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A PROSPECTIVE STUDY EVALUATING ELECTIVE ORTHOPEDIC OPERATING THEATRE EFFICIENCY AT A SOUTH AFRICAN TERTIARY HOSPITAL

[1]Hylda Makanisi[*], [2]Thenjiwe Hlongwane, [1]Toms Lushiku, [3]Kena Mogotsi
[1]Department of Anaesthesiology, School of Clinical Medicine, University of the Witwatersrand, Johannesburg, South Africa
[2]Senior anaesthesiology consultant at Chris Hani Baragwanath Academic Hospital and in private practice.University of Witwatersrand
[3]Anaesthesiology consultant and intensive care fellow at Chris Hani Baragwanath Academic HospitalUniversity of Witwatersrand

ABSTRACT

Background
The demand for elective orthopedic surgery has increased in South Africa due to an increasing burden of trauma and financial constraints caused by a poorly performing economy. This highlights the importance of orthopedic operating theatre (OT) efficiency in this resource-constrained country. This study aimed to assess the efficiency of elective orthopedic operating theatres at a SA tertiary hospital.

Methods
This was a cross-sectional study of elective orthopaedic OT lists over 8 weeks, at Chris Hani Baragwanath Academic Hospital, SA. Data assessed during the study included sub-specialty, number of scheduled and completed cases, time OT commenced activities, time OT ceased activities, case time, turnover time, raw theatre utilization as well as the day of surgery cancellations. The data was collected using a password-protected REDCap database form and analyzed with descriptive statistics.

Results
A total of 117 OT lists equating to 342 cases were included from different orthopaedic subspecialities. The total available OT time was 58331 minutes, of which a large majority, 46638 minutes (80%), was used as case time during conventional OT working hours (95.4%). Fifty-three percent of OT lists started early, whereas 29.9% started late; 65% of them were underran and 30% overran. The mean turnover and first-case starting times delays were 39 minutes and 7.1 minutes, respectively. The overall raw theatre utilization was 83.0% (range: 71.8-88.2%, SD 16.3) with a DOSC (day of surgery cancellation) rate of 19%.

Conclusion
Overall, elective orthopedic OT utilization was efficient at CHBAH. The challenge posed by cancelled surgeries in CHBAH must be addressed as facility-related reasons were cited as the main reason for cancellations. This will further improve the orthopedic OT efficiency in this hospital.

Recommendation
Optimizing preoperative patient assessment and preparation to identify cases that could lead to DOSC

***Keywords**: Theatre utilization, Day of surgery cancelation rate, Operating theatre efficiency, Orthopedic procedures, South Africa*
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***Corresponding author:** Dr. Hylda Makanisi*
***E-mail:** m.hylda1989@gmail.com*
Department of Anaesthesiology, School of Clinical Medicine, University of the Witwatersrand, Johannesburg, South Africa

INTRODUCTION

The operating theatre (OT) is a complex entity and is an essential part of any hospital [1]. In turn, the efficient administration of an OT is a core component of the surgical and anesthetic unit [2] and requires close cooperation and interaction between medical and non-medical personnel [1]. Up to 30% of any hospital's allocated budget is used to

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ensure that operating theatres run smoothly [2], and a large portion of a hospital's earnings (40-70%) is derived from the services provided by the OT [3]. The rising cost of healthcare and limited budget allocations have driven the need for better OT administration to maximize overall OT productivity and efficiency [2, 4, 5].

Efficiency refers to the ability to obtain the best possible output with minimal resources [6]. Concerning an OT, efficiency is the ability to safely perform as many surgeries as possible with the resources available at the OT [6]. This can be accomplished by improving patient flow through the OT and by minimizing the wastage of resources, such as those that may arise from day-of-surgery cancellations (DOSCs) [5, 6].

Time is the most valuable commodity in the OT. Any unused or wasted OT time will translate into poor efficiency. Thus, many of the variables or performance indicators that are used to assess OT efficiency will often measure OT time utilization [6]. OT time utilization is especially important in the South African (SA) public healthcare sector, where resources are limited in the face of an increasing demand for medical and surgical services [1]. SA needs better-administered OTs given the high trauma rate and the restricted healthcare budgets [1, 7]. Up to 90% of all trauma admissions in SA need after-hours surgical treatment, which invariably involves the OT [1]. The orthopedic department in SA is heavily burdened by this trauma with high running costs and strain on scarce OT availability as shown by Klopper et al [7]. It costs R14 404.11 per orthopedic theatre per hour, excluding the implants' cost which could average R20 473.31 per case [7].

Although there are studies on OT efficiency in SA [8, 9], none of them focus on orthopedic OTs whether elective or emergency and this paucity of information must be addressed given the rising demands for orthopedic OTs. This research aimed to assess the efficiency of elective orthopedic OTs at a South African tertiary-level hospital.

MATERIAL AND METHODS

Study design

This was a prospective cross-sectional study conducted for 8 weeks (24 October to 18 December 2023).

Study setting

The study setting was Chris Hani Baragwanath Academic Hospital, which is in Johannesburg, Gauteng Province, South Africa. CHBAH is the seventh largest hospital in the world, with over 3000 beds and nearly 7000 staff members. It is a public hospital that is financed and run by the Gauteng Provincial Health Authorities. CHBAH is a tertiary-level facility and is one of the designated teaching hospitals for the University of the Witwatersrand's Medical School. This hospital has several elective OTs: some within the main theatre complex and others in remote locations. Of the elective 11 OTs within the main complex that function during the day, 3 are allocated to orthopedics and are shared between its sub-specialties namely: arthroplasty, foot and ankle, lower limb, upper limb, spine, and pediatric orthopedics.

Study sample

The study sample was comprised of elective orthopedic OT lists performed at CHBAH in the main theatre complex between 24 October 2023 and 18 December 2023. This included the 3 elective orthopedic lists booked daily within the main theatre complex. A total of 117 elective orthopedic theatre lists were included in our study.

Bias

To minimize bias during this project, the included OTs were allowed to function undisrupted, as per usual. The data collection happened randomly throughout the day as well as after hours (after the theatre staff had left). Routine collection times were avoided as much as possible. Some data were collected from observations (e.g., starting time) and others from theatre logbooks, anesthetic charts, and theatre booking list forms (e.g., DOSC). The reasons for cancellations, delays, and variations in starting and ending times were collected from the staff members (passive listening and active inquiries). The theatre staff members were not informed formally of the project. HM was assigned randomly to orthopedic theatres on some days, and on others, she worked out of the main theatre complex.

Data collection and definitions used

The study data was prospectively collected using an online REDCap data collection form. No patient information was collected, and therefore no informed consent was needed for this study. Permission to collect the data was acquired from the anesthesia and the orthopedic departments, as well as the theatre complex's nursing matron and the hospital's medical advisory committee. The collected data was stored in a password-protected REDCap database and can be accessed by the researcher and the supervisors. The following variables were collected during the study period: number of OT lists for each orthopedic sub-specialty, number of scheduled surgical cases (completed and canceled, with broad reasons for canceled cases also collected), time OT commenced activities with the first surgical case for the day, time OT ceased activities following completion of the last surgical case for the day, case time, turnover time, and raw theatre utilization.

DOSCs were cases that were scheduled for surgery on an OT list but not operated on. Ideally, elective OTs at CHBAH

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seek to commence daily activities with the first surgical case at 08:00 and cease daily activities with the last surgical case being completed by 16:00 (this is known as the block time or allocated time). Late starts and early starts were defined as OT lists commencing after 08:00 and before 08:00, respectively. Overruns and underruns were defined as OT lists completed after 16:00 and before 16:00, respectively. Case time was defined as the time during which surgeries are conducted (inclusive of anesthetic induction, surgical preparation time, and the amount of time between incision and skin closure for each surgical case). Turnover time was defined as the time between one surgical case leaving the OT and the time that the next surgical case entered the OT. Raw theatre utilization was defined as the percentage of time between 08:00 and 16:00 that surgeries were performed. Case prediction bias was the ability to correctly predict the duration of an operation or procedure. Following completion of the data collection, the database was exported into Microsoft Excel for analysis.

Data analysis

The data analysis was performed in Microsoft Excel. Data was analyzed with descriptive statistics. The mean with standard deviation (SD) and range (minimum-maximum value) were calculated for continuous variables. Frequencies and percentages were calculated for categorical variables. The results of the statistical analysis are presented in tabular or graphical format.

Ethical approval

This study was approved by the Human Research Ethics Committee, University of the Witwatersrand. Protocol number M230805 and ethics approval reference number R14/49 (approved on 23 October 2023).

RESULTS

The study sample was comprised of 117 OT lists with a total of 342 cases. Of these 117 OT lists, the majority were related to lower limb surgery (25 lists) and arthroplasty (24 lists). Foot and ankle surgery contributed the least to the study sample (6 lists). Table 1 describes how these lists were distributed between the different subspecialties.

Table 1. Theatre utilization during the study period, stratified by orthopedic sub-specialty

	Utilization of operating theatre		
Sub-specialty	Lists, n	Cases, n	Mean utilisation % (SD)
Arthroplasty	24	84	85.9 (12.4)
Foot and ankle	6	15	88.2 (8.2)
Lower limb	25	62	86.3 (17.9)
Pediatric orthopedics	16	70	86.5 (13.9)
Spine	17	41	71.8 (19.8)
Sports	11	28	84.4 (8.3)
Upper limb	18	42	79.8 (18.7)
Total	117	342	83.0 (16.3)

SD: Standard deviation

There were 58331 minutes of OT time available during the study period. A large fraction of the time was utilized as case time (46638 minutes, 80% of available OT time). Of the total case time utilized, 95.4% (44484 minutes) was within the conventional working hours (the block time). The rest were due to early starts of the first case (860 minutes, 1.8%) and overruns (1294 minutes, 2.8%). Time lost due to early finishes (underrun theatre) comprised the next highest fraction of total available OT time (6280 minutes, 10.8%), followed by turnover time (4579 minutes, 7.9%) and time lost due to late start (834 minutes, 1.4%). An analysis of overall case time during the study period is shown in Table 2 and Figure 1. The overrunning of the last case and the early start of the first case only accounted for a small fraction of overall case time (2.8% and 1.8%, respectively). A description of the number of early starts, underruns, late starts, and overruns for OT lists across the various orthopedic sub-specialties is shown in Tables 2 and 3. Figure 2 provides the main reasons cited for theatre underruns as well as overruns.

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Table 2. Analysis of available OT time during the study period

Activity	Time, min	Mean per list (SD), min	Range, min	% Total available time
Time lost due to a late start	834	7.1 (16.8)	0-120	1.4
Time lost due to underrun	6280	53.7 (67.0)	0-295	10.8
Turnover time	4579	39.1 (29.8)	0-165	7.9
Case time	46638	398.6 (78.1)	150-655	80.0
Total available time	58331	-	-	100.0

Figure 1. Utilization of available OT time (58331 hours) amongst various orthopedic sub-specialties

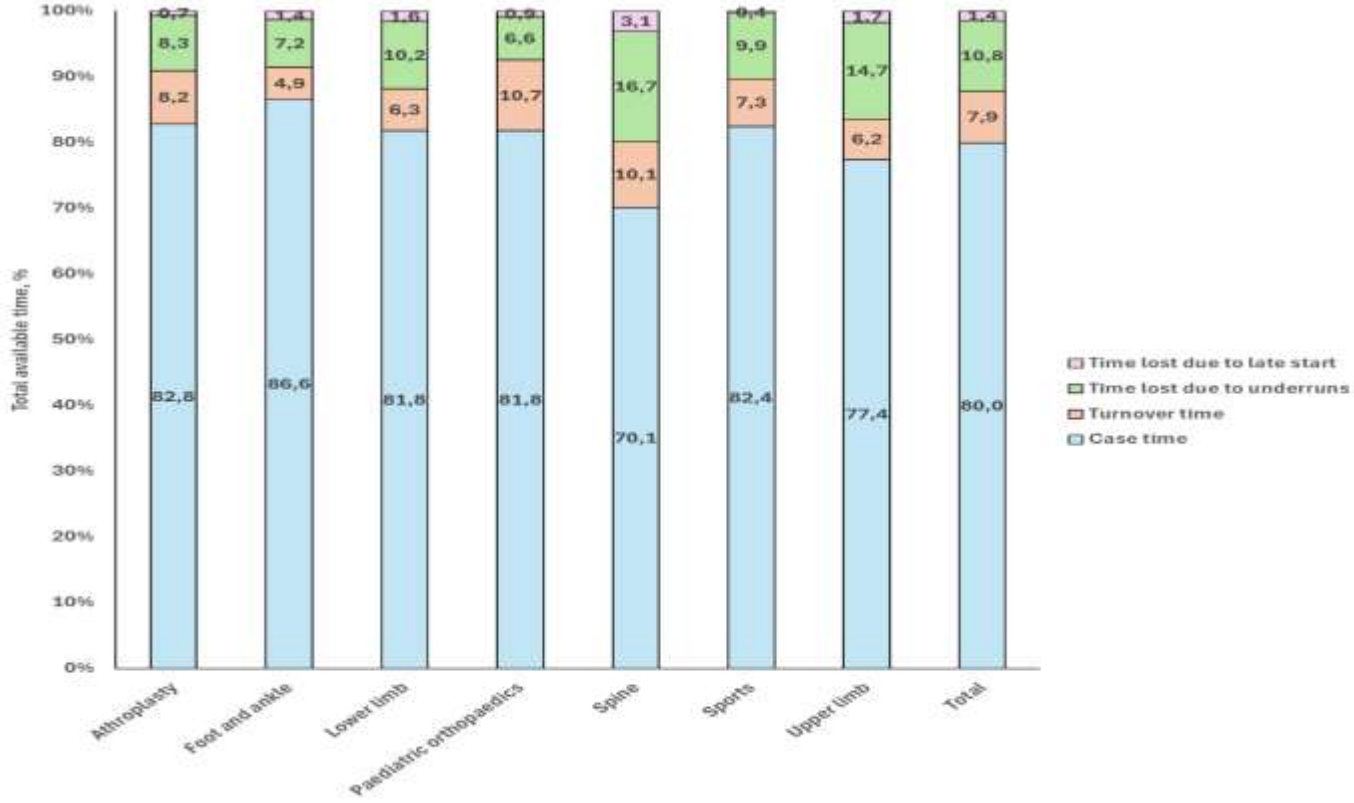

Table 3. Analysis of OT lists with early starts, underruns, late starts, and overruns

Sub-specialty	Lists, n	Early start, n (% lists)	Underruns, n (% lists)	Late start, n (% lists)	Overruns, n (% lists)
Arthroplasty	24	15 (62.5)	18 (75.0)	3 (12.5)	6 (25.0)
Foot and ankle	6	3 (50.0)	5 (83.3)	3 (50.0)	1 (16.7)
Lower limb	25	17 (68.0)	13 (52.0)	5 (20.0)	8 (32.0)
Pediatric orthopaedics	16	9 (56.3)	8 (50.0)	5 (31.3)	8 (50.0)
Spine	17	5 (29.4)	13 (76.5)	9 (52.9)	4 (23.5)
Sports	11	8 (72.7)	9 (81.8)	1 (9.1)	2 (18.2)
Upper limb	18	6 (33.3)	10 (55.6)	9 (50.0)	7 (38.9)
Total	117	63 (53.8)	76 (65.0)	35 (29.9)	36 (30.8)

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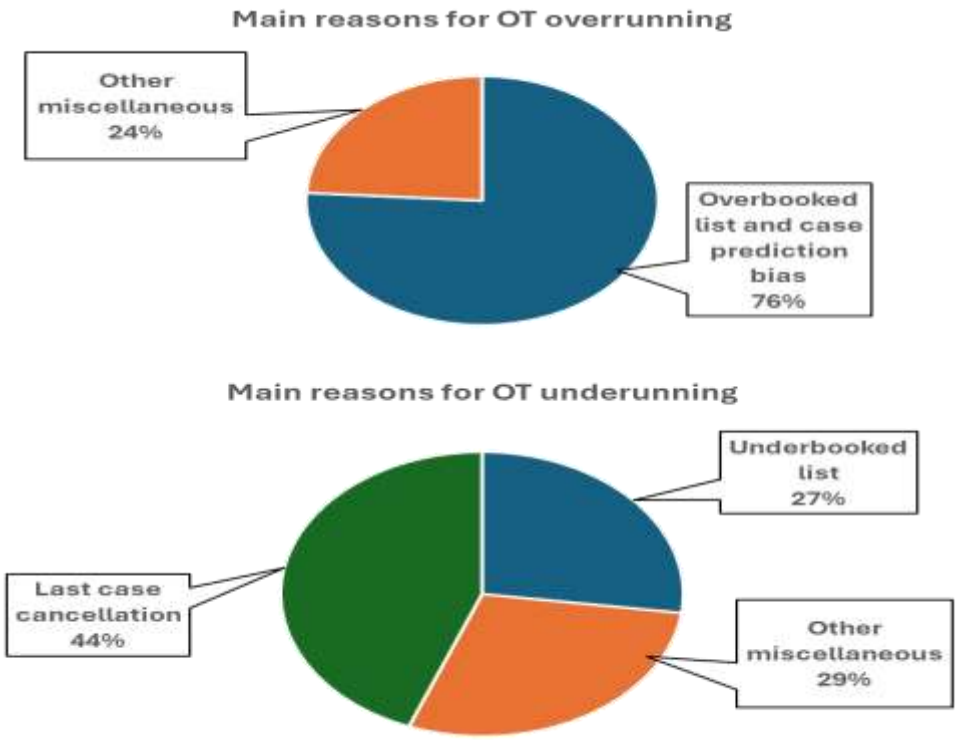
Figure 2. Reasons for OT overrunning and underrunning.



The overall raw theatre utilization was 83.0% (range: 71.8-88.2%, SD 16.3). When stratified by orthopedic sub-specialty, raw theatre utilization ranged from 71.8% (spine) to 88.2% (foot and ankle). Table 4 shows the results of the analysis of scheduled cases (completed and canceled) during the study period. Overall, there were 422 scheduled cases, of which 80 cases were canceled, giving an overall DOSC rate of 19.0%. The orthopedic sub-specialty with the highest DOSC rate was lower limb surgery (27.9%), followed closely by foot and ankle surgery (25.0%). The lowest DOSC rate was observed for spine surgery (10.9%). The most common reasons for cancellation of cases were facility-related and accounted for 39% of all canceled cases.

Table 4. Analysis of completed and canceled cases during the study period, stratified by orthopedic sub-specialty

Sub-specialty	Scheduled cases, n	Completed cases, n (% of booked cases)	Cancelled cases, n (% of booked cases)
Arthroplasty	98	84 (85.7)	14 (14.3)
Foot and ankle	20	15 (75.0)	5 (25.0)
Lower limb	86	62 (72.1)	24 (27.9)
Pediatric orthopaedics	87	70 (80.5)	17 (19.5)
Spine	46	41 (89.1)	5 (10.9)
Sports	32	28 (87.5)	4 (12.5)
Upper limb	53	42 (79.2)	11 (20.8)
Total	422	342 (81.0)	80 (19.0)

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DISCUSSION

There were two important findings from this study of elective orthopedic OTs at an SA tertiary hospital. The most important finding was that the overall raw theatre utilization was 83.0%, with the range of raw theatre utilization amongst the seven subspecialties ranging from 71.8% (for spine surgery) to 88.2% (for foot and ankle surgery). This is comparable to the international benchmark set at 70-80% [5]. Furthermore, all the individual orthopedic subspecialties included in this study met or exceeded this benchmark. Most of the OT time in this study was utilized appropriately as case time. Based on the overall OT utilization in this study and the financial projections related to OT costing by Samuel and Reed [10], who reported a 2.5-fold reduction in the cost of OT services when theatre utilization was 50% versus theatre utilization at 20%, it can be said with confidence that the orthopedic OTs at the CHBAH are running cost-effectively and efficiently.

The reported theatre utilization, in this study, is notably higher than those reported by previous South African studies. Most hospitals in SA were shown to operate sub-optimally. A study in 2013 reported OT efficiencies of 30-40% in a private hospital [11]. More recent studies by Asmal and Tsimanyane reported better results in South African public hospitals. Asmal conducted a study at a regional hospital in the city of Durban and reported the raw theatre utilization for two orthopedic OTs at 62% and 81%, respectively [8]. Although this is lower than what is reported in the current research study, it must be noted that the current research study was conducted at a higher-level healthcare facility, where resources that contribute to an efficiently run OT are more readily available. Tsimanyane looked at theatre efficiency in ophthalmology OTs that form part of the remote location theatres of CHBAH and reported theatre utilization of 62% [9]. Beyond the African borders, Delaney et al. looked at non-elective orthopedic trauma OTs during weekdays in the United Kingdom (UK) and reported theatre utilization of 78.8% [12]. The theatre utilization found in this study was therefore acceptable and encouraging.

This study also looked at other performance indicators (PIs) that influence theatre efficiency, such as OT's first case-on starting times and ending time variations causing late starts, underrunning, and overrunning; turnover time; and case prediction bias. The mean (SD) first-case starting time delay was 7.1 (16.8) mins and accounted for 1.4 % of the total allocated OT time. An OT is said to be efficient if its first-case starting time delay is less than 15 minutes on average [5]. In addition to this, we found that the starting delays found during our study period were balanced by the early start times, case times, and raw theatre utilization and so didn't significantly impair the OT's efficiency. The turnover time found in this study comprised 7.9% of the total allocated OT time with a mean of 39 mins. Prolonged turnover time is defined as being more than 60 minutes, but the best-performing OT suites average less than 25 minutes in turnover time [5, 8]. And thus, our turnover time, although not prolonged, did not meet the requirements for best performance.

The case prediction bias was not analyzed in our study due to poor reporting in the booked OT lists. This is a limitation that we hope can be addressed in future studies seeing that the ability to accurately predict and schedule theatre lists is important in lowering the DOSC rate (see Figure 1). The main causes of overrunning OT lists were overbooked lists and case prediction bias. Last case cancellation was the underlying reason for almost half of underrunning OT lists, highlighting the need for improved approaches to case time prediction. Not only are these causes addressable, but they once again emphasize the need for improved perioperative planning and preparation in our setting.

The second significant finding of this study is the DOSC rate of 19%. Although the DOSC rate in the current study was within the range reported in other African and high-income countries, the international benchmark is set at <2% by the New South Wales Agency for Clinical Innovation for all surgeries [5]. In general, the DOSC rate amongst orthopedic surgery populations in resource-constrained African countries varies considerably, ranging from 11.1 to 43.5% [13-17]. The wide range of DOSC rates in orthopedic surgery populations is also evident in published studies from well-resourced, high-income countries. An Irish study reported that 3.5% of patients with planned total joint arthroplasty had their surgery canceled [18]. A Canadian study by Koh et al. reported that the rate of DOSC in the orthopedic specialty was 14.8% [19]. A similar DOSC rate (13.8%) was obtained from researchers in New York who studied orthopedic sports medicine surgeries [20]. On the other end of the spectrum for high-income countries, a Swedish study found that 39% of elective orthopedic surgery patients had their procedure canceled at least once, with some patients having their surgery canceled multiple times [21]. The 19% DOSC rate found in this study is in keeping with global research, thus emphasizing the importance of addressing this problem, especially in orthopedic populations.

The most common causes for DOSC in this study were facility-related factors, such as time constraints, equipment issues, low theatre temperatures, surgical sets being unavailable scrub sister being unavailable, and delay in morning theatre preparation resulting in delay with the first case on starting time. A systematic review by Al Talalwah cited unavailability of OT time, the prioritization of emergency cases, broken equipment, poor planning around

the surgery, a shortage of hospital beds, and a shortage of medical personnel as some of the specific factors associated with DOSCs [22]. A more concerted investigation into the causes of DOSC is required, and a subsequent plan of action needs to be developed between the relevant stakeholders, including the hospital administration, the surgical unit, and the anesthesia unit.

This research has identified some areas that could be optimized, should there be future declines in raw theatre utilization. This could include reducing the number of late starts (29.9%) and underrunning lists (65%). Based on the research of Samuel and Reed [9], these parameters would have implications for the period that OTs are occupied by patients and will hence have a direct impact on raw theatre utilization. Delays in starting an OT list are multifactorial but are often linked to preoperative planning and preparation [23]. Thus, processes that seek to streamline preoperative planning and preparation of patients may be beneficial in reducing delays in commencing OT lists.

GENERALISABILITY

The generalisability of the findings to other SA hospitals is limited given the variations in patient demographics, infrastructure, and specialists' availability.

CONCLUSION

Previous South African studies showed suboptimal theatre utilization and higher than acceptable DOSC rates. However, none looked at elective orthopedic OTs specifically. The DOSC rate in this study was within the range of reported rates for other countries around the world but fell short of the international benchmark of <2%, confirming DOSC as a global problem that can impact the efficient delivery of surgical services. The mean turnover time was acceptable but not ideal. While the findings on raw theatre utilization in this study are encouraging, regular assessments are required to ensure that the orthopedic OTs keep meeting international standards.

STUDIES' LIMITATIONS

The limitations in the current research study were, firstly, that the study sample was accrued in a single, tertiary-level hospital. The data collection period represented a "snapshot" of orthopedic OT utilization at CHBAH, and therefore the sample size was modest, and a longer data collection period would have covered seasonal variations that may exist. This limited the analysis to descriptive analysis, and statistical associations between variables and raw theatre utilization could not be established. The anesthetic induction and surgical procedure duration were measured as a single variable (case time), and therefore a granular analysis of these could not be undertaken. Researchers conducting future assessments of orthopedic OT efficiency at CHBAH must attend to these identified limitations.

RECOMMENDATIONS

- Optimizing preoperative patient assessment and preparation to identify cases that could lead to DOSC
- Better case predictions and list allocations to avoid last-case cancellations caused by overbooked lists and underrunning theatres.
- Timely theatre preparation according to the booked lists (especially the assessment of the availability of equipment for the following day's list) to identify daily problems that could lead to late starting times and DOSC.
- The implementation of an efficient reporting system that allows prompt resolution of issues within the theatre complex, such as temperature irregularities and equipment malfunctions.
- Introduction of an electronic booking system to create a database that will assist in developing a computer model to improve case predictions, thereby improving theatre list allocations to curb underrunning and overrunning theatre times.
- The allocation of 2 anesthetists per theatre decreases the turnover time by allowing one to manage the recovering patient so the 2nd one can start the next case.
- Better allocations and replacements of theatre nursing staff to ensure timely theatre preparation and uninterrupted theatre functioning.

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ABBREVIATIONS

CHBAH	Chris Hani Baragwanath Academic Hospital
OT	Operating Theatre
DOSC	Day of surgery cancelation
SD	Standard deviation
SA	South Africa
UK	United Kingdom

USA	United States of America
PI	Performance indicator
MMED	Masters of medicine
REDCap	Research Electronic Data Capture
HM	Hylda Makanisi

SOURCES OF FUNDING

There was no funding requirement for this project.

CONFLICT OF INTEREST

All authors declare no conflict.

MAIN AUTHOR'S BIOGRAPHY

Hylda Makanisi is a medical doctor who specializes in anaesthesiology. She is currently doing her 3rd year as a registrar, and this research was done in partial fulfillment of her MMed degree. She did her undergraduate medical studies at the University of Pretoria where she graduated in 2013. She is currently doing her clinical rotations in the different hospitals forming part of the University of Witwatersrand's anesthesia circuit; of which CHBAH is the largest. She is an avid reader and has a keen research interest.

AUTHORS CONTRIBUTIONS

H Makanisi: Research idea's conception, proposal's write-up and corrections as per supervisor's input, departmental permissions applications, post-graduate committee review, and ethics application processes, data collection and analysis with the assistance of a statistician, research report write-up and corrections as per supervisors' input and submission for publication.

T Hlongwane: Research idea's modification and development, research proposal's corrections and review during the post-graduate committee review phase, final report corrections, and finalization to a publishable article.

T Lushiku: Modifications and corrections to the research proposal through the post-graduate committee review process and ethics approval phase, and corrections to the final project report to make it publishable.

K Mogotsi: Research idea's modification and development, project proposal corrections to submit for post-graduate committee's review, and final report's modifications to publication.

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