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ORIGINAL RESEARCH

Towards improved theatre efficiency: a study of procedural times for common elective surgical procedures at Tygerberg Hospital

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Background: In many hospitals, theatre slates are booked according to potentially inaccurate estimations of procedural times. Furthermore, inaccurate time predictions can contribute towards suboptimal utilisation of theatre time. This study was conducted to evaluate theatre procedural time parameters and predictions. The objectives were to determine the average duration of common elective surgical procedures at Tygerberg Hospital (TBH) and to determine whether there are discrepancies between the estimated procedural times and the actual procedural times for selected common surgical procedures.

Methods: We performed a single-centre retrospective observational study, analysing data from January to December in 2019, obtained from electronic theatre records. A total of 32 elective procedures were examined for total procedural, surgical, and non-surgical times. Additionally, we prospectively compared the durations of the five most frequent procedures with their estimated times to assess discrepancies.

Results: The time parameters of the 32 common elective surgical procedures performed at this institution were recorded. The cohort was further divided into minor and major surgery groups. The average mean non-surgical time for minor and major surgery was 36 and 44 minutes, respectively. Prospective data analysis showed a statistically significant underestimation of procedural time when compared to the actual duration of total abdominal hysterectomy ($p = 0.011$), total hip replacement ($p < 0.001$), transurethral resection of the prostate ($p < 0.001$), and above knee amputation ($p = 0.013$). The average procedural time underestimation for the four procedures ranged between 33% and 61%.

Conclusion: Our study showed that procedural times of selected common elective procedures are frequently underestimated at our institution. This study also collected data that can assist with improving the accuracy of procedural time estimations at TBH, potentially improving theatre efficiency.

Keywords: theatre efficiency, common elective surgical procedures, Tygerberg Hospital

Introduction

The operating theatre should provide a safe environment for the performance of a large variety of surgical procedures. To provide this service, multiple components are required to work together smoothly and efficiently. If theatre efficiency is compromised, it may have significant negative implications for the hospital, staff, and patients.

There are multiple potential reasons why theatres may not operate efficiently. Examples include staff shortages, equipment failure, and medical complications.[1] Another significant source of potential inefficiency lies in the difficult task of determining the number and type of procedures that are logistically appropriate for the available theatre time.[2] Central to this decision is the prediction of the expected durations of the respective procedures. However, the accurate prediction of the duration of a surgical procedure is challenging, with many variables to consider.[3]

The traditional method for planning a theatre slate at most institutions, including the site of this study, has relied largely on the subjective, personal experience of the surgeon to estimate the procedural times.[3,4] These estimations have frequently been shown to be inaccurate in studies at other institutions and result in suboptimal theatre time utilisation.[3,5,6] If the surgical times are overestimated, then an early finish may result in wasted available theatre time. Underestimation may result in a late finish or cancellations.[7,8]

One measure suggested to improve accuracy has been to use data collected from previous procedures to inform time predictions for similar future procedures. However, there is a paucity of published literature describing the average duration of common elective procedures.[9] Moreover, significant variation in procedural times has been shown between different institutions.[5] This is to be expected, as each institution has a unique set of variables. This highlights the importance of collecting and analysing institution-specific data to assist with the accuracy of procedural duration estimates.

The primary objective of this study was to provide data on the durations of common elective surgical procedures performed at Tygerberg Hospital (TBH), to inform future surgical time estimations. Secondary objectives were to compare the estimations with the actual, observed times for common surgical procedures at this institution, and to determine the current level of accuracy. We also sought to compare our data with relevant data collected in a previous unpublished audit of procedural times at TBH. Ultimately, this research intends to contribute to

the improvement of theatre efficiency at TBH, and perhaps other similar institutions.

Methods

Study design

This was primarily a retrospective observational study with an additional prospective component. Approval was obtained from the Human Research Ethics Committee of the University of Stellenbosch (HREC number: S21/07/126) before data collection.

Study setting

This study was conducted at TBH, a tertiary teaching institution. The focus was on a selected group of elective procedures that took place between 7:30 a.m. and 4:30 p.m. from Monday to Friday.

Sampling method

Based on a convenience sample, the retrospective component collected data from the hospital's electronic database between January and December in 2019.

At our institution, theatre nursing staff are responsible for capturing the starting and finishing times of both surgery and anaesthesia for each surgical procedure. The data is captured in the theatre registry booklet at the beginning and end of each procedure. Anaesthesia starting time at our institution is defined as the time at which the anaesthesiologist takes the patient's first blood pressure and the ending time is when the patient is handed over in the recovery room. Surgical time is defined as the time from incision until the time when all the dressings and drains are secured. The data is then transferred by the theatre management secretarial staff onto an electronic system called Clinicom. Thereafter, the data is uploaded automatically to an archive-storing system called Sinjana, which is managed by the TBH information management team. The accuracy of data capturing is overseen by the theatre complex operational manager. Data from 32 common surgical procedures performed during this period in the theatre complex at TBH was captured, totalling 2 002 individual procedures.

Inclusion and exclusion criteria

Emergencies, after-hour procedures, cardiothoracic surgery, obstetrics surgery, and patients under the age of 18 years were excluded.

Variables captured included: type of procedure, date of procedure, surgical start and finish times, and anaesthesia start and finish times. The latter (anaesthesia time) was used to represent the total procedural time. Total procedure time includes both the surgical and non-surgical time required for that procedure. Non-surgical time is defined as everything that takes place for a particular patient, both before and after that period in the operating theatre. This would include anaesthesia induction and emergence, cleaning and draping, positioning of the patient on the table, and emergence.

For the prospective component of the study, we selected the five most frequently occurring procedures performed during the retrospective period. The reason for the selection of only the most common procedures was to ensure sufficient sample sizes for statistical power analysis. Data from a minimum of 30 cases for each of these procedures was collected. The prospective data was collected by the researcher from the theatre slates submitted on paper to the theatre management secretary. On these paper submissions, the surgeon books the full theatre slate. The order and type of procedures are recorded, as well as the estimated total procedural times for each procedure. This data was collected over five months in 2021 and was analysed to determine the relationship between the estimated total procedural time for a specific procedure compared to the actual observed time for that procedure. This analysis would inform the study's secondary objective.

Data was captured onto an Excel spreadsheet. No patient identifiers or personal data were captured. Statistical analysis was performed using Python 3.5.2 and graphs were created using Matplotlib and the Seaborn library. Descriptive statistics, including means, confidence intervals, interquartile ranges, and medians were reported where appropriate. The estimated and observed procedural durations were compared using agreement analysis. The mean procedure duration was compared as two independent populations through the t-test. All values used an alpha of 0.05 and results were considered significant at $p < 0.05$.

Results

The retrospective analysis of the hospital electronic theatre records retrieved 2 002 elective surgical procedures eligible for this study. The mean age of the cohort was 57.3 years and 58.79% were female. Table I displays the details of the 32 most performed surgical procedures in this dataset.

We further divided the cohort into minor and major surgery groups and focused on determining the non-surgical time component (total procedure time minus surgical time, Figure 1). Minor surgery can be defined as surgery associated with an expected blood loss (EBL) of < 500 ml, minimal fluid shifts, and is typically done on an ambulatory basis. Major surgery, on the other hand, is associated with an EBL of > 500 ml, significant fluid shifts, and typically at least one night's stay in the hospital.[10] The mean non-surgical time was 36 minutes for minor and 44 minutes for major surgery.

Table II displays the data comparison of the estimated procedural time data (collected prospectively) and the actual (observed) procedural time data (collected retrospectively) for the five most performed elective procedures at our institution during the sampling period. A statistically significant underestimation of estimated versus actual procedural duration was shown for total abdominal hysterectomies (58.9 minutes; $p = 0.011$), total hip replacements (62.8 minutes; $p < 0.001$), transurethral resection of the prostates (87.1 minutes; $p < 0.001$), and above knee amputations (64.3 minutes; $p = 0.013$). While the estimated procedural time for transurethral resection of the bladder

Table I: Total procedure time of common elective surgical procedures

Procedure	Count	Total procedure time (minutes)
Total abdominal hysterectomy	255	Mean = 179.9 95% CI = [172.3 to 187.4] Median = 175.0 IQR = [140.0–215.0]
Total hip replacement	226	Mean = 160.8 95% CI = [155.6 to 166.0] Median = 155.0 IQR = [135.0–180.0]
Transurethral resection of the prostate	154	Mean = 143.1 95% CI = [126.3 to 159.9] Median = 101.5 IQR = [75.0–172.5]
Amputation above knee	151	Mean = 120.3 95% CI = [106.1 to 134.4] Median = 100.0 IQR = [80.0–128.0]
Transurethral excision or destruction of bladder tissue	148	Mean = 88.8 95% CI = [75.7 to 101.9] Median = 80.0 IQR = [60.0–101.3]
Excision or destruction of breast tissue	125	Mean = 73.9 95% CI = [65.4 to 81.8] Median = 63.0 IQR = [46.0–83.0]
Unilateral simple mastectomy	114	Mean = 98.4 95% CI = [90.3 to 106.4] Median = 90.0 IQR = [68.0–120.0]
Total knee replacement	84	Mean = 182.4 95% CI = [174.2 to 190.7] Median = 177.5 IQR = [160.0–200.0]
Peripheral vascular shunt or bypass	80	Mean = 247.1 95% CI = [219.8 to 274.4] Median = 230.0 IQR = [174.8–282.8]
Unilateral radical mastectomy	80	Mean = 110.3 95% CI = [102.0 to 118.6] Median = 104.0 IQR = [85.0–126.8]
Amputation below knee	72	Mean = 123.5 95% CI = [112.1 to 135.0] Median = 115.0 IQR = [90.0–145.0]
Unilateral repair of inguinal hernia	66	Mean = 158.6 95% CI = [141.3 to 175.8] Median = 135.0 IQR = [120.0–177.5]
Tympanoplasty	56	Mean = 154.3 95% CI = [143.4 to 165.3] Median = 143.0 IQR = [120.0–180.8]
Complete nephrectomy	55	Mean = 237.1 95% CI = [213.9 to 260.2] Median = 220.0 IQR = [167.5–302.5]
Arthroscopy, knee	54	Mean = 91.7 95% CI = [82.5 to 100.9] Median = 87.5 IQR = [65.0–110.0]
Arthroscopy, shoulder	41	Mean = 154.1 95% CI = [141.6 to 166.6] Median = 150.0 IQR = [122.0–180.0]
Extracranial ventricular shunt	39	Mean = 164.2 95% CI = [126.9 to 201.4] Median = 130.0 IQR = [105.0–177.5]
Partial thyroidectomy	37	Mean = 202.6 95% CI = [175.8 to 229.4] Median = 185.0 IQR = [151.0–235.0]
Mastoidectomy	28	Mean = 253.7 95% CI = [223.0 to 284.5] Median = 237.5 IQR = [215.0–291.3]
Cholecystectomy	27	Mean = 169.0 95% CI = [95.3 to 242.7] Median = 155.0 IQR = [37.5–212.5]
Radical neck dissection, bilateral	24	Mean = 402.9 95% CI = [321.3 to 484.5] Median = 360.0 IQR = [230.0–615.0]
Total reconstruction of the breast	21	Mean = 258.1 95% CI = [201.6 to 314.7] Median = 262.0 IQR = [190.0–295.0]
Excision of inguinal lymph node	17	Mean = 132.7 95% CI = [92.0 to 173.4] Median = 130.0 IQR = [57.0–185.0]
Radical neck dissection, unilateral	14	Mean = 221.9 95% CI = [141.0 to 302.9] Median = 187.5 IQR = [156.3–238.8]
Closed (percutaneous) (needle) biopsy of the prostate	8	Mean = 32.6 95% CI = [13.3 to 52.0] Median = 21.5 IQR = [9.8–50.8]
Bilateral simple mastectomy	7	Mean = 174.7 95% CI = [109.1 to 240.3] Median = 150.0 IQR = [121.5–208.0]
Complete substernal thyroidectomy	6	Mean = 220.2 95% CI = [125.7 to 314.7] Median = 160.0 IQR = [143.8–279.8]
Radical excision of cervical lymph nodes	3	Mean = 26.0 95% CI = [18.6 to 33.4] Median = 25.0 IQR = [22.5–29.0]
Bilateral breast implant	3	Mean = 120.0 95% CI = [65.4 to 174.6] Median = 120.0 IQR = [92.5–137.5]
Open and other left hemicolectomy	3	Mean = 331.7 95% CI = [167.1 to 296.3] Median = 345.0 IQR = [262.5–407.5]
Perineal prostatectomy	2	Mean = 43.5 95% CI = [0 to 99.4] Median = 43.5 IQR = [29.3–57.8]
Closed (transurethral) biopsy of the bladder	2	Mean = 20.5 95% CI = [0 to 48.9] Median = 20.5 IQR = [13.3–27.8]

CI – confidence interval, IQR – interquartile range

Table II: Comparison of actual total procedure times and surgeons' estimations for the five most frequently occurring surgical procedures from this cohort

Procedure	Actual total procedure time (N = minutes)	Estimated by surgeons (N = minutes)	Average surgeon's underestimated surgical time*
Total abdominal hysterectomy	N = 255 Mean = 179.9 95% CI = [172.3 to 187.4] Median = 175.0 IQR = [140.0–215.0]	N = 30 Mean = 121.0 95% CI = [110.3 to 131.7] Median = 120.0 IQR = [90.0–120.0]	58.9 minutes 33% underestimation
Total hip replacement	N = 226 Mean = 160.8 95% CI = [155.6 to 166.0] Median = 155.0 IQR = [135.0–180.0]	N = 30 Mean = 98.0 95% CI = [90.1 to 105.9] Median = 90.0 IQR = [90.0–120.0]	62.8 minutes 39% underestimation
Transurethral prostatectomy	N = 154 Mean = 143.1 95% CI = [126.3 to 159.9] Median = 101.5 IQR = [75.0–172.5]	N = 30 Mean = 56.0 95% CI = [53.2 to 58.8] Median = 60.0 IQR = [60.0–60.0]	87.1 minutes 61% underestimation
Amputation above knee	N = 151 Mean = 120.3 95% CI = [106.1 to 134.4] Median = 100.0 IQR = [80.0–128.0]	N = 30 Mean = 56.0 95% CI = [47.8 to 64.2] Median = 45.0 IQR = [45.0–60.0]	64.3 minutes 53% underestimation
Transurethral excision or destruction of bladder tissue	N = 148 Mean = 88.8 95% CI = [75.7 to 101.9] Median = 80.0 IQR = [60.0–101.3]	N = 30 Mean = 50.7 95% CI = [46.1 to 55.2] Median = 60.0 IQR = [45.0–60.0]	38.1 minutes 43% underestimation

*Calculated as (1 - [estimated surgical time / actual surgical time]) × 100% = underestimation
CI – confidence interval, IQR – interquartile range

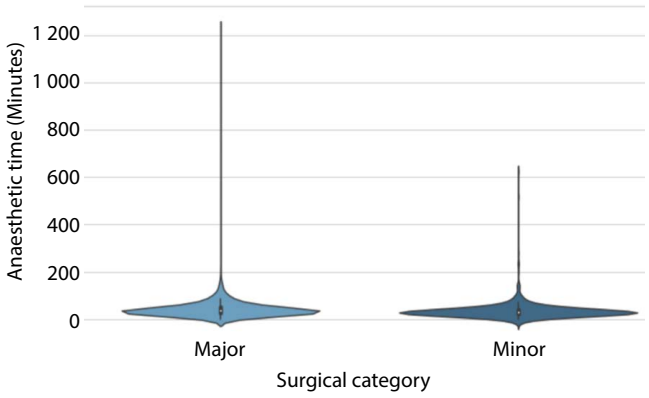

Figure 1: Violin plot comparing the non-surgical times (anaesthetics time = total procedure time - surgical time) for minor and major surgical procedures (minutes); the mean non-surgical time was 36 minutes for minor surgery and 44 minutes for major surgery

tumour was less than the actual procedural time, this difference was not statistically significant (38.1 minutes; $p = 0.178$). The average time underestimation for each of the five procedures ranged between 33% and 61%.

Discussion

"Efficiency" in operating theatres has been defined as "treating the right patients and providing the right care, within clinically recommended timeframes, with the optimal use of resources required to deliver safe, quality care at or below an efficient price for the service."[11] While this definition is cumbersome, it touches on the complexity of the system and some of the potential negative outcomes of compromised theatre efficiency.

The operating theatre is one of the largest sources of expenditure for many hospitals and the large proportion of staff employed to work in theatres becomes wasteful if productivity is poor.[12,13] A lack of efficiency can lead to cancellations on the day of surgery. A tertiary hospital in Pietermaritzburg estimated that a single day-of-surgery cancellation costs the health department R25 860 and resulted in an average of four days longer admission.[14] Many surgeries are time-sensitive, and prolonged waiting periods can have negative health implications.[15] Additionally, prolonged in-hospital admissions increase the risk of hospital-acquired infections.[16] Patients may suffer loss of income, psychological disturbance, and prolonged fasting when their surgery is delayed.[17] Theatre inefficiency also affects staff members.[18] Poor time efficiency can lead to unscheduled late days and prolonged working hours. In academic hospitals, fewer surgical cases result in the loss of learning opportunities for trainee staff.[19]

There are a multitude of potential causes for poor efficiency in theatre. This study has focussed on improving the accuracy of the process of determining the number and type of procedures that are logistically appropriate for the available theatre time. Estimations can seldom be exact as many factors may influence the duration of a surgical case, such as the level of experience, complexity of the procedure, and time of the day.[3] However, the better the estimate, the better the theatre efficiency is likely to be. Analysis of institution-specific data from actual past procedures has been shown to assist with the prediction of procedural times for future procedures.[20]

The values displayed in Table I provide surgeons with objective, institution-specific data on the total procedural durations of various common procedures. When booking a procedure for theatre, the surgeon can use the mean value as a prediction guide. The interquartile ranges are large for certain procedures. This is to be expected as other variables (e.g. individual surgical expertise or patient-specific factors) will influence the procedural time. However, to a certain extent, the surgeon has some insight into these variables and can adjust the time prediction within the range displayed to account for these. While this still requires a level of subjective estimation, and not every variable can be accounted for, this data-driven prediction will probably be more accurate as it is based on actual historical records. The data may also be useful in guiding the theatre team in deciding whether there is enough time available on a theatre slate to add a case. For example, if the data shows the average time it takes to complete a certain procedure is 180 minutes, then it would likely be unwise to attempt that procedure when there are less than 120 minutes available time remaining.

The inclusion of non-surgical time in the prediction model is important because this time is frequently not taken into consideration when procedures are booked. The findings in our study show that an additional 36 minutes for minor and 44 minutes for major surgery should be added to the expected surgical time to improve accuracy in predicting the total time for the procedure. The findings correlate with the results of an unpublished audit conducted in 2012 by a registrar in the Department of Anaesthesia and Critical Care at TBH (Dr. Theodor Egmont Wenhold, unpublished thesis). In this audit, the average non-surgical time for a procedure was 37 minutes, which is similar to the numbers in this study.

It should be noted that the data does not include turnover time. This is the time from when one patient is pushed out of the theatre until the next one enters the theatre (benchmark of 15 minutes).[11] Though two first-world countries reported that turnover time has an insignificant effect on theatre efficiency at their institutions, this may not apply to local institutions.[5,21] Unfortunately, we do not have data on the turnover times at TBH.

The data from the prospective component of this study (Table II) shows a statistically significant underestimation of the actual time for four out of the five procedures. These procedures are the five most performed procedures during the sampling period. While data was not collected for other procedures, the strong trend demonstrated is likely to be present. It can be noted that the mean underestimations ranged from 38.1 to 87.1 minutes. This finding should be noted as it has been shown that underestimating the time required to complete a procedure by as little as 10 minutes has been associated with a cancellation rate of 11%.[3] As discussed previously, cancellations of surgery cause financial and other logistical inefficiencies.

We can only speculate as to the reasons behind the bias towards underestimation of procedural times. Concern about underbooking the list may play a role, or perhaps limited surgical experience plays a role. (Although, in our institution, booking of the slate is always guided by the consultant responsible for the list.) Perhaps the non-surgical time is not factored into time estimates. The latter is significant as surgeons did not indicate whether the predicted times on the slate were total procedure time or only the estimated surgical time. Nevertheless, the tendency to underestimate actual procedural times should be borne in mind when planning a surgical slate.

There is a paucity of published literature that describes the average duration of common elective procedures at different institutions.[22] Table III demonstrates the procedural times for common surgical procedures at various institutions and compares the times with selected data from this study. It is evident that while there are similarities in the procedural times between the different institutions, there is also significant variation between them.[5] The latter is to be expected, as each institution has its own set of variables, which may influence the surgical times. This highlights the importance of collecting institution-specific data to assist with the accuracy of procedural duration estimates.

Study limitations

The large variability in procedural times for certain surgeries was noted, which is expected due to numerous influencing factors such as surgeon experience, patient anatomy, time of day, and equipment reliability. This causes a certain amount of limitation in terms of using this data to accurately predict future procedural times. Nevertheless, by accounting for anticipated variables, surgeons may refine time estimates within the provided range. It is an assumption in this study that the theatre registry booklets contain accurate and consistent information.

Table III: Comparison of published times with our study (data from Table I); times in minutes[5]

Procedure time in minutes	Widdison*	Kendall et al.	Centers for Medicare & Medicaid Services*	Pandit et al.	This study (Table I)
Breast lumpectomy (full definition: excision biopsy of breast lesion after localisation)	20	_	58	54	73.90
Inguinal hernia repair (unilateral)	41	70	_	63	158.57
Laparoscopic cholecystectomy	65	_	_	86	169.03
Lymph node biopsy	24	_	_	50	132.70
Mastectomy (including axillary node dissection)	_	_	115	101	110.30
Hemicolectomy	_	_	138	142	331.66

*Only surgical times, the non-surgical times are excluded

Table IV: Example of a future theatre slate

Patient name	Folder number	Planned procedure	Surgical time (minutes)	Anaesthesia time Major = 45 min Minor = 35 min	Turnover time (minutes)	Total procedure time (IQR from this study) minutes*
Mrs. X	1234567	Laparoscopic cholecystectomy	90 min	35 min	15 min	120.0–180.8
Mr. Z	1234569	Total abdominal hysterectomy	120 min	45 min	15 min	140–215

*Surgeon's discretion used for the surgical time based on patient factors, surgical factors, and surgeon factors

A further limitation is that the results of this study are specific to TBH. We cannot assume that they would apply to other institutions. However, the methodology could potentially be applied to studies at other institutions to enable them to collect data about their environment.

Recommendations and future research

It is intended that these times be used by surgeons to structure future theatre slates and potentially avoid some of the negative implications of inaccurate time estimations. This data is relatively simple to collect from hospital records. Potentially, each surgical discipline could employ this concept and collect data relevant to their particular procedures. The data could be displayed in a clear, user-friendly format that is available when the theatre slates are constructed (Table IV).

Perhaps the theatre slate booking form could be adjusted to be more specific. It could specifically include columns for non-surgical time and turnover time. A point of data entry for the total estimated slate time could also be included. Furthermore, we recommend the audit of turnover time for elective procedures at TBH.

While this study did not assess the impact of data usage on prediction accuracy or theatre efficiency, a prospective study addressing these outcomes would be a valuable continuation of this research.

Conclusion

Our study showed that procedural times of selected common elective procedures are frequently underestimated at our institution. Inaccurate procedural time estimations are known to harm theatre efficiency. The data provided by this study can potentially be used to guide procedural time estimations, thereby improving theatre efficiency at our institution.

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Conflict of interest

Nothing to declare.

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Ethical approval

Ethical approval was obtained from the Health and Research Ethics Committee of the University of Stellenbosch (ref. no. S21/07/126). Permission to conduct research and access patient records was received on 23/08/2021.

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