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Analysis of operating theatre utilisation to drive efficiency and productivity improvements

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Abstract. There is an urgent need in the acute health system to use resources as efficiently as possible. One such group of resources are operating theatres, which have an important impact on patient flow through a hospital. Data-driven insights into the use of operating theatres can suggest improvements to minimise wastage and improve theatre availability. In this paper, a short extract of surgical data from participating Queensland public hospitals was statistically analysed to examine the effects of session type, session specialty, scheduling the longest case first and day of the week on theatre utilisation. It was found that day-long sessions (as opposed to separate morning or afternoon sessions), mid-week sessions, certain specialties (eg. neurosurgery sessions) and not doing the longest case first were most beneficial to theatre utilisation. Awareness of these findings is important in any redesign activity aimed at improving flow performance.

Keywords. Hospital administration, efficiency – organisational, time management, evidence-based practice

1. Introduction

1.1. Background and Operating Theatre Utilisation

Australian public hospitals operate under a strong performance framework with access based targets for the emergency (NEAT: National Emergency Access Target) and elective (NEST: National Elective Surgery Target) business streams of a hospital [1]. The goal of the targets is to address hospital overcrowding and long wait lists, yet current performance indicates there is much room for improvement [2] - particularly in progress towards NEST compliance.

In this study, we focus on theatre utilisation, an indicator of theatre performance [3,4]. Previous studies looking at factors which effect theatre utilisation use many techniques, including linear/multivariate regression [3**,**5**]** and computer simulations [6], as well as covering many specialties (e.g orthopaedic [7], paediatric [8] and neurosurgery [9]) and countries (eg, Australia [7], US [8], UK [3,5]). Findings range from audits of hospital performance to algorithm to add cases to current schedules.

Several definitions of theatre utilisation have been proposed [4]. In this study, utilisation is defined as the percentage of an operating theatre session (block of time an operating room (OR) is booked for) spent with patients (cases) [5] – refer Equation 1.

$$U = \frac{\sum_{Cases\ in\ Session}(Time\ patient\ exits\ OR - Time\ patient\ enters\ OR)}{Session\ end\ time - Session\ start\ time}$$

Equation 1. Definition of theatre utilisation used in the study (U)

1.2. The ORMIS Data Set and Research Questions

Surgical data was obtained from Queensland Health via the Operating Room Management Information System (ORMIS v7), following ethical review. Data consisted of two sub-sets. The first sub-set was a session schedule for all elective surgery sessions at participating Queensland public hospitals over a two year period (the exact dates varied between hospitals, ranging from November 2011 to June 2013). This dataset contained the variables Hospital, Start time of session, End time of session, Specialty assigned to the session and Session ID number. The second sub-set was a list of the patients operated on (cases) in the time period, and contained the variables of Hospital, Date, Patient identifying number, Session ID number, Procedure Code, Procedure Description, Procedure Specialty, Assigned Operating Theatre, Time patient underwent anaesthetic, Time patient entered the operating room (OR), Procedure start time, Procedure end time and Time patient left the OR.

Assumptions are often made when scheduling elective surgery. For example, it is beneficial to schedule the longest case first, and schedule cases in day-long sessions [6]. Additionally it was desired to understand how other factors influence theatre utilisation, such as the specialty performed in a given session, and differences across days of the week. Based on these assumptions, it was decided that the effect of four main variables on theatre utilisation would be examined:

- Booking sessions as day-long sessions or morning/afternoon sessions (both as straight comparisons between the session types, as well as comparing day sessions to pairs of morning and afternoon sessions on the same day);
- Different specialties assigned to sessions;
- Scheduling the "Major" (ie, longest cases) first in a session;
- Different days of the week.

Since a hospital can choose to use a theatre as a day session, or a morning and an afternoon session, morning and afternoon sessions for the same operating room on the same day were paired together, and the overall utilisation (or "Paired Utilisation") was found for the pair, and compared to day sessions. The "Paired Utilisation" for these sessions is defined by equation 2. ("Paired Utilisation" for day and singular morning/afternoon sessions was simply defined as the regular utilisation of Equation 1).

$$U_{paired} = \frac{\sum_M(Patient\ \ out\ \ OR - Patient\ \ in\ \ OR) + \sum_A(Patient\ \ out\ \ OR - Patient\ \ in\ \ OR)}{(Session\ \ finish\ time_M - Session\ \ start\ \ time_M) + (Session\ \ finish\ time_A - Session\ \ start\ \ time_A)}$$

Equation 2. Definition of "Paired Utilisation" for paired Morning/Afternoon sessions, (M) indicates Morning session, and (A) Afternoon session

2. Methods

2.1. Data selection and model fitting

All statistical analysis was conducted using the R statistical package (v3.0.3, The R Foundation for Statistical Computing). Sessions with utilisation greater than 2 (ie. 200%) and equal to 0 were excluded, being deemed as to be misrepresentation of actual theatre use.

Tests were done using a generalised linear model of the Gaussian family, using the variables hospital, hospital size, specialty, specialty size, session type, spread of case durations, longest case first and day of the week. The model equation is shown in equation 3.

$$Utilisation = \mu + \beta_{Hospital} + \beta_{Hospital\ Size} + \cdots + \beta_{Day\ of\ Week} + \beta_{Hospital\ Size} * \beta_{Specialty\ Size} + \beta_{Specialty\ Size} * \beta_{Session\ Type} + \beta_{Hospital\ Size} * \beta_{Longest\ First} + \beta_{Longest\ First} * \beta_{Session\ Specialty} + \varepsilon$$

Equation 3. The generalised linear model equation. μ is the overall baseline level, The β terms are the coefficients for the effects of the variables in the model e.g, $\beta_{Hospital}$ is the effect of the hospital on theatre utilisation (likewise for other variables). Note that these terms are different for each level of the variables. * indicates and interaction term between the indicated variables. ε is the error term. It is assumed that the error terms are normally distributed around 0.

All values reported are mean utilisation ± margin of error for a 95% confidence interval, unless otherwise indicated.

2.2. Model validation

The model was validated by selecting a sample of 75% of the dataset, fitting the model to this data and using this model to predict on the remaining 25%. The specialties of cardiovascular surgery and epilepsy monitoring (all procedures specifically assigned to the specialty "Epilepsy Monitoring Unit' for a particular hospital as opposed to procedures on patients with epilepsy) were excluded from the validation as due to insufficient sample size. It was found that 94.7% (± 0.25%) of the remaining data points fell in the 95% prediction interval (Figure 1).

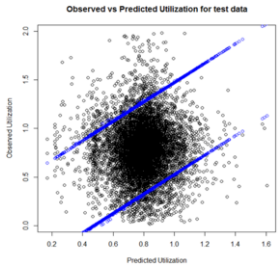

Figure 1. Observed vs Predicted Utilisation for test data set. Blue lines indicate bounds on 95% prediction interval

3. Results

3.1. Session Type

It was found that day-long sessions (mean=0.78 ± 4.45 x 10^{-3}, n = 10371) had higher utilisation than afternoon sessions (mean=0.77 ± 5.70 x 10^{-3}, n = 10105, $p < 0.01$) but lower utilisation than morning sessions (mean = 0.80 ± 5.52 x 10^{-3}, n = 12320, $p < 0.001$) (Figure 2 – left plot).

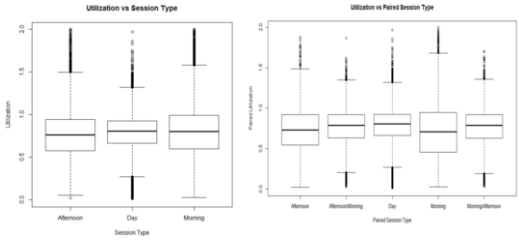

Figure 2. Utilisation vs Session Type. Left: Utilisation vs true session type. Right: Utilisation vs Paired Session Type (Day, singular Morning, singular Afternoon, paired Morning/Afternoon)

When pairing corresponding morning and afternoon sessions, it was found that day-long sessions (0.79 ± 4.51 x 10^{-3}, n = 10151) had the highest utilisation, being significantly greater ($p < 0.001$) than paired morning and afternoon sessions and singular morning and afternoon sessions. Paired combination of both morning and afternoon sessions (0.77 ± 4.75 x 10^{-3}, n = 9078) utilised theatres more than both morning (0.72 ± 1.26 x 10^{-2}, n = 3173, $p = <0.001$) and afternoon (0.74 ± 1.44 x 10^{-2}, n = 1596, $p = 0.028$) sessions singularly (Figure 2 – right plot).

3.2. Session Specialties

Table 1 shows the mean difference between specialty-specific sessions and sessions with no specialty assigned. It can be seen the majority of specialties have some influence on theatre utilisation, with the greatest being Neurosurgery (NEU) (mean difference = 0.532 ±0.060, n = 333).

3.3. Longest Case First

It was found that doing the longest case first (mean = 0.77 ± 5.31 x 10^{-3}, n = 13619) was actually less beneficial to theatre utilisation than scheduling other cases (mean = 0.81 ± 3.72 x 10^{-3}, n = 17845) earlier in the session (Figure 3 – left plot). The two groups were found to be significantly different ($p < 0.001$).

3.4. Day of the Week

There was a clear difference between weekdays and weekends in theatre utilisation (Figure 3 – right plot). Within the weekdays themselves, it was found that Monday and Friday (mean = 0.78 ± 5.14 x 10^{-3}, n = 12072) had significantly different utilisation statistics ($p < 0.01$) to Tuesday, Wednesday and Thursday (mean = 0.80 ± 3.80 x 10^{-3}, n = 20724).

Table 1. Mean difference in utilisation between specialty-specific sessions and sessions with no specialty assigned

Specialty	Mean	ME	*n*	p-value	Specialty	Mean	ME	*n*	p-value
NEU	0.532	0.060	333	<0.001	CAE	0.293	0.233	13	0.009
RAD	0.460	0.123	75	<0.001	END	0.275	0.037	920	<0.001
PAE	0.429	0.126	27	<0.001	ENT	0.271	0.032	2107	<0.001
VAS	0.418	0.055	376	<0.001	OPH	0.256	0.036	1015	<0.001
BUR	0.417	0.066	174	<0.001	MIX	0.241	0.030	4347	<0.001
THO	0.414	0.172	23	<0.001	DIA	0.213	0.080	91	<0.001
PUB	0.406	0.053	318	<0.001	URO	0.212	0.033	1917	<0.001
ANA	0.393	0.082	151	<0.001	CAR	0.204	0.353	8	0.107
DEN	0.386	0.044	920	<0.001	GAS	0.183	0.035	1000	<0.001
MAX	0.377	0.052	389	<0.001	RES	0.183	0.092	76	<0.001
UNK	0.366	0.079	164	<0.001	DER	0.148	0.065	158	<0.001
TRA	0.347	0.077	127	<0.001	ONC	0.103	0.098	51	0.020
ORT	0.343	0.030	5469	<0.001	PHY	0.082	0.206	23	0.208
PRI	0.330	0.160	21	<0.001	CHR	0.067	0.095	54	0.082
GEN	0.328	0.031	4069	<0.001	PSY	0.030	0.050	734	0.118
REN	0.316	0.260	11	<0.001	EME	0.022	0.104	81	0.335
OBS	0.310	0.035	1423	<0.001	MED	0.017	0.114	64	0.381
SUR	0.310	0.032	2390	<0.001	CER	-0.070	0.114	32	0.891
PLA	0.307	0.042	689	<0.001	EPI	-0.137	0.320	5	0.850
GYN	0.301	0.033	1997	<0.001					

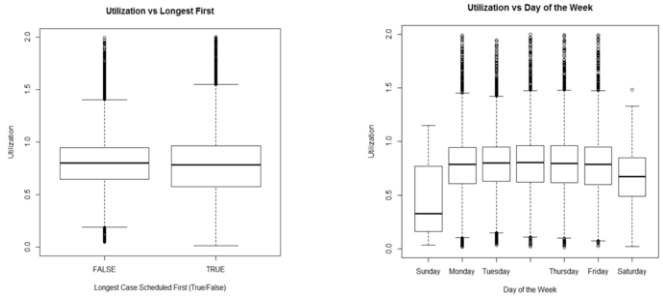

Figure 3. Left: Utilisation vs Longest Case**;** Right: Utilisation vs Day of the Week

4. Discussion

This study has provided insight into surgery scheduling to help improve theatre efficiency and productivity. The research questions assessed were selected in response to current assumptions made about schedule efficiency, such as day sessions being more efficient than split morning/afternoon sessions, and that scheduling the longest cases first is beneficial to theatre utilisation. Effects of session specialty and day-of-the-week were also analysed.

When testing session type, it was found that when comparing sessions singularly, morning sessions utilised theatres slightly more efficiently than day-long sessions (which utilised theatres slightly more than afternoon sessions). However, when pairing morning and afternoon sessions scheduled in the same operating theatre on the same day, day-long sessions were found to be most efficient, supporting the assumption made by the state health department. It should be noted that the differences in utilisation between day-long and morning/afternoon paired sessions was small (2%).

It was also found that scheduling cases other than the longest case first in a session was 4% more efficient than scheduling the longest case first. This is significant, as it contradicts an assumption by Queensland Health. Again, it should be noted that this difference is very small.

When testing the differences between the specialties, it was found that 31 out of 39 specialties had a significant ($p < 0.05$) effect on theatre utilisation. The specialty with the highest utilisation was found to be neurosurgery.

It was found that there was a significant reduction in theatre utilisation between the weekends and the weekdays. This is to be expected, as surgeons try to avoid scheduling cases on these days. When looking at weekdays, Tuesday, Wednesday and Thursday was found to have slightly higher utilisation than Monday and Friday.

The authors intend to assess the findings generated from this analysis against a longer, four-year extract of data from the participating hospital sites, focusing on additional response variables such as patient throughput, and including other explanatory variables such as time spent by patients in the hospital before and after the procedure, and waiting times for procedures (NEST performance in particular). Combining these will aid the development of a simulation model to optimise elective patient flow.

In conclusion, different session types, specialties, days of the week and the ordering of the longest case do influence theatre utilisation, challenging some current assumptions. These results can inform scheduling procedures in public hospitals and lead to more efficient use of hospital resources.

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