

Emergency Department Trends and Outcomes: A Data-Driven Analysis

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Abstract. This study analyzes hospital Emergency Department (ED) data from 2016 to 2024, examining trends in Waiting Times (WT), Lengths of Stay (LoS), and patient outcomes. WT and LoS increased after the pandemic, indicating operational issues, even though patient volumes remained consistent throughout the whole period. Longer delays were observed on weekends and throughout the colder months, according to temporal analysis. Younger age groups and NZ European/Pākehā and Māori populations dominated ED visits, with older patients experiencing higher mortality rates. Mortality analysis revealed an inverse relationship between WT and patient mortality, with extended LoS correlating with increased severity. The results emphasize the use of predictive analytics to enhance healthcare equity and optimize ED operations.

Keywords. Data Analysis, Waiting Time, Length of Stay, Emergency Department, ED Operations

1. Introduction and Background of the Research

Emergency departments face challenges such as overcrowding, prolonged WT, and extended LoS, which negatively impact operational efficiency and patient outcomes [1]. Temporal and demographic variations further complicate ED operations [2]. As an example, longer delays and increased patient flow are common during the colder months, which requires flexibility in staffing and resource management [3]. One of the demographic factors that can have major impact on ED operations and patient outcomes is ethnicity, which highlights the importance of customized interventions for vulnerable populations [4]. To address these challenges and identify the possible contributing factors, we adopted a data-driven approach to identify inefficiencies and forecast trends [5].

Several studies have measured ED performance concerning the impact on patient care and system effectiveness [6]. These evaluations emphasize how care route mapping and health information systems can improve ED operations and patient flow [5]. The

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critical need of having stronger operational strategies could be highlighted by events like COVID-19 pandemic, which have shown shortcomings in ED, such as increases in patient flow and shortage of resources [7].

Despite these efforts, little study has been done to determine how operational, demographic, and temporal factors contribute to ED outcomes, especially mortality. Thus, the purpose of this study is to examine trends in WT, LoS, and mortality by analyzing the ED data. Through examining demographic and temporal trends, the study seeks to identify important connections influencing ED operations and patient outcomes, providing information for future studies and possible system enhancements.

2. Research Method

We used a comprehensive dataset, covering ED presentations from 2016 to 2024 from Health New Zealand's Waikato Hospital. The data included WT, LoS, mortality status, patient demographics, and operational metrics. In order to guarantee data consistency and dependability, preprocessing included handling missing data using imputation techniques like mean for demographic variables, Z-Scoring normalization, and interquartile range filtering to address outliers. Also, data visualization techniques were used to uncover patterns related to temporal and demographic factors in ED. Python and Plotly enabled comprehensive data analysis, manipulating and visualizing data to explore correlations between operational inefficiencies and patient outcomes. This method offers a solid basis for analyzing how important elements interact throughout ED processes.

3. Results and Discussion

This section presents key findings from Waikato Hospital's ED data, highlighting trends, demographic patterns, and mortality correlations.

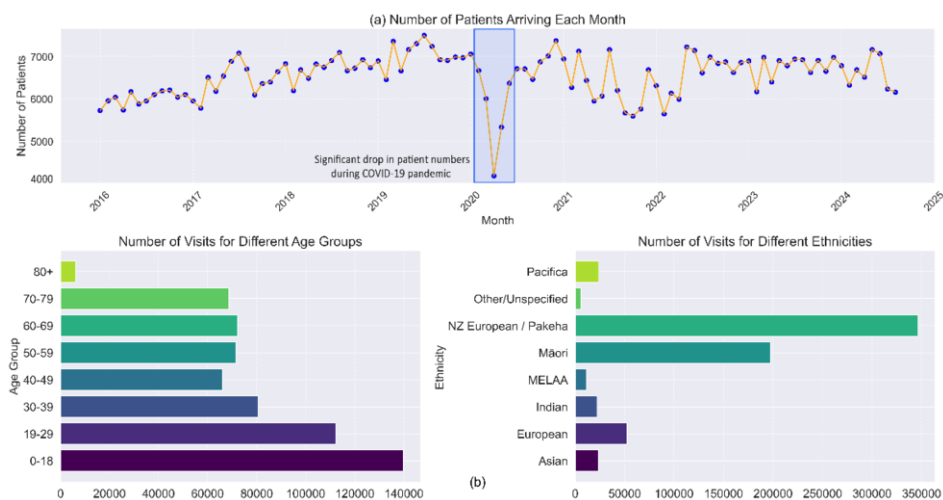


Figure 1. Monthly trends of ED visits (a) and distribution of visits by age group and ethnicity (b)

Figure 1(a) shows monthly ED patient volumes. Patient volumes remained relatively consistent, with a significant drop during the early COVID-19 pandemic period in 2020. Nevertheless, volumes quickly returned, indicating the strong need for ED services. **Figure 1(b)** illustrates demographic patterns in ED visits. Younger age groups (0–18 and 30–39 years) dominated visits, while older groups had fewer. The majority of users were NZ European/Pākehā, then Māori, suggesting that there may be inequalities in healthcare use.

As presented in **Figure 2** WT and LoS consistently increased throughout the study period, with a sharper rise after 2020. According to these increases, systemic inefficiencies or modifications to ED procedures are probably the cause of the changing operational issues.

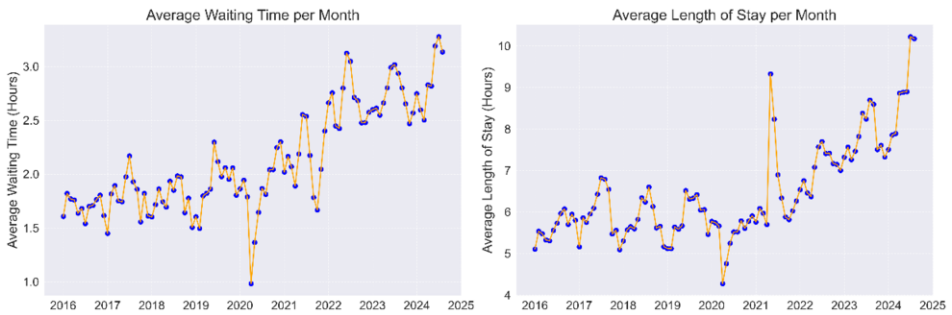


Figure 2. Average of WT and LoS monthly.

Figure 3 reveals seasonal variations in WT and LoS. Colder months showed longer delays, possibly due to seasonal illnesses and weekend’s WT was higher than weekdays, while LoS remained stable across the week. Additionally, the connection between mortality and ED measures is examined (Figure 4). Less critical conditions may be present because longer WT was associated with reduced mortality. Higher mortality was correlated with longer LoS, suggesting more severe cases. Age distribution showed significantly higher mortality rates among patients over 60, highlighting the vulnerability of older populations.

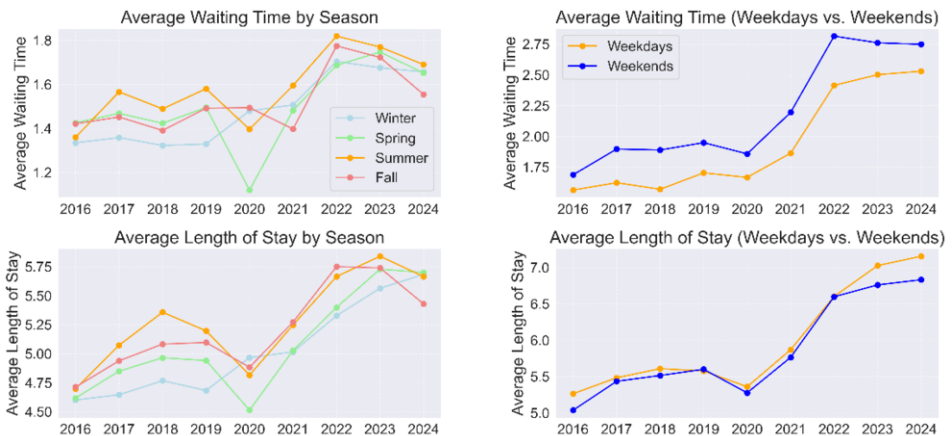


Figure 3. Average waiting time and LoS during weekdays, weekends and seasons.

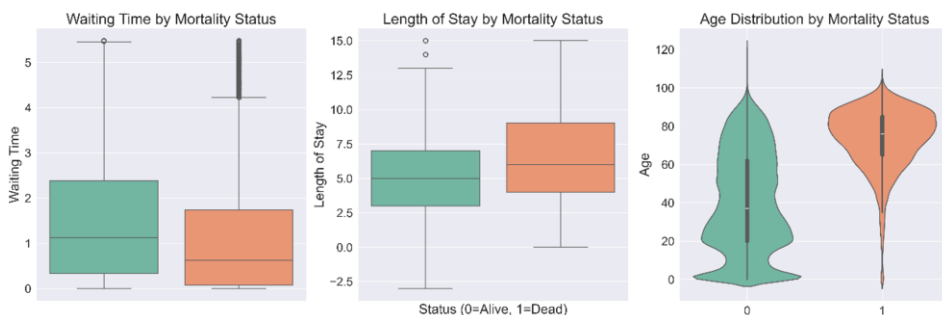


Figure 4. Comparison of waiting time, LoS, and age distribution by mortality status in the ED.

These analyses reveal significant challenges in ED operations, unveiling a complex and dynamic healthcare landscape. Despite the COVID unprecedented challenges, patient volumes remained stable, which could highlight the consistent and unyielding demand for critical ED services. This highlights the ED's vital role in providing healthcare and the system's flexibility in the face of unforeseen events. Significant systemic constraints were indicated by the considerable increase in WT and LoS observed in the post-COVID era. These challenges stem from multifaceted operational constraints, including critical staffing shortages, increasingly complex patient acuity, and the continuous evolution of clinical care protocols. The ongoing delays seen throughout New Zealand's colder months are especially noteworthy, highlighting the significant burden that seasonal illnesses have on ED resources.

The demographic analysis demonstrated that provides critical insights into ED utilization and patient outcomes. The ED's vital role in acute and pediatric treatment was highlighted by the fact that patient volumes were dominated by younger age groups, particularly those between the ages of 0 and 18. In contrast, older populations, while numerically fewer, experienced significantly higher mortality rates, a stark reflection of their increased clinical vulnerability and complex healthcare needs. Systemic inequities in healthcare utilization are shown by the majority of Māori and European/Pākehā populations in New Zealand's ED visits, which further highlights issues with healthcare access and equity.

From an operational standpoint, the complex correlation between mortality and ED measures provides important information for resource management and triage. The observed inverse relationship between WT and mortality suggests an effective triage system that prioritizes urgent cases for immediate intervention. On the other hand, the positive relationship between LoS and mortality highlights the nature of emergency medical care and the complexity of medical conditions requiring prolonged treatment.

Addressing these systemic inefficiencies necessitates a comprehensive, targeted approach. During times of high demand, possible interventions should concentrate on resource enhancement, strategic staffing, and workflow optimization. The seasonal variation in WT and LoS highlights how crucial it is to create predictive models to anticipate and lessen possible stress on the healthcare system, especially during New Zealand's colder summer months.

These results highlight the need for demographic-specific healthcare policies that guarantee fair access to ED services and focused interventions for high-risk groups.

Together with improved triage techniques, proactive resource management may be able to shorten wait times, boost patient outcomes, and eventually raise the overall operational effectiveness of emergency medical services. By implementing advanced triage systems capable of rapidly identifying high-risk patients and optimizing resource allocation, healthcare providers can address the complex challenges revealed by this research. The study indicates that emergency healthcare should adopt a dynamic, flexible strategy that responds to changing patient needs, seasonal fluctuations, and systemic limitations.

4. Conclusion and Future Research

The relationship between patient outcomes, demographic heterogeneity, and temporal metrics is highlighted in this study's investigation of emerging patterns in emergency department operations. By examining the ED data, this research provides foundational insights into the rising WT and LoS, demographic disparities in ED utilization, and their associations with mortality. Future studies will examine multifaceted parameters such as age, ethnicity, clinical complexity, triage score, WT, and LoS, through the application of advanced statistical inference methods such as regression analysis and hypothesis testing, alongside machine learning techniques like logistic regression, Random Forests, and neural networks. These methods aim to develop predictive risk stratification models that can inform operational decisions and improve patient prioritization. The anticipated outcome is a robust, data-driven framework for enhancing ED efficiency, addressing healthcare inequities, and implementing targeted, high-impact interventions. In order to facilitate dynamic resource allocation and evidence-based decision-making, which will eventually improve patient outcomes and operational resilience, future research should also look into the integration of predictive models into real-time ED procedures.

References

- [1] Al Harbi S, Aljohani B, Elmasry L, Baldovino FL, Raviz KB, Altowairqi L, et al. Streamlining patient flow and enhancing operational efficiency through case management implementation. *BMJ Open Quality*. 2024;13(1):e002484.
- [2] de Groot B, Meijs NT, Moscova M, Raven W, Gaakeer MI, Thijssen WA, et al. Characteristics and outcomes of emergency department patients across health care systems: an international multicenter cohort study. *International Journal of Emergency Medicine*. 2024;17(1):123.
- [3] Samadbeik M, Staib A, Boyle J, Khanna S, Bosley E, Bodnar D, et al. Patient flow in emergency departments: a comprehensive umbrella review of solutions and challenges across the health system. *BMC Health Services Research*. 2024;24(1):274.
- [4] Cobb S, Bazargan M, Assari S, Barkley L, Bazargan-Hejazi S. Emergency department utilization, hospital admissions, and office-based physician visits among under-resourced African American and Latino older adults. *Journal of Racial and Ethnic Health Disparities*. 2023;10(1):205-18.
- [5] Manktelow M, Iftikhar A, Bucholc M, McCann M, O'Kane M. Clinical and operational insights from data-driven care pathway mapping: a systematic review. *BMC medical informatics and decision making*. 2022;22(1):43.
- [6] Davari F, Nasr Isfahani M, Atighechian A, Ghobadian E. Optimizing emergency department efficiency: a comparative analysis of process mining and simulation models to mitigate overcrowding and waiting times. *BMC Medical Informatics and Decision Making*. 2024;24(1):295.
- [7] Walker LE, Heaton HA, Monroe RJ, Reichard RR, Kendall M, Mullan AF, et al., editors. *Impact of the SARS-CoV-2 pandemic on emergency department presentations in an integrated health system*. Mayo Clinic Proceedings; 2020: Elsevier.