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Do Midnight Censuses Accurately Portray Hospital Bed Occupancy?

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Abstract. Hospital bed occupancy serves as an important indicator of healthcare system efficiency, directly impacting patient care quality and staff workload. This study delves into the efficacy of midnight census, a conventional method for assessing bed occupancy, in supporting hospital operational planning. Historically, the midnight census has been utilised to gauge bed occupancy; however, its reliability is debated due to fluctuations throughout the day. This paper presents an analysis of 5.5 years of patient flow data from one of the hospitals in Queensland, Australia, scrutinising the statistical associations between different occupancy levels, e.g., midnight, peak, average, and minimum. The findings shed light on the efficacy of the midnight census and suggest the adoption of an hourly-based occupancy rate for more accurate capacity planning and management.

Keywords. bed occupancy, midnight census, hospital bed capacity.

1. Introduction

Hospital bed occupancy (the ratio of occupied beds to available beds) stands as a crucial metric for assessing the efficiency of a health system. High bed occupancy levels can indicate extensive workloads for staff, impulsive patient discharges and severe adverse events [1,2]. Extant literature shows that high bed occupancy correlates with increased risks of patient readmission and post-discharge mortality on days of high bed occupancy, suggesting potential associations between full bed capacities and taking riskier discharge decisions [3-5]. Given hospital operational constraints and the impracticality of

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consistently operating near 100% utilisation, studies have explored the concept of an optimal bed occupancy rate [6]. While the traditional benchmark of 85% bed occupancy is widely acknowledged, finding an ideal occupancy rate remains challenging as it may depend on the time of day, the day of the week, the medical specialty, and even hospital size [7].

Hospitals have historically regarded midnight census as the surrogate for bed occupancy rate to assist with strategic planning and management of inpatient capacity, i.e., the determination of necessary bed numbers and staffing levels. However, the reliability of the midnight census has been questioned due to fluctuations in bed occupancy throughout the day from the churn of patients arriving and departing, which are not adequately captured or statistically accounted for when measuring occupancy around midnight [8,9].

In this paper, the efficiency of the midnight census in supporting operational planning was investigated. Patient flow over 5.5 years (66 months) was analysed and also the statistical associations between midnight, peak, average and minimum occupancy levels at one of the hospitals in Queensland, Australia. The hospital used as the case study is a 208-bed, metropolitan-based hospital with seven operating theatres, an Intensive Care Unit and a 24-hour Emergency Department that provides services to approximately 60,000 patients per year.

2. Methods

The inpatient data for this study was sourced from a larger project assessing patient flow across the major reporting hospitals in Queensland, Australia. The hospital investigated in this study was selected on the basis that it was a typical medium-sized hospital in a metropolitan area (i.e. not a large tertiary hospital, nor a specialist or children's hospital, nor located in a regional or remote area). The study duration was 2017-2022, but the start and end periods were trimmed to avoid edge artefacts, such that the analysis period spanned from April 2017 to August 2022 (1979 days). An ethics exemption for the study was obtained from the Metro South Human Research Ethics Committee (EX/2022/QMS/89905).

The hourly occupancy rate was calculated using the ratio of occupied beds to available beds for every hour of the analysis period. Using the hourly rate, the daily levels of peak, average, minimum and midnight census were calculated. Firstly, historic hourly occupancy was visualised in different occupancy bands (e.g. ≤85%, >95%, etc.), and then average occupancy was analysed by hour of the day. To test the linear dependence between the various occupancy levels, i.e., peak, average, minimum and midnight census, Pearson product-moment correlation (ρ) was measured. In addition, the relationship between peak and average occupancies with one-day and seven-day lag (average of the last seven days) of various occupancy levels was investigated.

3. Results

Figure 1 presents the hourly occupancy rate (47,496 hours) separated into weekends and weekdays. On weekends, for the majority of hourly intervals, occupancy remained under 85%, with only one occurrence for the occupancy band (90,95). On weekdays, however, 14% of hourly intervals exceeded 85% (compared with 1.66% on weekends), and 164 intervals (0.34%) exceeded an occupancy rate of 95%. It is worth noting that there was a substantial change in hourly occupancy rates after the first wave of the COVID-19 pandemic – 93% of hourly intervals were below 85% occupancy before March 2020 compared to 79% afterwards.

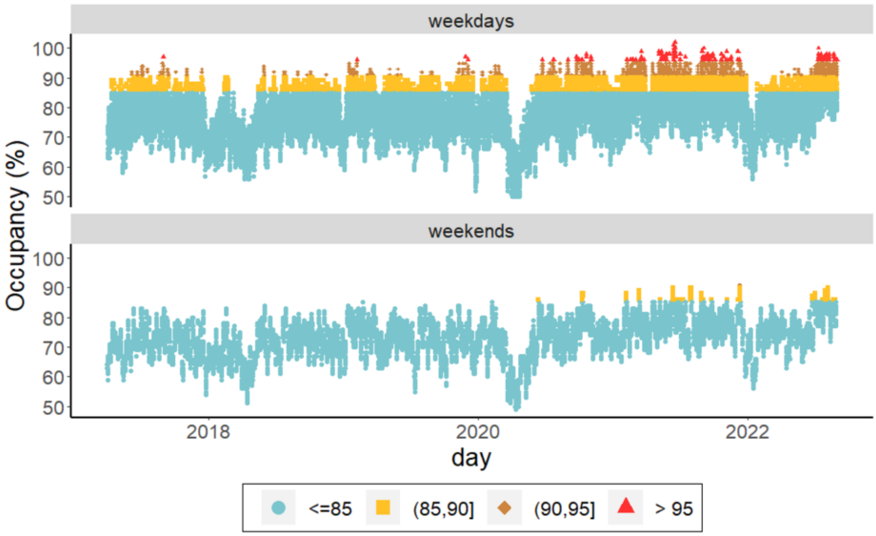

Figure 1. Hourly occupancy for weekends and weekdays.

Figure 2 shows the average bed occupancy throughout each hour of the day for all days (comprising weekends and weekdays) and separately for weekend and weekday categories. Notably, hour 24 denotes the midnight census. The visual depiction indicates that the midnight census closely aligns with minimum occupancy levels rather than the peak or maximum occupancy levels, especially on weekdays. Figure 3 compares average bed occupancy (left axis) and average admission and discharge rates (right axis) for each hour of the day for all days. During morning hours, the number of admissions exceeds that of discharges, leading to a surge in occupancy levels. However, as the afternoon progresses, the discharge rate begins to surpass admissions, contributing to decreased occupancy levels.

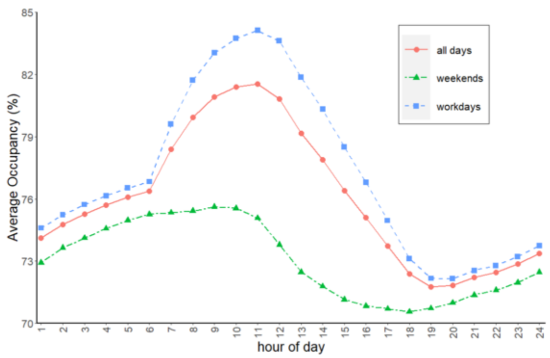

Figure 2. Average occupancy over each hour of a day.

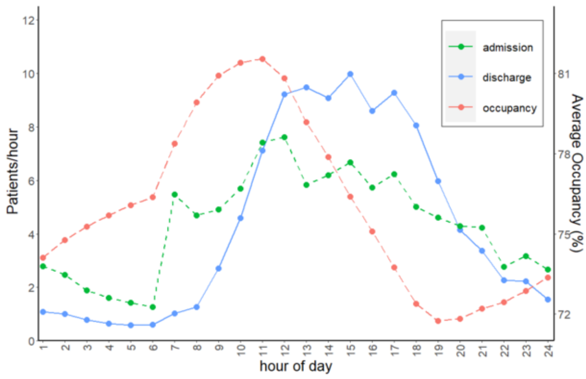

Figure 3. The hourly occupancy vs hourly admission and discharge.

Figure 4 provides an overview of the weekly average occupancy throughout the study period, offering insights into the interplay between various occupancy levels. It is evident from this figure that the midnight census consistently reflects the minimum occupancy (i.e., highlighting the lowest point of bed utilisation), and there is a large disparity between the midnight census and peak occupancy.

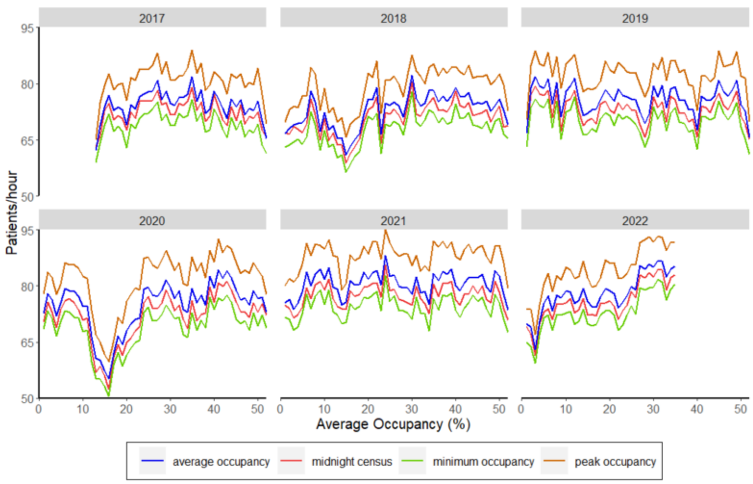

Figure 4. Weekly basis average occupancy for different occupancy levels.

Table 1 provides the Pearson product-moment correlation (ρ) coefficients that quantitatively demonstrate the statistical relationships among the midnight census, peak occupancy, average occupancy, and minimum occupancy. From this table, the midnight census has the strongest correlation with minimum occupancy (ρ=0.95). While statistically significant, considering all days, its correlation with the average and peak occupancy levels are comparatively weaker with coefficients of ρ=0.89 and ρ=0.75, respectively. **Table 2** shows the correlation between peak and average occupancy with the occupancy measures of the previous day (1-day lagged) and an average of the prior seven days (7-day lagged) for all days, weekends, and weekdays categories. Comparing 1-day and 7-day lagged occupancy measures shows that the peak and average occupancy of a given day has a stronger correlation to occupancy levels from the day before compared with an average of the week before. Also, the midnight census is statistically correlated to the average and peak occupancy of the following day. Similar patterns were observed across weekends and weekdays.

Table 1. Pearson product-moment correlation between occupancy measures.

Occupancy	All days	weekdays	weekends
Midnight and peak	0.75	0.80	0.86
Midnight and average	0.89	0.90	0.93
Midnight and minimum	0.95	0.95	0.96
Peak and average	0.94	0.96	0.97
Peak and minimum	0.81	0.85	0.91
Average and minimum	0.94	0.95	0.97

Table 2. Pearson product moment correlation between occupancy measures (previous day relationship).

	All days		Weekdays		Weekends	
	Peak occupancy	Average occupancy	Peak occupancy	Average occupancy	Peak occupancy	Average occupancy
Midnight census *	0.84	0.92	0.88	0.93	0.96	0.94
Peak occupancy *	0.72	0.73	0.74	0.74	0.77	0.72
Average occupancy *	0.80	0.85	0.84	0.86	0.90	0.86
Midnight census **	0.69	0.78	0.79	0.82	0.79	0.80
Peak occupancy **	0.67	0.73	0.78	0.79	0.72	0.72
Average occupancy **	0.68	0.75	0.78	0.80	0.76	0.76

* The day before,

** Average of previous 7 days, p-value < 0.05 in all cases.

4. Discussion

This study investigates the efficacy of the midnight census employed by hospitals for the facilitation of inpatient capacity planning and management. This research indicates that bed occupancy fluctuates throughout the day, with the midnight census exhibiting a notably strong correlation to minimum occupancy as opposed to average and peak occupancy levels. Hospital administrators commonly use the midnight census as a pivotal reference point, deeming it a comprehensive snapshot of daily occupancy trends, informing decision-making processes such as prioritising patient discharge and bed capacity adjustments. Given the substantial variation in bed occupancy within a single day, adopting an hourly-based occupancy rate may present a more dependable approach.

One of the primary rationales underlying the use of the midnight census by hospitals is rooted in the pattern of patient admissions typically occurring during the early afternoon, followed by discharges in the early hours of the subsequent morning, thereby representing a period of peak occupancy [7]. However, the research findings reveal that midnight, in actuality, coincides closely with the time of lowest patient presence within the hospital over a 24-hour day. Despite the start of patient discharge procedures in the morning, a significant proportion of patients remain within the hospital until late afternoon (e.g., awaiting arrangements for post-discharge care or pending receipt of final test results before being released). On the other hand, admissions start early in the morning and reach a peak in the afternoon before the majority of discharges are completed. Consequently, while the hospital census may register 85% at midnight, it could escalate to full capacity, reaching 100% by 1:00 in the afternoon. Such circumstances necessitate the retention of patients in postoperative recovery areas, resulting in additional labour costs incurred for overtime compensation for dissatisfied recovery room nurses unable to depart and leading to patients being "boarded" within the emergency department.

A limitation of this study is the increasing use of virtual wards, given they have an expansile capacity, enabling the absorption of all relevant patients. Discussing occupancy in the context of a virtual ward is meaningless. Increasingly, virtual care will be used for many hospital admissions, with "bricks and mortar" hospital beds reserved for severely ill patients [10,11].

5. Conclusions

This study assessed the midnight census method's efficacy to support hospital bed occupancy planning. Analysing 66 months of patient flow data from a Queensland hospital, it compared the reliability of the midnight census with other measures like peak, average, and minimum occupancy. The findings suggest that hourly-based occupancy rates could provide more accurate capacity planning than relying solely on the midnight census. However, the midnight census could be a lead indicator of average and peak occupancy levels the following day.

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