ORIGINAL ARTICLE

Factors Predicting Burn Surgery Operative Time in a Middle-Income Country Regional Burn Service

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Access to theater is essential for the surgical management of deep burns. This is a scarce resource in low-middle-income countries. It underpins the importance of optimizing theater time. We sought to look at specific factors and their influence on operative time in minor to moderate burn surgery. This knowledge can assist teams where theater planning and optimization may be beneficial in resource-limited settings. Operative records between January and December 2018 at the Regional Hospital were analyzed. Data fields included age, gender, TBSA of burn, surface area burn operated on, intraoperative position change, seniority of surgeon, presence of an assistant, inclusion of special areas, predicted operative time, and actual operative time. Operative records for 265 patients were analyzed, with a median operative time of 40 minutes (interquartile range 25-64). Overall factors that predict longer operating time are larger total body surface area burn, larger surface area burn operated on, an operation involving at least one special area, number of special areas operated on, position change, presence of an assistant, and longer predicted operative time. Total percentage burn, operated percentage, special areas to be operated, and position change are overall factors to be considered when planning a burns list for the nonspecialist burn surgeon. This knowledge may be useful for an inexperienced surgeon to understand and aid in the effective utilization of limited operative time available for the surgical management of deep burns in resource-limited settings.

Keywords: burn surgery; operative time prediction; theater efficiency

INTRODUCTION

This Burn Service (PBS) functions in a constrained resource setting with a high burden of disease-to-resource ratio that is typical of low- and middle-income countries. One of the critical resources is theater time, which is essential to the surgical management of deep burns. A previous publication shows that only 33% of hospitals treating burn patients had access to a dedicated burns theater, with 22 scheduled burns lists per week across the country.[1] The scarcity of theater time dedicated to burns patients underpins the importance of optimizing theater time, as delayed definitive management of deep burns leads to long length-of-stay and complications both acutely, for example, sepsis, and long-term complications such as cosmetic and functional deficits.

This problem is not unique to burn teams, and the operating room has been the focus of much research with the aim of improving efficiency. This has become a core theme of modern hospital management.[2] Poorly planned slates can lead to canceled or delayed surgery, theaters standing empty, unplanned overtime for staff, and general dissatisfaction for both patients and staff. This leads to downstream problems such as bed occupancy. Surgical workflow redesign, standardizing instruments and supplies, team huddles, checklists, working with the same teams regularly, specialization of personnel, space redesign, and parallel processing are some of the strategies targeting improved efficiency.[3] However, optimization of operating theater activities is complex. Accurate operative time prediction is one of the components of theater time optimization, but it is difficult to predict and often inaccurate.[4,5] One author showed that surgeon-generated operative time estimation was more accurate than a generic system approach of averaging previous operative times. This was likely because surgeons looked at individual patient characteristics when estimating operative time. However, no objective variables were identified.[6]

The surgical approach to minor and moderate deep burn injuries is reasonably standard: excise nonviable tissue down to a healthy wound bed and close with autograft. The variability of the procedure is linked to predictable and practical factors. We sought to look at specific factors and their influence on operative time as part of an overall strategy for better theater planning and optimization in the burn service, as this

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knowledge may assist other LMIC teams performing burn surgery. There is no hospital initiative for theater efficiency.

Setting

The Regional Hospital provides regional-level burn care for a population of 3 million people. Patients present to the emergency department or are referred from surrounding clinics and district hospitals. There is a dedicated burn service run by a single specialist with 2 surgical trainees in the team on a rotational basis. There are 2 operating lists per week. Data are routinely collected electronically at the time of admission and discharge as well as surgery. This database has class approval granted by the Biomedical Research and Ethics Committee (BCA106-14). This burn service serves as a training center for interns, medical officers, and registrars. As part of preoperative preparation, a prediction of operative time is made by the consultant. Operative time in this article is the time spent operating or touch time and excludes anesthetic and turnover times.

METHODOLOGY

Operative records, during the period between January 1, 2018, and December 31, 2018, were exported from the above database as an Excel spreadsheet for analysis. Data fields routinely collected and retrospectively chosen for analysis include age, gender, TBSA of burn, TBSA burn operated on, intraoperative position change, seniority of surgeon, presence of an assistant, whether special areas were operated on or not, and the number thereof. Special areas included face, hands, and feet. Other variables collected were predicted operative time and actual operative time. Data analysis was performed using R version 4.2.1 (The R Foundation for Statistical Computing).

Descriptive statistics were performed for the overall sample. Continuous variables were described as medians and interquartile ranges (IQR). Categorical variables were described as frequencies and percentages. Face validation was used to identify independent variables that were possibly associated with operative time. The outcome variable "operative time" was noted to be non-normally distributed. Tukey's transformation ladder was used to convert the variable "operative time" to a normal distribution. Univariate linear regression was used to examine relationships between independent variables and the dependent variable "operative time." When *P* values were <.05, relationships were expressed as odds ratios and 95% confidence intervals. Similar subanalyses were performed for the age categories 5 years old and below, 6-12 years old, and older than 12 years. In order to examine for agreement between predicted operative time and actual operative time, a Bland–Altman plot was created. The predicted operative time was used as the "experimental measure" and the actual operative time as the standard against which it was measured.

RESULTS

Operative records for 265 patients were analyzed, with a median operative time of 40 minutes (IQR 25-64). Patients were grouped by age with 119 (44.9%) patients being 5 years old and under, 30 (11.3%) patients aged 6-12 years old, and 116 (43.8%) patients older than 12 years old. Females accounted for 41.1% of patients. The median TBSA of injury was 10% (IQR 3-10), with a median of 4% (IQR 2-8) burn surface area operated on. Intraoperative position change occurred in 51 patients (19.2%). In 85 patients (32.1%), special areas were involved. The operating surgeon was a consultant in 124 (46.8%) cases, a senior medical officer in 94 (35.5%) cases, and a junior medical officer in 47 (17.7%) cases. An assistant was present in 161 cases (60.8%). Description of all patients undergoing burn surgery at the Regional Hospital and the significance of variables in predicting operative time are seen in Table 1. Overall factors that predict longer operating time are larger TBSA burn, larger surface area burn operated on, an operation involving at least one special area, number of special areas operated on, position change, presence of an assistant, and longer predicted operative time.

Subgroup analysis

Age group 5 years old and below

The median age was 3 years (IQR 2-4 years), and females accounted for 38.7% of patients in this group. The median %TBSA in this group was 17 (IQR 6%-25%), and the median operated percentage was 4% (IQR 2-10). In this group, operated percentage, change of position, presence of a consultant, and assistant were all positively associated with longer operative times. Operating on special areas was not associated with longer operative times. Detailed results can be seen in Table 2.

Age group 6-12 years

The median age in this group was 9.5 years old (IQR 7-10 years). Females accounted for 56.7% of the group. The median %TBSA was 7% (IQR 1%-14%), and the median operated percentage was 2% (IQR 1%-5%). Factors associated with longer operative times were %TBSA, operated percentage, position change, at least one special area, and the number of special areas operated on. Female sex was inversely related to operative time (OR 0.981; 95%CI [0.963-0.999]). Details can be seen in Table 3.

Age group above 12 years old

The median age of this subgroup was 36 years (IQR 30-46 years). Females accounted for 39.7% (46 patients) in this subgroup. The median operative time was 44 minutes (IQR 29-67 minutes). The median %TBSA of the group was 7% (IQR 3%-13%), and the median percentage operated on was 3% (IQR 2%-7%). A consultant was present in 43.1% of the cases and an assistant was present in 65.5% of cases. There were 43 patients who had special areas operated on. Prolonged operative time was associated with female, overall %TBSA, operated percentage, and position change, when the primary surgeon was either a consultant or a junior medical officer. Senior medical officers had shorter operative times. Operating in a special area also increased operative time. Details of these results are shown in Table 4.

Table 5 summarizes the significant factors predicting longer operating time by age group categories.

Table 1. Description of All Patients Undergoing Burn Surgery and Significance of Variables in Predicting Operative Time

Operative time in minutes:median, (IQR) = 40 (25-64), *N* = 265				
	All[a]	***P*-value**	**OR**	**95% CI**
Age median (IQR)	9 (3-34)	.546		
Age < 5	119 (44.9%)	.807		
Age 6-12	30 (11.3%)	.008	0.98	(0.97-0.99)[a]
Age > 12	116 (43.8%)	.053		
Female	109 (41.1%)	.021	0.99	0.983-0.999[a]
TBSA%	10 (3-20)	<.001	1.001	1.0009-1.002[a]
% operated	4 (2-8)	<.001	1.003	1.003-1.004[a]
Predicted time	45 (30-60)	<.001	1.0007	1.0007-1.0009[a]
Position change	51 (19.2%)	<.001	1.02	1.02-1.03[a]
Consultant present	124 (46.8%)	.003	1.01	1.004-1.019[a]
Assistant	161 (60.8%)	<.001	1.016	1.008-1.024
Senior MO	94 (35.5%)	.064		
Junior MO	47 (17.7%)	.153		
SA	Any = 85 (32.1%)	<.001	1.011	1.006-1.016
Number of SA as % of overall sample	1 = 58 (21.9%)			
	2 = 21 (7.9%)			
	3 = 5 (1.9%)			
	4 = 1 (0.4%)			

Abbreviations: CI = confidence interval; IQR = interquartile range; OR = odds ratio; SA = special areas.
[a]IQR in parentheses where applicable or % of the total population where applicable.

Table 2. Predictors of Operative Time in Children 5 y Old and Below

Operative time in minutes:median (IQR), 40 min (24-61), *n* = 119				
	All	***P***	**OR**	**95% CI**
Age median (IQR)	3 (2-4)	.649		
Female	46 (38.7%)	.139	1.001	1.001-1.002*
TBSA%	17 (6-25)	<.001		
% operated	4 (2-10)	<.001	1.003	1.002-1.004*
Position change	34 (28.6%)	<.001	1.02	1.01-1.03*
Consultant present	63 (52.9%)	.025	1.013	1.002-1.024*
Assistant	70 (58.8%)	.004	1.017	10005-1.028*
Senior MO	44 (37%)	.221		
Junior MO	12 (10.1%)	.084		
SA	Any = 28 (23.5%)	.467		
Number of SA as % of overall sample	1 = 21 (17.6%)			
	2 = 7 (5.9%)			
	3 = 0			
	4 = 0			

Abbreviations: CI = confidence interval; IQR = interquartile range; OR = odds ratio; SA = special areas.

Agreement between predicted and actual operative times

A Bland–Altman plot was constructed, plotting the difference between the predicted and actual operative times against the mean of the predicted and actual operative times for each case. The bias line represents the mean difference, and the ±1.96SD represents the upper and lower limits of the 95% confidence interval. This plot found that the mean difference between actual and predictive operative times was 4 minutes. We found this level of agreement to be acceptable. These results are illustrated in Figure 1.

DISCUSSION

Resource limitation for burns care in low- and middle-income countries is a well-described global challenge.[7] However, in the current fiscal climate, resources are unlikely to increase. Although the value of increased resource allocation is not in question, we have previously described the impact of an improved process of care within our service without the allocation of more resources.[8] We continue aiming for optimization of our service within the resource constraints, and this project is part of the strategy for

Table 3. Predictors of Operative Time in Children Between 6 and 12 y Old

Operative time in minutes:median (IQR), 26 (20-37), *n* = 30

	All	*P*	OR	95% CI
Age median (IQR)	9.5 (7-10)	.138		
Female	17 (56.7%)	.037	0.981	0.963-0.999*
TBSA%	7 (1%-14%)	.010	1.001	1.001-1.002*
% operated	2% (1-5)	<.001	1.003	1.002-1.004*
Position change	3 (10%)	.001	1.048	1.021-1.076*
Consultant present	11 (36.7%)	.603		
Assistant	15 (50%)	.314		
Senior MO	11 (36.7%)	.188		
Junior MO	8 (26.7%)	.395		
SA	Any = 14 (46.7%)	<.001	1.016	1.001-1.023*
Number of SA as % of children between 6 and 12 y	1 = 9 (30%)			
	2 = 2 (6.7%)			
	3 = 2 (6.7%)			
	4 = 1 (3.3%)			

Abbreviations: CI = confidence interval; IQR = interquartile range; OR = odds ratio; SA = special areas.

Table 4. Predictors of Operative Time in Patients Older Than 12 y Old

Operative time in minutes:median (IQR), 44 min (29-67), *n* = 116

	All	*P*	OR	95% CI
Age median (IQR)	36 (30-46)	.039	0.9995	0.9991-0.1000
Female	46 (39.7%)	.471		
TBSA%	7% (3-13)	<.001	1.002	1.001-1.002*
% operated	3% (2-7)	<.001	1.004	1.003-1.005*
Position change	12 (10.3%)	.003	1.031	1.011-1.051*
Consultant present	50 (43.1%)	.032	1.013	1.001-1.026*
Assistant	76 (65.5%)	.023	1.015	1.002-1.028*
Senior MO	39 (33.6%)	.049	0.987	0.974-0.999*
Junior MO	27 (23.3%)	.753		
SA	Any = 43 (36.1%)	<.001	1.015	1.007-1.022*
Number of SA as % of patients over 12 y	1 = 28 (24.1%)			
	2 = 12 (10.3%)			
	3 = 3 (2.6%)			

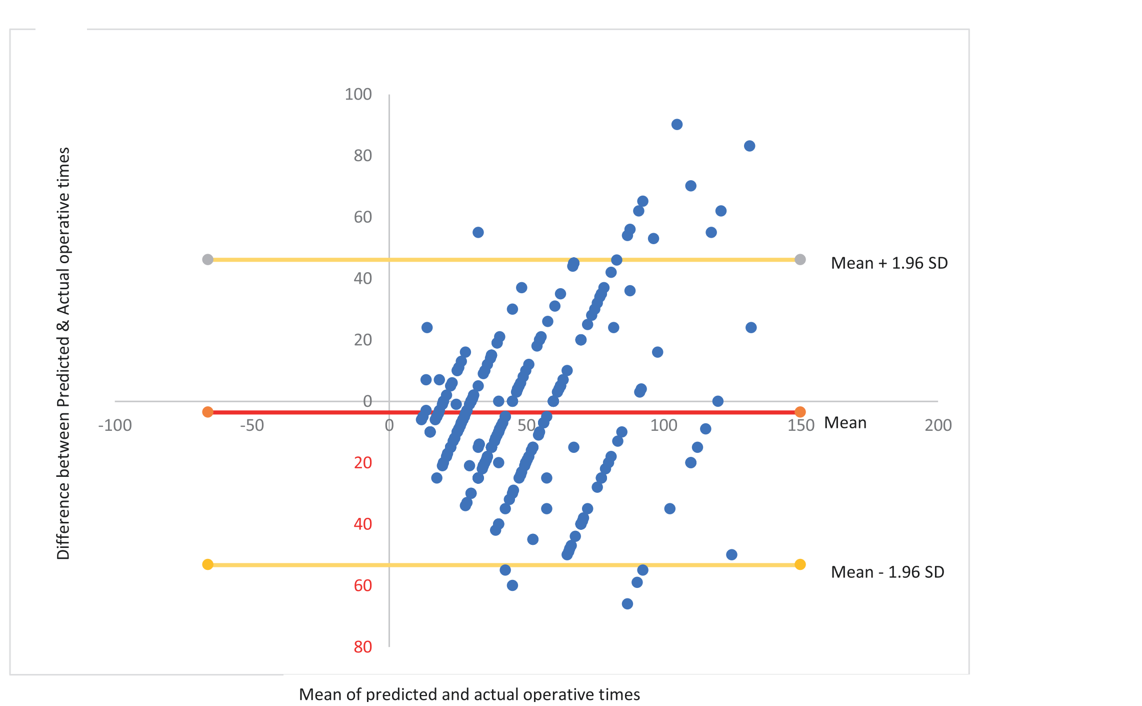
Abbreviations: CI = confidence interval; IQR = interquartile range; OR = odds ratio; SA = special areas.

Table 5. Significant Factors Predicting Longer Operating Time by Age Group Categories

	<5 y	6-12 y	>12 y
Larger total body surface area burn		X	X
Larger surface area burn operated on	X	X	X
Special areas operated on		X	X
Position change	X	X	X
Presence of consultant	X		
Presence of an assistant	X		
Presence of a senior MO			X
Younger age			X
Male patient		X	

improving the utilization of theater time. Preoperative prediction of theater time is one of the components of theater scheduling; however, the literature is variable, and although some say the surgeon accuracy in prediction of operative time is poor, it is still better than computerized scheduling systems.[4,9] There is no published literature on theater optimization in burns, and this article sought to explore and understand factors influencing operative time in burn surgery.

In our analysis of burn surgeries, for all cases, it is logical that surface area operated on is directly proportional to operative duration. The overall TBSA injury also influences operative duration, which could be due to dressing changes needed in burn wounds not operated on, and other issues in larger burns could be contributory. For example, larger surface area burn injury patients are generally less physiologically well. Our surgical approach in larger burns is one where we operate,



The above figure indicates that the mean difference in predicted and actual operative times was approximately 4min (95% CI -53 to 46 min).

Figure 1. Bland–Altman Plot for Operative Time

resuscitate, transfuse, warm, and then continue operating in constant flux as opposed to a simple small skin graft with no systemic or hypothermia issues. The presence of a consultant or an assistant is most likely due to the higher complexity of the case and therefore longer operative time. Position change and involvement of special areas start influencing operative duration in older children and adults. This is likely due to the logistical difficulty of turning or repositioning larger patients. In the case of special areas, they are more complex to position and fix the graft as well as perform the dressing. The presence of a senior medical officer predicting a shorter operative time is likely because they have more surgical experience as opposed to a junior medical officer. In patients over 12-year age however, this is inversely proportional to time, which is difficult to explain.

The predicted operating time being in close agreement with actual operating time demonstrates the experience of the specialist surgeon in understanding factors influencing operative time. This may not be case in other regional hospitals or hospitals where there is no burn service and general surgeons perform burn surgery. Understanding the factors that influence operative time can help in planning theater lists to make the best use of the time available for nonspecialist units. This is likely to be common in low-middle-income settings where many minor and moderate operative cases are treated by nonspecialist burn surgeons. One of the limitations of this article is the investigation of factors influencing operating time only. Many patients are critically ill, and anesthetic time can make a significant contribution to total time in theater and should be taken into account when planning a list. This should be investigated. Another limitation is the lack of data on case cancelations due to poor planning.

Process mapping is a technique used to map out workflows to *promote a better understanding of processes and then identify areas for* improvement.[10] This is recognized as a strategy to improve surgical efficiency. Perioperative process mapping includes preoperative, intraoperative (holding bay, anesthetic time, operative or touch time, transfer out of theater), and postoperative components.[10] Other authors have described potential areas for improvement in each of these components. While our aim was to focus on awareness of factors influencing operating time for the nonspecialist burn surgeon, the other perioperative components should not be ignored. Further investigation into perioperative processes should be undertaken in our service to determine areas for improvement.

In conclusion, total percentage burn, operated percentage, special areas to be operated, and position change are overall factors to be considered when planning a burns list for the nonspecialist burn surgeon. This knowledge may be useful for an inexperienced surgeon to understand and aid in the effective utilization of limited operative time available for the surgical management of deep burns. This should form part of a larger project for improving theater utilization and productivity including anesthetic and turnover times.

REFERENCES

1. Allorto NL, Wall S, Clarke DL. Quantifying capacity for burn care in South Africa. *Burns Open*. 2018;2(4):188–192. https://doi.org/10.1016/j.burnso.2018.07.002

2. Barbagallo S, Corradi L, de Ville de Goyet J, et al. Optimization and planning of operating theatre activities: an original definition of pathways and process modeling. *BMC Med Inform Decis Mak.* 2015;15:38. https://doi.org/10.1186/s12911-015-0161-7
3. Fong AJ, Smith M, Langerman A. Efficiency improvement in the operating room. *J Surg Res.* 2016;204(2):371–383. https://doi.org/10.1016/j.jss.2016.04.054
4. Roque DR, Robison K, Raker CA, Wharton GG, Frishman GN. The accuracy of surgeons' provided estimates for the duration of hysterectomies: a pilot study. *J Minim Invasive Gynecol.* 2015;22(1):57–65.
5. Wu A, Huang CC, Weaver MJ, Urman RD. Use of historical surgical times to predict duration of primary total knee arthroplasty. *J Arthroplasty.* 2016;31(12):2768–2772.
6. Stavrides KP, Lindemann TL, Harlor EJ, Haugen TW, Purdy N. Accurate operative time prediction in thyroid surgery: a rural tertiary care facility experience. *Ear Nose Throat J.* 2021;102(8):498–503. https://doi.org/10.1177/01455613211016702
7. Thomson IK, Iverson KR, Innocent SHS, Kaseje N, Johnson WD. Management of paediatric burns in low- and middle-income countries: assessing capacity using the World Health Organization Surgical Assessment Tool. *Int Health.* 2020;12(5):499–506. https://doi.org/10.1093/inthealth/ihz068
8. Allorto NL, Clarke DL. Merits and challenges in the development of a dedicated burn service at a regional hospital in South Africa. *Burns.* 2015;41(3):454–461. https://doi.org/10.1016/j.burns.2014.07.021
9. Goel R, Kanhere H, Trochsler M. The "Surgical Time": a myth or reality? Surgeons' prediction of operating time and its effect on theatre scheduling. *Aust Health Rev.* 2020;44(5):772–777. https://doi.org/10.1071/AH19222
10. Chung RD, Hunter-Smith DJ, Spychal RT, Ramakrishnan VV, Rozen WM. A systematic review of intraoperative process mapping in surgery. *Gland Surg.* 2017;6(6):715–725. https://doi.org/10.21037/gs.2017.11.02