MEDINFO 2023 — The Future Is Accessible
J. Bichel-Findlay et al. (Eds.)

doi:10.3233/SHTI231072

Modelling Planned vs. Actual Start Time to Control the Efficiency of Surgery

Justin BOYLE[a,1], Hamed HASSANZADEH[a], Sankalp KHANNA[a], Barbara BIKI[b], Faraz SYED[b], Ellen BORKWOOD[b] and Lianne SWEENEY[b]
[a] *CSIRO, Australian E-Health Research Centre, Australia*
[b] *Fiona Stanley Hospital, Perth, Western Australia*

Abstract. To control the efficiency of surgery, it is ideal to have actual starting times of surgical procedures coincide with their planned start time. This study analysed over 4 years of data from a large metropolitan hospital and identified factors associated with surgery commencing close to the planned starting time via statistical modelling. A web application comprising novel visualisations to complement the statistical analysis was developed to facilitate translational impact by providing theatre administrators and clinical staff with a tool to assist with continuous quality improvement.

Keywords. Operating Rooms; Operative Time, Surgical Procedures, Operative

1. Introduction

Operating theatre efficiency remains a key priority for health jurisdictions seeking to deliver safe, high quality, patient-focused care, provide value for money and meet public expectations [1]. Operating theatres represent a significant cost burden for healthcare providers, particularly in an environment of capitated (bundled payment) models which shift the burden of cost minimisation away from insurers and on to clinicians and administrators [2].

One of the key contributors to improving theatre cost efficiency is starting on time [3]. Starting surgery on time and as planned will ensure the greatest opportunity to finish on time (and thus minimise overtime costs), avoid unnecessary cancellations and maximise the use of available theatre time to increase productivity and reduce the need for and cost of staff working overtime.

An audit of elective surgeries performed in Australian operating theatres over a 6-year period concluded that efforts by the hospitals to improve operating theatre efficiency tended to be ad hoc with limited use of available data and analytics to identify efficiency issues [1]. The audit estimated that just addressing late starts and early finishes of more than one hour could have feasibly delivered approximately 3000 hours to treat additional patients. Among the reasons identified for time being lost was that more than a third of the sessions did not “start-on-time”, i.e. when the first case of a session started more than 10 minutes after the schedule session start time.

[1] Corresponding Author: Justin Boyle, Level 7 – Surgical Treatment and Rehabilitation Service – STARS, Royal Brisbane and Women's Hospital, Qld, 4029, email: justin.boyle@csiro.au.

The objective of this study was to fill a gap in this area using statistical modelling and visualisation of the difference between planned and actual starting time to better understand start-on-time performance.

2. Methods

The study setting was a 783-bed hospital in Western Australia, comprising 15 operating theatres which are available 24 h/day, 5 endoscopy suites, 2 interventional theatres, a dedicated emergency obstetric theatre, 20 preoperative holding bays and 37 post anaesthetic care unit bays. Data used in the project was obtained from the hospital's Theatre Management System (TMS) which is standardised across the state-wide health department, and comprised episode-level data, session-level data, cancellations, and bookings data from November 2014 to March 2019 (4.4 years).

The difference in minutes between Planned and Actual starting time was investigated using a generalised additive model (`gamlss` in the statistical package *R*). This difference between planned and actual start time can take on negative values where a negative time difference denotes operations that started earlier than planned. The approach adopted for analysis was to model the absolute values of the response variable (e.g. surgery that started 1 hour earlier than planned was equivalent in terms of a desired aim to surgery starting 1 hour late). Using the absolute values of the time difference enabled Poisson regression and Negative Binomial Regression models to be considered. Likelihood Ratio Tests were used to determine that the data was overdispersed (higher variation than expected) and a Negative Binomial Regression model was the most appropriate model to use.

Statistical models were generated for the main effects - time within the study period, day of week, seasonality, medical specialty, number of procedures within the operation, patient frailty (ASA score), whether the operation was elective or emergency, and session type. Additional models were generated that explored interactions between specialty and day-of-week, and also between specialty and operation type.

To further interrogate the data and visualise the difference between these time stamps, an interactive web application was developed which allows customisable views of the relative time difference before and after the planned start time.

3. Results

3.1. Surgeries Performed

Across the study period there were 99,933 surgical operations performed in the hospital. A comparison of planned to actual starting times found that:

- 2% of operations (n=1695) actually started at the exact minute that they were planned.
- 21% of operations (n=21,111) started earlier than planned, 91% started within 4 hours of the planned start, and 99% started within 12 hours of the planned start.
- The median difference between planned and actual operation start times was 58 minutes.

The 98,238 surgery cases with different planned vs actual starting times were almost equally split between elective cases (47%) and emergency cases (53%) and occurred across a range of medical specialties.

3.2. Visualising the difference between planned and actual starting time

For a given time-window selected by a user, the dashboard displays the count, cumulative percentages by hour, proportion of elective and emergency cases, frequency by theatre specialty, days of the week, operating theatre, patient ASA score, number of procedures within the operation, and data table of the corresponding theatre records matching the time-window selected.

To control the efficiency of surgery, it is ideal to have actual processes match planned cases. Consequently, a checkbox has been included to exclude or include cases with zero-time difference. This is useful for example to display surgery cases which started at the exact minute that they were planned to identify characteristics of those cases (62% of these cases were elective, 10% occurred in Theatre No. 7, etc.)

Similarly a user can choose to focus only on those cases which occurred at least say 24 hours before they were planned (11 elective radiology cases which may indicate operationally responsive scheduling) or conversely, cases which occurred more than 24 hours after they were planned (3 obstetric emergency and 6 radiology elective cases).

A novel heat map representation of planned vs actual start time as well as the delta time difference between the two time-stamps has been included within the dashboard. The heat map representation of planned vs actual start time indicates when most plan changes occur during a day. In Figure 1A, the ideal situation to control the efficiency of surgery is to have the planned start time coincide with the actual start time i.e. have cases represented along the diagonal in the plot below. We observe there is bias evident with numerous cases above the diagonal indicating an actual start time that occurred after the planned start. We observe 'hotspots' at 8am, 9am, and 1pm. This plot has been made interactive within the dashboard to allow a user to explore multiple combinations of planned start and actual start times.

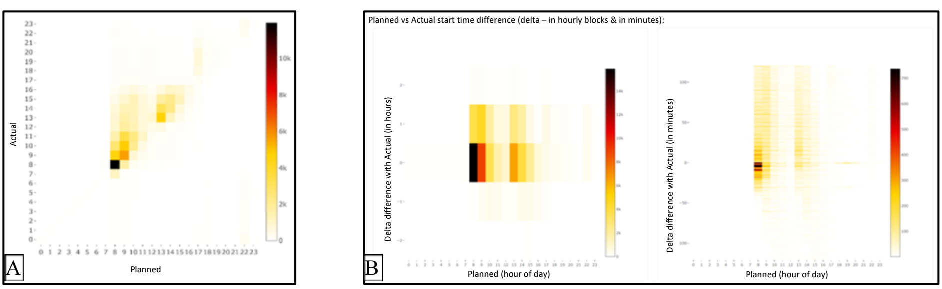

Figure 1. Extracted elements of the interactive dashboard showing a heat map representations of planned vs actual start time. Left image (Fig 1A): plot axes referring to 24hour clock times; Right image (Fig 1B): delta (Δ) time differences with a cohort selected to be ± 2hours of the planned start.

In Figure 1A, the axes represent starting times on a 24-hour clock. The depiction of data in this way includes those cases which may have actually started on a different day but prevents a user identifying those larger time differences or exploring differences at a finer timescale (e.g. in minutes). Consequently, versions of this heat map were also included on the dashboard (Figure 1B) which include the difference in hours or minutes between the two timestamps (representing the delta time difference).

The web application with its embedded interactive plots allows a user to explore a large range of time differences. For example, an observation reported earlier was that historically, 99% of operations started within 12 hours of their planned start. Considering this threshold of 12 hours, the dashboard allows easy interrogation of those surgeries that started 12 hours or more after they were planned. This cohort comprised 855 patients, 96% of which were emergency surgery, 93% were obstetric patients, and they were more prevalent on a Friday, Wednesday, or Saturday than on a Monday or Tuesday. The heat map plots indicate that some of these surgeries that were planned to commence in the morning started late in the evening or early hours of the following day.

Similarly, we can consider a different threshold of 4 hours after the planned start (91% of operations started within 4 hours of the planned start), and in this case the dashboard indicates key characteristics of these surgery cases: of the 14,151 cases in this cohort, 72% were emergency, the most prevalent specialty was orthopaedic (21%) and they were more common on a Friday compared to the weekend. Inspection of the heat map plots indicate the majority of these cases actually started within a few hours of their planned start.

3.3. Statistical Modelling to explore Planned vs Actual starting time

Moving beyond visualising the difference between planned vs actual starting time via dashboards and filtering the data to focus on particular cohorts of interest, additional insights were obtained by modelling this time difference based on candidate predictors obtained from theatre data. This statistical modelling was undertaken on data extracts predating the availability of the dashboards and complements the visualisation of starting time performance depicted within the dashboards. As mentioned earlier, for efficient surgery scheduling, it is ideal to have actual processes match planned cases, and the modelling was on the premise that a shorter time difference was preferable. Significant observations from this model output are as follows:

- As time has progressed through the study period, the difference between Planned and Actual starting time has got smaller (i.e. improved).
- The time difference is likely to be longer on a public holiday, Saturday, Sunday, and shortest on Thursdays.
- The time difference is likely to be shortest for burns, ENT, gastroenterology, gynaecology, haematology, and renal transplant surgery specialties.
- The time difference is likely to be longer for emergency haematology and emergency obstetric patients.
- The more procedures within an operation, the smaller the time difference.
- A frailer patient (higher ASA score) leads to a longer time difference.
- The time difference is likely to be longer for particular session types (e.g. Emergency surgery sessions conducted on weekend mornings with on-call staff, and Emergency All Day Extended sessions).

A check was made of the model output by adding the smallest negative value to all observations to force the response variable to be positive and applying a box-cox transformation in *gamlss* known as the Box-Cox Cole and Green (BCCG) transform, which confirmed the above findings.

4. Discussion

To control surgery efficiency, it is ideal to have actual start times of surgery coincide with planned start time. The web application developed in this study allows easy identification of surgery cases which started at the exact minute that they were planned to identify characteristics of those cases. Similarly it allows focusing on cases which occurred a given period before or after they were planned. The exact times when differences are large can be pinpointed to assist with continuous quality improvement.

Statistical modelling confirmed that as time has progressed at the study site, the difference between planned and actual starting time has reduced (a good result), the time difference is longer on weekends and public holidays, for frailer patients (higher ASA score), and for specific medical specialties and session types. Surprisingly the more procedures within an operation, the smaller the time difference. Inspection of the dashboard that visualises this time difference verifies the output from the statistical model. While the majority of cases had a single procedure, for cases with a time difference between 0-1 hour, 20% had more than one procedure, whereas for cases with a time difference of between 12 hours and 76 hours, 14% had more than one procedure.

In addition to theatre start time, numerous other measures of theatre efficiency exist, including the turnover time between cases, the number of cancellations, over-runs and utilisation [3,5]. Theatre start time is a particularly good measure as it is easily definable, simple to measure and theoretically comparable between different studies and institutions. The authors have recently extended this work by predicting daily surgery caseload [6] and developing simulation models to assess the impact of hypothetical operational changes such as varying the availability of theatres, case-mix of patients, or turnover [7] which are other ways analytics can assist in improving theatre efficiency.

5. Conclusions

Scrutiny of historic theatre performance via visualisation and statistical modelling can pinpoint areas in most need of start-on-time improvement. Other interventions to improve start time such as financial incentives, educational approaches, communication, and the 'golden patient' initiative [3] remain areas for future exploration.

References

[1] Office of the Auditor General Western Australia. Operating Theatre Efficiency. Report 25: Nov 2015

[2] Childers CP, Maggard-Gibbons M. Understanding Costs of Care in the Operating Room. JAMA Surg. 2018 Apr;153(4):e176233, doi: 10.1001/jamasurg.2017.6233.

[3] Halim UA, Khan MA, Ali AM. Strategies to Improve Start Time in the Operating Theatre: a Systematic Review. J Med Syst. 2018 Jul;42(9):160, doi: 10.1007/s10916-018-1015-5.

[4] Phieffer L, Hefner JL, Rahmanian A, et al. Improving Operating Room Efficiency: First Case On-Time Start Project. J Healthc Qual. 2017 Sep/Oct;39(5):e70-8, doi: 10.1097/JHQ.0000000000000018.

[5] Pandit JJ, Westbury S, Pandit M. The concept of surgical operating list 'efficiency': a formula to describe the term. Anaesthesia. 2007 Sep;62(9):895-903, doi: 10.1111/j.1365-2044.2007.05174.x.

[6] Hassanzadeh H, Boyle J, Khanna S, Biki B, Syed F. Daily surgery caseload prediction: towards improving operating theatre efficiency. BMC Med Inform Decis Mak. 2022 Jun;22(1):151

[7] Hassanzadeh H, Boyle J, Khanna S, Biki B, Syed F, Sweeney L, Borkwood E. A discrete event simulation for improving operating theatre efficiency. Int J Health Plan Manag. 2023 Mar;38(2):360-79.