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Title Page

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Assessing Operating Theatre Efficiency: A Prospective Cohort Study to Identify Intervention Targets to Improve Efficiency

Running Title:

Assessing Operating Theatre Efficiency

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Abstract

Background

Operating theatre efficiency is critical to providing optimum healthcare and maintaining the financial success of a hospital. This study aims to assess theatre efficiency, with a focus on staff activities, theatre utilisation and case changeover.

Methods

Theatre efficiency data was collected prospectively at a single centre in metropolitan Melbourne, Australia, over two five-week periods. Characteristics of each case and various time points were collected, corresponding to either in-theatre staff activities or patient events.

Results

299 cases were prospectively audited over a range of surgical specialties. Setting up represented 42.4% (37.28 min), operating time 40.1% (35.28 min) and finishing up time 17.5% (15.43 min). Theatres were empty (turnover time) for 17.42 min, which was 39.4% of the non-operative time between operations (44.25 min, turnaround time). Plastic surgery operations required the shortest set-up and finishing times on most of the measured metrics, with general surgery and obstetrics/gynaecology having longer times. List order made a significant difference, with efficiency improving over the list and over the day for separate am and pm lists. When a patient was not on time to theatre, efficiency in both set up and finishing up metrics was significantly worse.

Conclusions

A large proportion of theatre time was being spent on non-operative tasks, making staff activities potential targets for operating theatre improvement interventions. Motivation and team familiarity were identified as the major factors behind efficiently run operating theatres, supporting the use of regular operating teams and maintenance of a highly motivated workforce.

Keywords:

Theatre efficiency, operating theatre, efficiency

Introduction

The efficient management of operating theatres is pivotal to maintaining the financial success of a hospital, being both a large source of revenue and expenditure[1, 2]. Poor operating theatre efficiency is also detrimental to healthcare quality, resulting in both increased adverse events, longer elective waiting lists, and impacting on patient and staff wellbeing and satisfaction[1, 3, 4]. Given the complexities and variation in the theatre environments between hospitals, countries and specialities, different sources of inefficiency may co-exist.

While clinical problems form part of the uncertainty of the operating environment and are difficult to control for, many modifiable factors (including perioperative factors, staffing and intraoperative considerations) have been identified that contribute to inefficiency[2, 4-6]. Other aspects which contribute to theatre delays include patient factors, technical/equipment issues, and scheduling and transport factors[1, 2, 5, 7-10]. Poor communication, teamwork and punctuality (attributed to the surgeon, anaesthetist, nursing or other theatre staff) may have a cumulative effect on perioperative delays and theatre inefficiency[1, 5, 8, 11].

Despite the recognised importance of staff activities on theatre efficiency, limited research exists characterising the time points associated with them. Instead, studies often focus on patient time points and changeover metrics, such as turnover time between cases, theatre utilization rates, and first case on time starts to assess operating theatre efficiency[3, 4, 7, 12]. While these metrics are important in characterising theatre efficiency, in-theatre staff activities would further aid in dissecting the contributors to prolonged intervals, such as changeover times, and potentially highlight real areas for improvement.

This study aims to assess operating theatre efficiency at a single Australian metropolitan centre, with a focus on theatre staff activities. It also aims to identify factors which impact upon staff activities.

Materials & Methods

Study Design & Setting

This study was a single institution prospective cohort study performed at Northern Health, Epping, Australia. The audit period was from February to June 2019. Operating theatres were chosen at random on a daily basis and included all surgical lists. Operating lists at Northern Health do not have regular anaesthetists or nursing staff allocated to individual surgeons or theatres. This study was approved by the Northern Health Office of Research and Governance.

Data Collection

Data was collected by a single investigator for two five-week periods which were otherwise comparable, separated by a 6 week block to avoid holiday periods and reduce selection bias, during the audit period. This was done through direct observation of theatre activities across all surgical specialities with the exception of orthopaedic joint replacement theatres due to infection prevention driven theatre staff number limitations. Those requiring contact precautions were also excluded as they required a lengthy decontamination process. Once those theatres were excluded, theatre numbers were selected using an electronic random number generator to determine which theatre was observed for the day.

Time points were collected for activities completed by staff within theatre both pre-operatively and post-operatively including activities for nurses, anaesthetists, surgeons and theatre technicians. The official theatre session was defined by the study institution as starting at 0830 in the morning and 1330 in the afternoon and finishing time is 1230 and 1730 respectively, however these times are indicative of surgical operating time only. For the purposes of this study total theatre time was measured from the time the nurse brought in the first tray of instrument into theatre until the theatre technician finished cleaning after the last patient of the day. Any excess time between that endpoint and 1330 or 1730 was not recorded. The first patient was routinely required to be in the operating theatre by 0815 or 1315 respectively to allow surgical start at the required time and delay in arrival by this time was recorded. The time points and definitions are described in Figure 1. In particular, turnover time was defined as the time between a patient leaving theatre and the next patient entering theatre, and turnaround time was defined as the time between dressings placed on a patient and operating commencing (knife to skin) on the subsequent patient.

Time intervals were firstly compared between morning and afternoon lists, then between surgical specialties, and lastly between elective and emergency patients, examining the effect of these three factors on theatre efficiency. Time intervals were then compared in relation to list order throughout the theatre session. Comparison was also made between all time intervals combining the factors of elective or emergency patient and whether the first patient of the list arrived on time.

Statistical Analysis

Data was recorded and time intervals calculated using Microsoft Excel (Microsoft Corporation, Redmond, USA). All statistical analysis was performed using SPSS (IBM Corporation, Armonk, USA). Shapiro-Wilks test was used to assess the normality of distribution of continuous variables. Categorical data was compared using Chi-square test. Depending on the number of categories within the independent variable analysed, either a Mann-Whitney U test or Kruskal-Wallis H test with pairwise comparisons using Dunn's (1964) method was performed, with a Bonferroni correction for multiple tests, for each time interval.

Results

299 cases were included in the analysis. When comparing overall utilisation metrics for each case, a similar amount of time was spent setting up theatre and operating, representing 42.4% and 40.1% of theatre time respectively (Table 1). Time spent finishing-up a case represented 17.5% of theatre time. Median turnover time (17.42 min) was found to be less than half of median turnaround time (44.25 min), thus over half of the turnaround time was spent with the patient in theatre.

The median set up time was found to be 6.71 min shorter during the afternoon lists compared to morning lists (Table 1). Median times for pre-operative nurse and anaesthetist activities were also found to be shorter during afternoon lists compared to morning lists, while there was no difference in pre-operative surgeon activity times. Both changeover measures, turnover and turnaround time, were also shorter for cases in the afternoon than in the morning.

Median times per stage according to surgical specialty are listed in Table 1. Plastic surgery and ENT had the shortest intervals. Longer staff intervals between surgical specialties were often associated with longer utilisation or changeover metrics. For example, longer obstetrics/gynaecology pre-operative nurse and anaesthetist times were associated with a longer set-up, turnover and turnaround time compared to plastic surgery. Similarly, a combination of longer post-operative anaesthetic and technician time for both general surgery and obstetrics/gynaecology compared to plastic surgery were associated with a longer finish-up time and turnaround time. 70.6% of included cases were elective operations and 29.4% were emergency operations. Turnover time for elective cases was found to be shorter than for emergency cases. However, case turnaround time did not significantly differ between elective and emergency cases.

On analysis of list order as a potential factor to alter theatre efficiency, most metrics were observed to decrease with list order (Figure 2). The first case of the list resulted in a significantly longer median set-up time compared to all other list orders (Figure 2A). The operative time also significantly decreased over the course of the operating list. Median pre-operative nurse time was significantly longer during the first case of the list compared to all other list orders (Figure 2B). Median turnaround time prior to the second case of the list was significantly longer than the fourth case of the list (Figure 2C). There were no differences in the time taken for post-operative theatre technician activities by list order (Figure 2D). However, contrary to the pattern of all other times measured, there was an increase in post-operative anaesthetic time at the end of the list.

On examination of whether the first patient being on time to theatre affected efficiency, median time of both utilisation and changeover metrics were found to be longer when the patient was not on time to theatre (Figure 3A). Median turnover time was significantly longer than when the patient was prompt (Figure 3B). Similarly, median turnaround times were significantly longer when the patient was not on time to theatre compared to when they were on time (Figure 3C).

Discussion

Theatre time is a finite and expensive resource, which requires accurate allocation and effective utilisation to be used most efficiently. Inefficient use of time in the operating theatre has significant effects on upstream and downstream processes as reflected in elective waiting lists, intraoperative complications and length of stay, as well as undermining staff morale and work-life balance[13-17].

Maximal efficiency may be defined as the operating theatre with the least time spent doing nothing, often measured as a utilisation rate[16, 18-21]. Measuring utilisation rate is commonly used in Australia, however there remain problems in comparing between health systems with issues such as NSW and Queensland government audits considering operative start time to be when the patient enters theatre whereas the Victorian government measures from the start of anaesthesia[19-21]. Also, these are broad metrics that do not suggest individual areas for improvement. The dominant methodology in evaluating perioperative efficiency as decreased time points is Lean Six Sigma (LSS), a set of business management principles which use statistical analysis to reduce inefficiency in production lines and can be adapted to use in operating theatres looking at time points such as turnaround times[22-24]. There are, however, diminishing returns in the improvement of perioperative metrics, with the benefit of reducing the time eventually outweighed by the cost of the intervention[25]. Additionally, there is the concern that the adoption of LSS and pressure to work faster may expose staff and patients to harm[26]. Within this framework, this study assessed the individualised tasks as shown in Figure 1 and shown that up to 60% of operative theatre time is devoted to tasks of setting up and finishing up although no individual areas for improvement were identified.

The most commonly used individual metric is turnover time, representing the time when the theatre is not occupied by a patient[3, 15, 27, 28]. Interestingly, turnover times in this study averaged just under 18 minutes and are considerably shorter than most of those reported elsewhere, ranging from 29 to 45 minutes in American studies and 28 minutes in the Australian hospital system[3, 15, 27, 29]. This highlights the importance of collecting local data.

Delayed first case on time starts have been shown to contribute to poor theatre efficiency and theatre utilisation overall[5, 7, 10, 11, 30, 31]. This study has also shown that delayed start times impact on efficiency, including some of the changeover metrics at the end of the operation and leading into the following case. While this may be due to patient complexity factors such as patients arriving from, and requiring transport back to intensive care, it may also reflect some lethargy and loss of motivation in staff who may resent working harder to make up for the tardiness of other hospital processes and staff. The importance of motivation has previously been shown and this study strongly supports this as a key to efficiency improvements[2, 32].

Interestingly a strong list order trend was seen throughout lists, with many processes decreasing in time throughout the day. While this again may be possibly explained by cases becoming less complex throughout the day, the difference between the morning and afternoon lists also suggest an improved efficiency within the operating team over the day. As the institution in this study does not have set teams for surgeons or theatre lists, a likely explanation is the improved teamwork that develops through familiarity during the day. While our institution and others prefer a varied experience for anaesthetic and nursing staff that rotate through emergency and on call work with expected improvement in the ability to look after these patients, it would be also interesting to compare to institutions with set staffing per list. Of further interest is the unusual result of post-anaesthetic time increasing at the end of the list. Given that the measurement of post-anaesthetic time ends upon extubation of the patient, this suggests a decreased ability to predict the end of the last case to time extubation (thought unlikely), or a relaxed attitude to the timing of extubation due to factors such as a full recovery room, or procrastination to avoid having to perform an additional emergency case, which again highlights motivation as a key component to theatre efficiency.

This study is limited by potential Hawthorne effect bias[33], with an investigator located within the operating room to record times, and also by the inability of the investigator to record relevant times outside the operating theatre.

Conclusions

Theatre efficiency remains difficult to classify and the heterogenous nature of surgery within operating theatres makes comparisons difficult. This study has highlighted that a large component of operating theatre time is made up of non-operative tasks. Staff familiarity within a team and motivation may be two of the major factors behind improving theatre efficiency and this study supports the use and further research into the role of regular operating teams and maintenance of a highly motivated workforce.

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Figure 1. Definitions of utilisation metrics.

Figure 2 (A-C) Median time (minutes) of efficiency metrics by increasing list order. A) (♦) set-up, (▲) operative, (■) finish-up; B) (♦) pre-operative nurse, (▲) pre-operative anaesthetist, (■) pre-operative surgeon, (●) post-operative anaesthetist, (×) post-operative technician; C) (♦) turnover, (■) turnaround. A statistically significant difference between the indicated list order and the first case of the list (* and **) and the second case of the list (^ and ^^) is indicated (p-values <0.05 and <0.001 respectively).

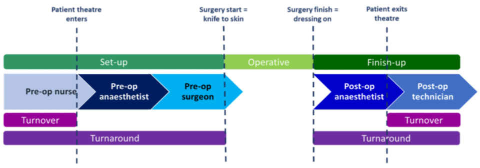
Figure 3 (A-C) Comparison of times when the patient was on time (■) and not on time (□) to theatre, for A) median turnover time (minutes) and B) turnaround time (minutes) for elective and emergency cases with outliers and extremes are represented by ○ and * respectively; C) median time (minutes) of various utilisation metrics. Statistically significant differences are represented by * and ** (p-values <0.05 and <0.001 respectively).

Table 1. Median (IQR) time (minutes) of utilization metrics, staff intervals and changeover metrics, including overall, comparing AM and PM lists, by speciality and case urgency.

	Total, n	Set-up (n=236)	Operative (n=202)	Finish-up (n=194)	Pre-op nurse (n=233)	Pre-op anaesthetist (n=212)	Pre-op surgeon (n=217)	Post-op anaesthetist (n=217)	Post-op technician (n=195)	Turnover (n=124)	Turnaround (n=126)
Overall	299	37.28 (25.92-54.48)	35.28 (18.20-69.75)	15.43 (11.8-20.78)	24.92 (17.13-39.81)	9.72 (7.32-12.21)	11.50 (7.57-16.15)	6.93 (4.55-10.43)	6.433 (3.47-10.92)	17.42 (12.95-23.48)	44.25 (34.56-54.50)
AM/PM											
AM	136	41.58 (30.17-61.68)	33.52 (16.47-64.00)	16.20(12.06-20.81)	27.71 (19.08-41.30)	10.72 (7.38-14.47)	11.75 (8.25-15.71)	7.12 (5.12-10.72)	6.43 (3.50-11.13)	19.90 (13.08-27.83)	48.56 (37.47-67.33)
PM	163	34.87 (23.62-48.72)	35.93 (19.27-73.00)	14.97 (11.35-20.08)	22.08 (15.43-37.28)	9.22 (7.30-11.20)	10.98 (7.08-16.50)	6.78 (3.90-9.61)	6.42 (3.47-10.78)	15.88 (12.48-20.02)	42.20 (32.65-49.27)
Mann-Whitney test p-value		p=0.006	p=0.683	p=0.530	p=0.013	p=0.025	p=0.543	p=0.206	p=0.838	p=0.022	p=0.005
Specialty											
ENT	20	27.61 (22.40-35.35)	16.41 (7.42-30.17)	17.98 (14.85-23.00)[†]	23.12 (16.95-27.13)	8.40 (7.88-11.20)	4.18 (2.15-5.18)[†]	9.13 (6.12-16.65)[†]	3.33 (2.48-4.45)	18.35 (15.28-23.02)	42.20 (36.62-51.19)
General	89	43.85 (30.77-60.72)[†,‡]	65.53 (29.82-84.12)	16.11 (13.27-22.70)[†]	29.37 (21.60-40.22)[†]	10.23 (7.54-13.31)	13.45 (10.35-17.40)[‡,§]	7.48 (5.47-12.88)[†]	7.83 (5.55-12.50)[†,‡]	15.57 (12.93-22.12)	49.59 (42.80-58.35)[†]
Obs/Gyn	60	46.68 (35.84-59.12)[†,‡]	46.41 (29.78-69.78)	17.87 (13.93-21.90)[†]	32.11 (21.37-40.58)[†]	11.39 (9.60-16.18)[†,§]	12.27 (8.32-15.55)[‡]	7.86 (6.64-9.84)[†]	9.18 (4.91-11.56)[†,‡]	23.13 (15.97-29.33)[†]	49.58 (46.92-61.53)[†]

Other	8	61.83 (48.83-94.98)[†, ‡]	108.92 (12.08-172.52)	25.11 (19.52-30.70)	40.83 (37.33-46.38)	22.20 (12.08-26.65)[†]	20.67 (4.75-31.98)[‡]	14.65 (12.45-16.98)[†]	8.68 (5.40-11.95)	46.54 (29.83-63.25)	69.52 (69.52-69.52)
Paediatric	16	48.63 (34.48-63.28)[†]	29.42 (19.85-32.55)	15.37 (12.23-19.33)	24.94 (15.83-39.83)	8.75 (6.32-14.47)	13.67 (9.52-20.60)[‡]	7.20 (5.73-8.63)	6.77 (5.23-8.93)	20.71 (14.46-25.57)	53.64 (45.07-70.88)[†]
Plastic	75	26.53 (20.33-37.30)	25.67 (14.33-40.00)	11.55 (6.18-15.40)	17.74 (11.95-25.17)	7.70 (6.89-10.29)	10.63 (6.42-16.50)[‡]	3.78 (1.88-7.08)[‡]	3.61 (2.17-6.88)	14.58 (9.78-18.11)	34.14 (25.24-41.42)
Urology	31	35.48 (25.05-56.62)	19.30 (10.92-44.98)	15.43 (11.68-21.72)	21.33 (17.08-43.98)	8.68 (7.03-10.07)	9.03 (6.60-10.08)	6.83 (4.58-9.45)	6.90 (3.75-11.75)	20.78 (15.88-25.85)	41.62 (35.62-47.00)
Kruskal-Wallis test p-value		p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p=0.003	p<0.001
Urgency											
Elective	211	36.61 (25.05-56.90)	36.24 (19.28-67.87)	14.83 (11.50-19.88)	24.97 (17.00-39.96)	9.95 (7.57-13.97)	11.83 (7.73-16.50)	6.93 (4.55-9.47)	6.28 (3.03-10.17)	15.73 (12.66-21.18)	42.80 (33.78-53.33)
Emergency	88	38.50 (27.40-50.97)	33.38 (13.45-76.12)	17.27 (12.94-23.69)	24.67 (18.92-38.67)	9.02 (6.95-11.33)	10.43 (6.53-13.94)	7.46 (4.75-11.18)	7.67 (5.28-12.02)	19.48 (15.63-30.15)	47.58 (35.88-61.50)
Mann-Whitney test p-value		p=0.866	p=0.694	p=0.024	p=0.983	p=0.064	p=0.097	p=0.372	p=0.023	p=0.019	p=0.291

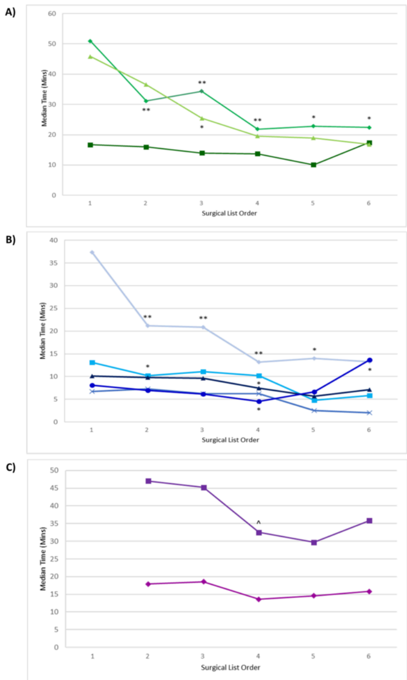
† significantly different to plastic surgery; ‡ significantly different to ENT; § significantly different to urology (Kruskal-Wallis H test with pairwise comparisons, adjusted p-values <0.05). Pre-op, pre-operative; post-op, post-operative; ENT, ear nose and throat; Obs/Gyn, obstetrics and gynaecology. ‘Other’ includes thoracic, vascular, orthopaedic and non-surgical cases.



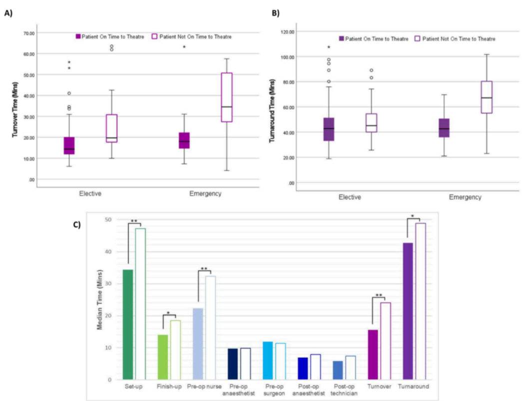
Calculated Interval	Definition
	Utilisation Metrics
Set-up	From start of pre-op nurse time to start of surgical incision
Operative	From start of surgical incision to surgical dressing applied
Finish-up	From surgical dressings applied to end of post-op technician time
	Staff Intervals
Pre-op nurse	From when the scrub nurse commences scrubbing, ready to prepare instruments into theatre; to scrub nurse completes instrument preparation and count, ready for surgery to begin
Pre-op anaesthetist	From when patient enters theatre to initial anaesthetic procedure completion (either intubation, spinal, sedation or local anaesthetic complete)
Pre-op surgeon	From initial anaesthetic procedure completion to start of surgical incision
Post-op anaesthetist	From surgical dressing applied to patient exits theatre
Post-op technician	From commencement of theatre clean/equipment manipulation by the technician, to completion of theatre clean and ready for next surgery to begin
	Changeover Metrics
Turnover	From patient exits theatre to next patient enters theatre
Turnaround	From end of operative time to commencement of the following operative time

Pre-op, pre-operative; post-op, post-operative

ANS_16991_Figure 1.tiff



ANS_16991_Figure 2.tiff



ANS_16991_Figure 3.tiff