Original Research Article

Estimating Surgical Duration for Surgeries: Towards an Efficient Schedule of Operating Theatre

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Abstract

Poor operation theatre (OT) scheduling is a common cause of case cancellation on the day of surgery. We analysed the accuracy of anaesthetists and surgeons in estimating the surgical time to complete an operation and investigated whether the estimated times was correlated with the actual surgical time. It was a prospective observational study with 369 elective cases from various surgical subspecialties which were performed within three months in a tertiary university hospital. Anaesthetists and surgeons were required to estimate the surgical time of the elective cases before the day of surgery. Their estimations were compared with the recorded actual surgical time. The primary outcome was the median time difference from the estimated surgical time. Anaesthetists accurately estimated surgical times of 82 cases (22%) and surgeons 59 cases (16%). Overall, anaesthetists overestimated the surgical time by 11 minutes of actual surgical times [interquartile range (IQR) -15 to 40 minutes]. Surgeons underestimated their surgical time by 15 minutes [IQR -60 to 20 minutes]. The median estimated surgical time difference between anaesthetists and surgeons was significantly different ($p<0.0001$). Among the surgical subspecialties, the longest overestimation by anaesthetists was up to 48 minutes in colorectal surgeries. The most underestimated median time difference by surgeons was 65 minutes, seen in upper gastrointestinal surgeries. A significant strong positive correlation existed between overall anaesthetists' estimated and actual surgical times ($r_s = 0.735$, $p<0.0001$). At the same time, there was a weak correlation between surgeons' overall estimation time upon booking and actual surgical times ($r_s = 0.492$, $p<0.0001$). In conclusion, both the anaesthetists and surgeons were significantly inaccurate in estimating the duration of surgical procedures. Although the anaesthetists tended to overestimate it while surgeons underestimated it, their estimations correlated strongly with the actual surgical times, whereas surgeons' estimations were weakly correlated.

Keywords: Estimated time; operation theatre; operative time; surgical time; time management

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Introduction

Surgeries incur many expensive expenses that include the wages for the professional staff, the acquisition and maintenance of the equipment, and the use of costly resources like post anaesthesia care unit (PACU) or possibly an intensive care unit (ICU) (1). In 2012, statistics in the United States of America (USA) showed the healthcare providers' expenditures went to surgery costs at 40% (1). Malaysia's total expenditure on health (TEH) was 4.3% of the National Gross Domestic Product (GDP) in 2019 and RM 43,553 million, which accounted for 68% of TEH allocated for curative care services (2). About 10% of the overall hospital budget was consumed by operation theatres (3). Malaysia had a lower Current Health

Expenditure (CHE) (3.8% of GDP) in 2018 compared to other countries such as Singapore (4.5%), Vietnam (5.9%), and the United Kingdom (10.0%) (2).

The 2017 budget for the Universiti Kebangsaan Malaysia Medical Centre (UKMMC) allotted RM 4,285 million for the General Operation Theatre (GOT), which accounted for 4.28% of the total hospital budget (4). Therefore, it is essential to maximise the usage of operating theatres to achieve the highest level of cost-effectiveness. Operation theatres (OT) are the most costly element in hospitals in the United Kingdom, and the rising expenses of healthcare providers place a financial strain on patients and healthcare providers (5,6).

The rising expenditures may also be attributed to inefficient healthcare practices, resulting in a rise from 13 to 20% (6). Cancelling a surgical case on the day of surgery is an inefficient utilisation of resources, as patients are admitted to the hospital for their planned operation but eventually need to postpone the procedure. Ang et al. discovered that a 16-minute surgical procedure delay could result in an additional cost of approximately USD 3000 per hospital in the United Kingdom (5). In a study conducted in Iran, Maimati et al. demonstrated an annual expenditure of USD 92,049 even if procedures were cancelled (7).

Approximately 10 to 40% of scheduled elective surgeries may be cancelled before the procedure (8). Various factors contributed to the cancellation of appointments, including patient-initiated cancellations, cancellations due to the patient's poor medical condition, and cancellations resulting from poor scheduling. Travis et al. discovered that the primary reason for cancellation was a 'lack in theatre time', such as operation lists exceeding their scheduled duration (9). In their investigation, Butler et al. determined that the inefficient utilisation of hospital theatre time, was resulted from surgery cancellations, then increased the expenditures (10).

Accurate prediction of surgical operation times is crucial for cost-efficient operation room planning in hospitals (10). Pandit and Carey discovered that the overrun of the operating lists was due to inaccurate projection and prediction times of procedures, as well as a scarcity of human resources (11). By accurately estimating the necessary duration, a surgeon or an anaesthetist can ensure that other team members effectively allocate their time for future tasks to proceed seamlessly, enhance productivity and foster team cohesion. Optimal planning can only be accomplished when surgeons and anaesthetists provide accurate time estimates for completing their respective tasks during the procedure (12). If an operation exceeds the projected duration, it might impact the following cases, perhaps resulting in delay or cancellation (13).

In our centre, we witnessed a comparable situation where 15% of scheduled cases were cancelled on the day of surgery in 2016 for various reasons (14). Some documented reasons were the excessive list and the lack of operating hours. We analysed the accuracy of surgeons and anaesthetists in estimating the surgical time and compared it to the actual time measured. We hope that with the awareness and knowledge, which were gained from this study, can improve the listing practices by the surgeons and, hence, minimising overbooking and case cancellations on the surgery day due to unavailable OT time.

Materials and Methods

This prospective observational study was conducted following approval of the Medical Research & Ethics Committee (MREC), UKMMC (Research code: FF-2017-201). Surgeons from various surgical specialties of UKMMC [Surgery (all subspecialties), Orthopaedic (all subspecialties), Ophthalmology and Otorhinolaryngology (ORL) and Maxillofacial (MF)], as well as anaesthetists were enrolled in this study. Only surgical times of elective cases were included in this study. Cases listed under emergency, semi-emergency, and day-care, which were posted on the operation day, were excluded. Considering the nature of this study, which involved an audit, informed consent was waived.

The surgical and anaesthesia teams received distinct briefings describing the definitions and data that were gathered for the study. The explanation encompassed the definition of the recorded times and instructions on filling out the data collection sheet and compiling the completed sheets. Consequently, the teams were given equal access to the study's information to reduce bias.

The Caring Hospital Enterprise System (C-HEtS), an integral component of the Total Hospital Information System (THIS) (15), documents several aspects of patient management, such as registration, admission, discharge, appointment scheduling, OT scheduling, and electronic medical records. This study recorded the surgeon's estimated surgical times obtained from the C-HEtS, which were entered during the scheduling of the procedure. The anaesthetist's estimated surgical times were recorded one day before the operation during the premedication rounds.

The actual surgical times were recorded by multiple operators who were the anaesthesia trainees stationed in their respective OTs. The cases' standard operating procedures (SOPs) were done as usual. The definitions of time intervals utilised terminology from the Association of Anaesthesia Clinical Directors Procedural Time Glossary (AACD) (16). The term 'surgical time' was defined as the time from the surgical instrument in contact with the patient (e.g., skin incision, scope insertion, beginning of examination for Examination Under Anaesthesia (EUA)) until the final dressings were applied, if necessary, or the drapes were removed if no dressing was needed (16).

The occurrences of challenging surgical procedures or administration of anaesthesia and types of anaesthesia were also recorded. Instructions on completing the data collection sheets were placed in each OT to facilitate and maintain accurate data collection. The surgical time differences from the estimated were calculated by subtracting actual surgical time from the estimated surgical time. If the result denoted a positive value, it meant an overestimation of surgical time and; a negative value it implied an underestimation of surgical time. The accuracy was determined by comparing the estimated surgery time to the actual time, with a tolerance of plus or minus five minutes. This was to rectify inaccuracies in documented time.

The sample size was determined using Epi Info 7.1.4.0, following the methodology described by Butler et al. (2016), with a 95% confidence level and a 5% confidence interval (significance level of 0.05) (10). The study included a population of 3538 instances, representing the entire number of surgical procedures completed in 2016. The expected frequency was 39%, and the confidence level was 5%. The required number of cases was calculated to be 331, considering an anticipated drop-out rate of 10%.

The data were analysed using Statistical Package for Social Science (SPSS) statistical software (Version 22.0. Armonk, NY: IBM Corp). The differences in median estimation times between the two groups were calculated and evaluated using a Wilcoxon signed rank test. The disparities in time were quantified in minutes. The Spearman's rank correlation coefficient test was employed to examine the correlation between the estimated time by the anaesthetists and surgeons and the actual surgical time in the operating theatre. A p-value less than 0.05 was considered statistically significant for all statistical analyses.

Results

A total of 685 elective cases were performed between July and September 2017 (17). Of those, 370 patients (54%) were recruited. However, we only captured one hand and microsurgery subspecialty orthopaedic case, which was inappropriate to be included in the statistical analysis. Hence, this case was dropped out. Thus, we analysed data from 369 patients. Table 1 showed the distribution of cases according to specialties. Most of the cases were surgical cases that were performed uneventfully under general anaesthesia (GA). A total of 9% of the total cases scheduled were cancelled during the study period.

TABLE 1: Characteristic of 369 observed elective cases operated from July to September 2017. Values were in numbers with percentages

Parameters	Variables	n (%)
Number of cases by specialities	Surgery	201 (54.5)
	Orthopaedic	92 (25.0)
	Otorhinolaryngology	46 (12.5)
	Maxillofacial	18 (4.8)
	Ophthalmology	12 (3.2)
Types of anaesthesia	General anaesthesia (GA)	300 (81.3)
	Regional anaesthesia (RA)	68 (18.4)
	Combined GA/RA	1 (0.3)
Perioperative anaesthesia problems	Difficult intubation	3 (0.8)
	Allergic reaction	1 (0.3)
	None	365 (98.9)
Perioperative surgical problems	Bleeding	3 (0.8)
	Change of procedure	5 (1.4)
	Instrument failure	2 (0.5)
	None	359 (97.3)

The distribution of accuracy in estimating surgical times by anaesthetists and surgeons was shown in Table 2. Anaesthetists demonstrated superior proficiency in accurately estimating the duration of surgical procedures compared to surgeons. Interestingly, half of the anaesthetists overestimated the surgical time, while just over half of the surgeons underestimated it.

Table 3 showed a statistically significant difference in anaesthetists' and surgeons' estimation times compared to the actual time. It was an accurate estimation when the median time difference between the estimated and actual surgical times was zero.

TABLE 2: Distribution of accuracy in estimating surgical times among anaesthetists and surgeons. Values were in numbers with percentages

	Anaesthetists		**Surgeons**	
	Number of cases (*n*)	**Percentage (%)**	**Number of cases (*n*)**	**Percentage (%)**
Accurate	82	22	59	16
Underestimate	103	28	199	54
Overestimate	184	50	111	30

Underestimation of time differences was denoted with a negative value, whereas positive values indicated overestimation. Anaesthetists accurately estimated the surgical times for procedures performed by the vascular, paediatric orthopaedic, spine, and maxillofacial surgical subspecialties. Meanwhile, urologists, orthopaedic arthroplasty, and ORL surgeons accurately estimated their surgical times. The median time of estimation showed that there was a significant difference in time estimation between the anaesthetists and surgeons in all except colorectal surgery, neurosurgery, paediatric surgery, plastic surgery, sports orthopaedics, and ophthalmology. The median time differences indicated that the anaesthetists had overestimated the surgical times; however, looking at the range of time estimation showed that the anaesthetist had also underestimated it.

Specifically looking at a few procedures, the surgeons in neurosurgical, upper gastrointestinal, vascular, and advanced trauma cases had underestimated their surgical times by 1.5 to 2 hours. The surgeons' interquartile range of time difference was larger than the anaesthetists' (80 versus 55 minutes). Therefore, there was not much variability among the anaesthetists in estimating these surgical times. However, 25% of surgeons estimated their surgical time to be an hour less, and 75% of surgeons predicted 20 minutes more than the actual procedure time.

Spearman's rank correlation coefficient test revealed a significant, strong positive correlation between overall anaesthetist estimated time and actual surgical time, as shown in Table 4. The actual surgical times tended to increase when the anaesthetists estimated longer surgical times. A strong and statistically significant positive correlation was seen when anaesthetists estimated the surgical time for the surgical subspecialties of endocrine and breast, paediatric surgery, paediatric orthopaedics, and arthroplasty orthopaedics. In contrast, surgeons' estimation was weakly correlated. Meanwhile, the colorectal, maxillofacial, and ORL surgeons' estimated surgical times were strongly correlated with the actual surgical times.

Discussion

Anaesthetists usually have a preconceived opinion that their optimistic surgical colleagues tend to underestimate their surgical time, which lead to overbooking of OT lists, and our study validated that. Our study also confirms anaesthetists' practice of overestimating the surgical time. The minor variability in the surgeons' estimations of surgical times seemed to indicate that their estimations were fairer. However, the anaesthetist's estimation of the surgical time correlated better with the actual surgical time than the surgeons. Other studies also observed similar findings, where general surgeons underestimated for 31 minutes and plastic surgeons underestimated for five minutes (9). Attaallah et al. found out that most subspecialties underestimated their scheduled procedure times, which resulted in using the operation rooms longer than the designated time (18).

It was reported that surgeons were accurate in estimating the actual duration of the procedure; however, they were poor at booking the OT list (11). These actions may lead to increased case cancellations. The possible reasons for overbooking lists include surgeons being pressured to reduce the surgical waiting list, thus adding more cases to the fully booked list. In our centre, OT bookings are made online via C-HEtS, which auto-limits the available surgical hours. This, however, does not prevent overbooking, as estimations of surgical times can still be manipulated to fit the limit. The surgeons' estimated surgical times in CHEts might not accurately reflect their actual estimations. Surgeons may fear criticism of not working hard by their clinical peers (11). The surgeons may intentionally overbook the OT list to ensure no OT time is wasted if any booked cases are cancelled perioperatively (11). However, this

TABLE 3: Numbers of cases (n), median of surgical times and median of time difference (interquartile range) by sub-specialties

Subspecialty	**Median surgical time (minutes)**					**Median time difference from estimated (minutes)**		
	Actual	**Estimated**						
		Anesthetists	**[a]*p* value**	**Surgeons**	**[b]*p* value**	**Anesthetists**	**Surgeons**	**[c]*p* value**
Overall (n=369)	94 (54 to 150)	120 (60 to150)	< 0.0001†	60 (60 to 120)	< 0.0001†	11 (-15 to 40)	-15 (-60 to 20)	0.0001†
Endocrine & breast surgery (n=23)	115 (55 to 140)	120 (60 to 180)	0.030†	65 (60 to 120)	0.167	10 (0 to 40)	-12 (-45 to 15)	0.001†
Colorectal surgery (n=10)	70 (30 to 215)	120 (113 to 195)	0.445	65 (60 to 113)	0.858	48 (-38 to 79)	-3 (-24 to 19)	0.044†
Hepatobiliary surgery (n=24)	131 (102 to 184)	120 (120 to 180)	0.917	60 (60 to 120)	0.009†	3 (-58 to 26)	-48 (-93 to -8)	0.002†
Neurosurgery (n=13)	180 (95 to 228)	120 (105 to180)	0.136	65 (60 to 180)	0.011†	-15 (-91 to 3)	-60 (-153 to 3)	0.074
Paediatric surgery (n=25)	40 (24 to 86)	60 (30 to 90)	0.115	60 (60 to 75)	0.372	15 (-15 to 38)	5 (-18 to 48)	0.615
Plastic surgery (n=11)	55 (40 to 70)	60 (60 to 120)	0.015†	60 (60 to 60)	0.086	30 (0 to 48)	13 (0 to 30)	0.102
Upper gastrointestinal surgery (n=30)	148 (104 to175)	165 (120 to 180)	0.078	60 (60 to 90)	<0.0001†	15 (0 to 33)	-65 (-105 to 30)	0.001†
Urology surgery (n=56)	63 (35 to 90)	75 (60 to 120)	< 0.0001†	60 (60 to 61)	0.657	25 (1 to 50)	0 (-30 to 27)	0.001†
Vascular surgery (n=9)	120 (110 to183)	120 (120 to 120)	0.398	70 (60 to 105)	0.017†	0 (-63 to 25)	-60 (-93 to -23)	0.017†
Advance trauma orthopaedic (n=25)	120 (70 to 175)	120 (120 to 165)	0.386	60 (60 to 120)	0.010†	11 (-18 to 48)	-20 (-100 to -5)	0.001†
Arthroplasty orthopaedic (n=10)	80 (55 to 124)	120 (90 to 150)	0.108	60 (20 to 120)	0.917	30 (19 to 53)	0 (-19 to 23)	0.011†
Orthopaedic Oncology (n=11)	62 (30 to 150)	120 (90 to 120)	0.182	60 (60 to 120)	0.859	33 (-20 to 40)	3 (-35 to 40)	0.026†
Paediatric orthopaedic (n=23)	65 (31 to 130)	60 (60 to 120)	0.432	60 (60 to 60)	0.648	0 (-10 to 29)	15 (-60 to 30)	0.036†
Spine orthopaedic (n=18)	118 (96 to 145)	120 (120 to 120)	0.623	65 (6 to 120)	0.003	0 (-25 to 27)	-35 (-60 to -22)	0.001†
Sport orthopaedic (n=5)	180 (115 to 207)	120 (90 to 150)	0.080	120 (60 to 135)	0.080	-33 (-85 to -17)	-56 (-115 to -13)	0.285
Maxillofacial surgery (n=18)	135 (64 to 289)	180 (113 to 300)	0.820	165 (90 to 218)	0.394	0 (-26 to 53)	-8 (-56 to 30)	0.014†
Otorhinolaryngology surgery (n=46)	113 (54 to 180)	120 (90 to 180)	0.442	90 (60 to 180)	0.230	8 (-40 to 53)	0 (-4- to 21)	0.002†
Ophthalmology surgery (n=12)	43 (30 to 85)	60 (33 to 113)	0.223	60 (38 to 61)	0.937	15 (-5 to 38)	15 (-30 to 29)	0.866

[a] p value comparing estimated and actual surgical times of anaesthetists (if result is statistically significant difference, indicates inaccurate estimation)
[b] p value comparing estimated and actual surgical times of surgeons (if result is statistically significant difference, indicates inaccurate estimation)
[c] p value comparing time difference from estimated surgical times of anaesthetists and surgeons
† statistically significant difference ($p < 0.05$)
Negative and positive values represent underestimation and overestimation of surgical times respectively

TABLE 4: Correlation between estimation of surgical and actual surgical times by anaesthetists and surgeons using Spearman's rank correlation coefficient (r_s)

Subspecialty	**Correlations**			
	Anaesthetists		**Surgeons**	
	r_s	p	r_s	p
Overall	0.735¶	< 0.0001†	0.492 Ŧ	< 0.0001†
Endocrine & breast surgery	0.851¶	< 0.0001†	0.561§	0.005†
Colorectal surgery	0.655§	0.040†	0.872¶	0.001†
Hepatobiliary surgery	0.605§	0.002†	0.511§	0.011†
Neurosurgery	0.459 Ŧ	0.115	0.279 Ŧ	0.357
Paediatric surgery	0.758¶	< 0.0001†	0.477 Ŧ	0.016†
Plastic surgery	0.697§	0.017†	0.465 Ŧ	0.149
Upper gastrointestinal surgery	0.514§	0.004†	0.086 Ŧ	0.650
Urology surgery	0.629§	0.0001†	0.315 Ŧ	0.018†
Vascular surgery	-0.275 Ŧ	0.474	0.053 Ŧ	0.892
Advance trauma orthopaedic	0.690§	< 0.0001†	0.230 Ŧ	0.268
Arthroplasty orthopaedic	0.722¶	0.018†	0.425 Ŧ	0.221
Orthopaedic oncology	0.642§	0.033†	0.129 Ŧ	0.705
Paediatric orthopaedic	0.826¶	< 0.0001†	0.162 Ŧ	0.460
Spine orthopaedic	-0.021 Ŧ	0.935	0.520§	0.027†
Sport orthopaedic	0.316 Ŧ	0.604	0.158 Ŧ	0.800
Maxillofacial surgery	0.831¶	< 0.0001†	0.846¶	< 0.0001†
Otorhinolaryngology surgery	0.694§	< 0.0001†	0.718¶	< 0.0001†
Ophthalmology surgery	0.450 Ŧ	0.142	0.190 Ŧ	0.554

Results were expressed as Spearman's correlation coefficient (r_s) and interpreted as:
Ŧ r_s: < 0.5 = weak
§ r_s: 0.5 – 0.7 = moderate
¶ r_s: > 0.7 = strong
† statistically significant difference ($p < 0.05$)

preemptive practice is not cost-effective. The OT list may be randomly booked, and the surgeons were subconsciously aware of how long the procedure would take despite consciously allowing their list to be overbooked (11). We believe that the daily working experience of anaesthetists, which requires them to be ready for expected problems and unexpected crises, may have shaped them to be overprepared and tend to overestimate.

We categorised the estimation accuracy among the anaesthetists and surgeons into three categories: accurate, underestimate, and overestimate. Butler et al. considered the estimations acceptable if they were within 20% under and 10% over the actual surgical time (10). A simple percentage is too tight for short procedures and too lax for lengthy procedures (11). Complicated surgeries such as brain surgery, transplants, and hepatectomies are potentially overestimated (19). Similar findings were observed in our study: complex surgeries tend to be overestimated by anaesthetists, with colorectal surgery being the most common. Other than simple tumour removal, the cases listed by the colorectal team involved long and complicated surgeries that mainly involved a laparoscopic approach.

Furthermore, it is not uncommon in oncology cases with curative intent; the planned operation may proceed and overrun OT time or conclude as inoperable intraoperatively and shorten OT time (13). The surgeons might have a more accurate estimation if asked to estimate intraoperatively (9,11). Factors that need to be considered apart from the complexities of the procedure to estimate the duration of surgery include high body mass index (BMI), history of previous surgeries, associated pathology, malignancy, sepsis, localised or advanced diseases, ASA (American Society of Anesthesiologists) grade, and type of anaesthesia (13,19).

The availability of historical surgical times for procedures is helpful as a reference for estimating surgical times (19). Anaesthetists in our centre had accurately estimated surgical times for spine and vascular surgery operations, mainly were performed by the surgical consultants they knew best for their performance. Their consistent and reproducible performance may allow anaesthetists to estimate accurately, especially when the same surgical team performs similar procedures. The single and typical operation is more straightforward to estimate than the multiple and uncertain operations, such as exploratory laparotomy and proceed or keep in view (KIV) procedures (9). We proposed the commonly done procedures, and a straightforward case may allow ORL, urology, and arthroplasty surgeons to estimate their operations accurately.

When the surgical time is underestimated, a series of events may follow. There will be a cascade effect that may delay the start of subsequent cases, drain OT time, increase usage of resources, and dissatisfy medical personnel and patients. The negative impacts are also seen in other units, including the post anaesthesia recovery unit (PACU), intensive care, and inpatient units. Conversely, extreme overestimation also results in the waste of resources due to underutilised operation rooms (18,19).

This study encountered several methodological limitations. This study was conducted in a tertiary university hospital with several trainees and fellows in various subspecialties. Several new surgical techniques and procedures were foreign to surgeons and anaesthetists. These factors may contribute to the assessor's uncertainty in estimating the surgical time. In addition, the multilevel of surgical skills made the estimation varied for each procedure. It was crucial to consider the competence and skill of the performing surgeon in constructing an OT schedule, as it can minimise delays and cancellation rates (20).

This study is the first audit on surgical time for our centre, which was done in a limited time. For the future, we suggest to record the experience level of the surgeon who performs the procedures. In our hospital setting, further standardisation could be done if samples are taken from the private operation lists operated by consultants only.

Our study could be expanded to examine variables which significantly influence the surgical time and the data pool for actual surgical times in Malaysian population. The total duration of an operation with more value for OT schedule efficiency should be added to future research (19).

Conclusion

This study reveals that the anaesthetists and surgeons needed to be more accurate in estimating the time for surgical procedures. Although the anaesthetists tended to overestimate it while the surgeons underestimated it. Anaesthetists' estimation correlated strongly with the actual surgical times, whereas the surgeons' estimations were weakly correlated.

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