Charles Gairdner Hospital (SCGH)	Fiona Stanley Hospital (FSH)	Royal Perth Hospital (RPH)		
KPI	May-24 to Jul-24 (Prior rollout, Adoption Phase)	Nov-24 to Jan-25 (Post rollout, operational integration)	May-24 to Jul-24 Nov-24 to Jan 25		
P2-16 Emergency ambulance transfer of care -Percentage of patients transferred within 30 minutes of arrival	61.4%	64.9% (improve 3.5%)	57.6% 62.6%	46.7%	46.8%
P2-3b Percentage of emergency department patients seen within recommended times: b) % Triage Category 2 (Seen within 10 minutes)	76.3%	78.8% (improve 2.5%)	47.9%	50.4%	68.8% 62.6%
P4-3b Percentage of Emergency Department patients who did not wait or left at own risk: b) Non-Aboriginal patients	6.28%	6.19% (Improve 0.1%)	10.72%	13.35%	9.07% 10.36%

The funnel plot charts (Figures 1 and 2) illustrates the KPI P2-16 Ambulance Transfer of Care within 30 minutes performance indicator across all public hospitals with emergency departments in Western Australia. While most teaching and tertiary hospitals fall below the control limits, SCGH has demonstrated notable improvement in this KPI, despite the rising demand for ED services. This positive trend has been observed during the monitoring control period following the implementation of the ED BRAG system.

<p>FIGURE 1</p> <p>P2-16 Ambulance transfer of care - transferred within 30 minutes of arrival</p> <p>Reporting Period: May-24 to Jul-24 (Prior rollout, Adoption Phase)</p>	<p>FIGURE 2</p> <p>P2-16 Ambulance transfer of care - transferred within 30 minutes of arrival</p> <p>Reporting Period: Nov-24 to Jan 25 (Post rollout, operational integration)</p>
<p>Figure 1: SCGH ambulance transfer of care performance (61.4%) score was above the lower 99% limit (61.2%), which indicating it was on the verge of exceeding natural variation while it was performing better than its counterparts i.e. FSH and RPH.</p>	<p>Figure 2: SCGH ambulance transfer of care performance improved by 3.5% reaching 64.9% and fell well within the control limit comparing to its counterparts FSH (62.6%) and RPH (46.8%) with both sitting outside of the lower 99% control limit.</p>

The primary objective of the automated system is to significantly reduce the administrative burden on senior nursing staff, saving valuable hours previously spent on manual processes. It has enhanced ED visibility for hospital staff, enabling them to identify delays and high-risk areas more effectively. By facilitating timely interventions, the system has optimised patient flow and resource allocation, ensuring a more efficient and responsive emergency department³. A number of SCGH's ED performance KPIs now reflect quantifiable improvements, outperforming similar facilities across Western Australia.

CONCLUSION

The ED BRAG Capacity Escalation System at SCGH represents a significant advance in emergency care delivery. By combining real-time operational monitoring with AI-based predictive analytics, the system offers a robust framework for managing ED flow, reducing congestion, and enhancing patient care. Results from the system's initial deployment show quantifiable benefits, including reduced administrative workload, improved patient throughput, and better coordination between hospital departments. As emergency departments globally face mounting demand and complexity, systems like BRAG provide a scalable, adaptable solution to improving performance and outcomes.

Future work should focus on expanding the system's deployment to other hospitals and health services, tailoring it to local operational nuances, and refining its predictive models using diverse data sets. Ultimately, the success of BRAG illustrates how technology can empower healthcare systems to move from reactive crisis management to proactive, data-driven decision-making.

ETHICAL CONSIDERATIONS

This project was classified as a quality improvement initiative and, therefore, did not require formal ethics approval. Approval from the designated data custodian was obtained prior to accessing and analysing the data. The analysis

utilised aggregated information sourced from the organisation's internal data repository, solely for the purpose of providing visibility to support operational processes. The study focused on local improvements, not publishing new clinical science. Additionally, the outcomes of the pilot are not intended to inform or implement changes to clinical or administrative processes within the healthcare setting.

References:

1. Janke AT, Overbeek DL, Kocher KE, Levy PD. Exploring the potential of predictive analytics and big data in emergency care. *Annals of emergency medicine*. 2016 Feb 1;67(2):227-36.
2. Boudi Z, Lauque D, Alsabri M, Östlundh L, Oneyji C, Khalemsky A, Lojo Rial C, W. Liu S, A. Camargo Jr C, Aburawi E, Moeckel M. Association between boarding in the emergency department and in-hospital mortality: a systematic review. *PloS one*. 2020 Apr 15;15(4):e0231253.
3. AM MF MS. Access block: A review of potential solutions. Sax Institute. 2022 Sep.
4. Lauque D, Khalemsky A, Boudi Z, Östlundh L, Xu C, Alsabri M, Onyeji C, Cellini J, Intas G, Soni KD, Junhasavasdikul D. Length-of-stay in the emergency department and in-hospital mortality: a systematic review and meta-analysis. *Journal of clinical medicine*. 2022 Dec 21;12(1):32.
5. Richardson DB. Increase in patient mortality at 10 days associated with emergency department overcrowding. *Medical journal of Australia*. 2006 Mar;184(5):213-6.
6. Hu Y, Cato KD, Chan CW, Dong J, Gavin N, Rossetti SC, Chang BP. Use of real-time information to predict future arrivals in the emergency department. *Annals of emergency medicine*. 2023 Jun 1;81(6):728-37.
7. Sprivulis PC, Da Silva JA, Jacobs IG, Jelinek GA, Frazer AR. The association between hospital overcrowding and mortality among patients admitted via Western Australian emergency departments. *Medical journal of Australia*. 2006 Mar;184(5):208-12.