Turnover Time Between Elective Operative Cases: Does the Witching Hour Exist for the Operating Room?

Stanley Kamande¹ · Kwadwo Sarpong¹ · Jerome Murray¹ · Ayodeji Ajayi¹ · Ehsan Dowlati² · M. Nathan Nair²

Abstract

Background Efficient resource management in the operating room (OR) contributes significantly to healthcare expenditure and revenue generation for health systems. We aim to assess the influence that surgeon, anesthesiology, and nursing team assignments and time of day have on turnover time (TOT) in the OR.

Methods We performed a retrospective review of elective cases at a single academic hospital that were completed between Monday and Friday between the hours of 0700 and 2359 from July 1, 2017, through March 31, 2018. Emergent cases and unplanned, add-on cases were excluded. Data regarding patient characteristics, OR teams, TOT, and procedure start and end times were collected and analyzed.

Results A total of 2174 total cases across 13 different specialties were included in our study. A multivariate regression of relevant variables affecting TOT was performed. Consecutive specialty (p < 0.0001), consecutive surgeon (p < 0.0001), anesthesiologist (p < 0.0001), and prior case ending before 1400 (p < 0.0001) were independent predictors of lower TOT. A receiver operating characteristic analysis demonstrated an area under the curve of 0.848 and a cutoff of 1400 having the highest sensitivity and specificity for TOT difference.

Conclusions TOT can be significantly affected by the time of the day the procedure is performed. Staffing availability during late procedures and the differences in how OR team staff are scheduled may affect OR efficiency. Additional studies may be needed to determine the long-term implications of changes implemented to decrease organizational operational costs related to the OR.

Introduction

As the Centers for Medicare and Medicaid Services has adjusted their reimbursement models to incentivize high-quality, low-cost healthcare [1], there has been an increased focus on efficient resource utilization. It is estimated that 70% of hospital revenue is generated in the operating room (OR) [2]. Thus, the effective and efficient management of OR resources are vital to organizational fiscal stability and quality healthcare.

Factors that influence effective OR management include staff utilization, OR allocation, case scheduling, accuracy of procedural timing, and pre-operative testing protocols [3]. Over time, healthcare systems have found that
Effective and efficient management of OR resources can be reflected by efficient OR start times and turnover time (TOT). The influence of OR staffing on TOT has previously been examined by assessing the impact of efficiency trainings, as well as the benefits of a nursing team during TOT [4]. Recent publications have reported that maintaining the same team for consecutive cases with the same surgeon independently predicted lower TOT [5–7].

Many studies have explored different tools and incentive programs to improve efficiencies in the OR [8]. Dexter et al. reported an incremental increase in TOT after the 8-h shift period with peak hour at 13:00 and progressive increase after each hour [3]. However, studies have been specialty specific or focused on ancillary staff. Additionally, the association between OR staffing changes and timing of day that further exacerbates inefficiencies in the OR has not been studied. This is particularly important today as the world continues to deal with the Coronavirus Disease 2019 (COVID-19) pandemic as it has negatively affected the utilization of OR resources, efficiency and presented a huge economic burden in many healthcare systems [9].

In this study, we assess elective OR procedures by different subspecialties and explore how staffing and specifically time of day potentially influence TOT in the OR. In addition, this report analyzes the TOT data to identify the etiology of staffing induced delays and introduce potential methods to optimize OR staffing to meet patient needs while ensuring optimal OR resource utilization. We hypothesize that there is a time of day at which point, OR TOT increases and this may correspond with staff shift hours.

Results

A total of 2174 cases from 13 different subspecialties were included in the analysis. Cases were analyzed by time of prior procedure end time over the course of the day and demonstrated that there was a significant difference in median TOT depending on time of day (Table 1, Fig. 1). Cases were then compared against each other by time of day using procedure end time of the prior case, with prior procedure end time before 14:00 (Tables 2, 3).

Upon completing a multivariate regression of relevant variables affecting TOT, consecutive specialty (Odds Ratio [OdR] 0.61; \( p < 0.0001 \)), consecutive surgeon (OdR 0.10; \( p < 0.0001 \)), consecutive anesthesiologist (OdR 0.28; \( p < 0.0001 \)), and prior procedure end time before 14:00 (OdR 0.59; \( p < 0.0001 \)) were independent predictors of lower TOT (Table 4). An ROC analysis was conducted to review the performance of our multivariate regression...
model against prior procedure end time (before vs. after 14:00), which demonstrated an area under the curve of 0.848 (Fig. 2). Calculated performance for this model yielded a specificity of 78.7% and sensitivity of 79.6% when using 14:00 as the threshold for increased OR TOT.

### Discussion

There are several staff team members who are involved in the OR case and OR turnover process: nurses, surgical technologists, anesthesia teams, and environmental services. The OR turnover process requires the efficient and timely coordination between multiple staff members throughout the day. Our study demonstrates there was a significant difference in TOT when comparing procedures that followed procedures that ended before 14:00 and after 14:00 (mean 78 vs. 96 min, \( p < 0.0001 \); Table 3) with relatively high sensitivity and specificity (79.6 and 78.7%; Fig. 2). 14:00 was specifically chosen for cutoff of the case prior end time since this correlated with the 15:00 h when the 8-h shift ends for many of the OR staff including surgical technologists, nurses, nurse anesthetists, and anesthesiologists. During this time, support staff end their shift and transfer their responsibilities to either a replacement or stay on for overtime in the event of staff shortage. Given this context, it is not surprising that our study found an increase in TOT for procedures that follow a procedure that ends after 14:00.

Our results also demonstrate that consecutive specialty, surgeon, and anesthesiologist have significant influence on TOT. Specifically, our results showed that TOT between cases with the same surgeon were shorter than that of cases with different surgeons (66 vs. 110 min, \( p < 0.0001 \)). These variables were included in our multivariate regression analysis to demonstrate that time of day is a significant contributor of TOT, when accounting for other variables. These factors go along with the idea that there is no interruption in staffing within the OR and there is continuity of the care team during and between cases. These variables have been previously discussed and analyzed [5]. Patient ASA status also included. Although not a marker of case difficulty, it may be used as a gross marker of patients’ medical complexity. It was not a significant factor related to TOT in our multivariate regression; however, in Sarpong et al., it was a significant variable when comparing ASA level 2, 3, and 4 patients [5]. This is likely related to difficult or longer intubation and/or extubation times. Since the collection of the data for the present study, our ORs have implemented staggered shifts for staff as to provide overlap between incoming and outgoing staff members and assigned dedicated subspecialty ORs since consecutive specialty cases have lower TOT.

The significance of such findings requires further investigation. Findings can be associated with inadequate staffing during the shift-change or due of the differences in incentivization structures between shift-based staff versus case-based employees. This is particularly important especially during the nationwide shortage of nurses and support staff—a growing shortage that has also been exacerbated by the ongoing COVID-19 pandemic due to the high demand and low supply [12, 13]. Perhaps, this is also deeply rooted in the fact that after a long day of work in the OR, staff members tend to be “physically” or “mentally” fatigued as their end of shift gets closer—a complex phenomenon that has been described in the literature as “Shift Work Disorder” [14, 15].

To understand if the increase in TOT at or after 14:00, one must delineate the differences in incentivization structure. Both nursing and anesthesia typically operate on a shift-based schedule that can range from 8- to 12-h shifts, while surgical teams are often operating on a case-based schedule. Studies have shown inefficiencies in OR scheduling stem from insufficient allotment of OR time beginning with the first case of the day [16]. For example, it would be inefficient to send 8-h shift staff to ORs where cases are run on a continuum and consistently run for more than 12 h due to the length of cases or case load. The differing scheduling structures create diverging incentives for each group. Case-based scheduling incentivizes surgeons to reduce delays in TOT and complete their assigned cases as efficiently as possible. Dexter et al. estimated that reductions in average TOT of 3–9 min would lead to a 0.8–1.8% reduction in costs, while reductions in

### Table 1: Median turnover time (TOT) based on time of day

| Case prior end time (hr) | \( N \) | TOT (min ± SD) | \( p \)-value |
|-------------------------|-------|---------------|-------------|
| 0800                    | 80    | 69.5 ± 60     | \(< 0.0001\) |
| 0900                    | 341   | 64 ± 51       |             |
| 1000                    | 482   | 70 ± 45       |             |
| 1100                    | 450   | 81.5 ± 54     |             |
| 1200                    | 430   | 84 ± 55       |             |
| 1300                    | 332   | 78 ± 54       |             |
| 1400                    | 274   | 89.5 ± 59     |             |
| 1500                    | 188   | 86.5 ± 81     |             |
| 1600                    | 77    | 95 ± 65       |             |
| 1700                    | 37    | 129 ± 76      |             |
| 1800                    | 9     | 218 ± 67      |             |
| 1900                    | 10    | 152.5 ± 20    |             |
| 2000                    | 2     | 122 ± 27      |             |
| 2100                    | 2     | 39 ± 37       |             |
10–19 min would result in 2.5–4.0% reductions in costs [17].

In identifying time of day and staff scheduling as factors that influence OR TOT, organizations must be creative in finding ways to streamline processes. A trend within healthcare has been the adoption of Lean Management (LM) principles. LM is anchored in the belief that positive improvement is created through eliminating waste and streamlining processes. One of the LM methods, value-stream mapping, applies the principles of LM and allows organizations to create a visual guide of all the components required to deliver an end-product. A study by Cerfolio et al. applied value-stream mapping to review the steps that go into OR turnover—finding that by eliminating non-valued processes and performing processes simultaneously rather than sequentially, improved median TOT from 37 to 14 min [18]. One study applied LM-5S methodologies to a neurosurgery OR at a large urban, academic, tertiary acute care hospital over an 8-week period, and found that there was a 68% reduction in costs associated with inventory and the ability to increase OR space capacity [19]. Additionally, by creating efficient checklists and structured communication, there is the potential for decreased work-related stress and greater workplace satisfaction.

Another factor often less emphasized the effects of scheduled breaks, and its impact of staff shift changes and TOT time. Scheduled break time is an important component impacting patient safety, staff satisfaction and TOT. Studies have shown that scheduled short breaks improve productivity in the workplace and reduces fatigue [20, 21]. Norman and Bidanda demonstrated that teamwork and staffing inefficiencies may contribute to the TOT because team members with fewer tasks simply took unscheduled breaks when their tasks were completed instead of assisting the rest of the team [22]. This is an area where cross-training staff and redefining roles can boost teamwork efforts and reduce TOT. Taking scheduled breaks requires planning and anticipation on the part of staff. For example,
an environmental service staff on break at the time of turnover will significantly delay TOT thereby affecting OR utilization [23].

Strengths and limitations

The strength of this study is that it presents the largest single-institution study evaluating OR TOT in an academic setting. It provides specific perspective on time of day in a situation where parties involved are designated shift time. Thus, we are able to answer the question of whether time of day does play a role in TOT efficiency in the OR.

The retrospective design and inclusion of a single institution in our study are a limitation. The data used were based on documentation available from operative and anesthesia records. The data are from pre-COVID-19 era which may not be directly applicable today. Other institutions may not have shift scheduling for OR staff limiting the generalizability of our findings. Our definition of TOT incorporates the time period between procedure end and when patient is wheeled out of the OR which may be variable due to prolonged extubation time, or post-anesthesia care hold times. The representation of different subspecialties within the study is also a limitation given that specialties may not have been represented equally. Only elective cases were included. Urgent or emergent cases may delay elective cases if there is not another available OR to accommodate these cases. Case difficulty is a variable not captured in our data collection that may influence TOT. However, subspeciality-specific data have been analyzed in a previous study and demonstrate that specialties such as transplant and urology have significantly higher TOTs compared specialties such as orthopedics and otolaryngology that have lower TOT [5]. Finally, TOT is influenced by multiple factors and there are other factors that may be at play which are not as easily captured in a retrospective study, including delays related to medical clearance, patient transport, and technical or equipment issues that may be encountered within or in between OR cases.

Conclusion

Our study shows that OR TOT can be significantly affected by the time of the day the procedure is performed. Moreover, it can be influenced by the OR team including the surgeon and anesthesia team. Staffing availability during

| Case Prior End Time | 800 | 900 | 1000 | 1100 | 1200 | 1300 | 1400 | 1500 | 1600 | 1700 | 1800 | 1900 | 2000 |
|---------------------|-----|-----|------|------|------|------|------|------|------|------|------|------|------|
| 800                 |     |     |      |      |      |      |      |      |      |      |      |      |      |
| 900                 | 0.25|     |      |      |      |      |      |      |      |      |      |      |      |
| 1000                | 0.68| 0.00|      |      |      |      |      |      |      |      |      |      |      |
| 1100                | 0.01| 0.00| 0.00 |      |      |      |      |      |      |      |      |      |      |
| 1200                | 0.00| 0.00| 0.00 | 0.00 |      |      |      |      |      |      |      |      |      |
| 1300                | 0.05| 0.00| 0.00 | 0.00 | 0.28 |      |      |      |      |      |      |      |      |
| 1400                | 0.00| 0.00| 0.00 | 0.00 | 0.04 | 0.00 |      |      |      |      |      |      |      |
| 1500                | 0.00| 0.00| 0.00 | 0.00 | 0.07 | 0.26 | 0.03 | 0.68 |      |      |      |      |      |
| 1600                | 0.00| 0.00| 0.00 | 0.00 | 0.05 | 0.15 | 0.03 | 0.66 | 0.58 |      |      |      |      |
| 1700                | 0.01| 0.00| 0.00 | 0.00 | 0.05 | 0.12 | 0.06 | 0.28 | 0.28 | 0.56 |      |      |      |
| 1800                | 0.00| 0.00| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.12 |      |      |
| 1900                | 0.00| 0.00| 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.03 | 0.02 | 0.12 | 0.60 | 0.12 |      |
| 2000                | 0.26| 0.17| 0.22 | 0.28 | 0.30 | 0.36 | 0.60 | 0.53 | 0.68 | 0.93 | 0.28 | 0.65 |      |
| 2100                | 0.26| 0.21| 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.17 | 0.20 | 0.27 | 0.23 | 0.69 |

Bold p-values denote statistical significance
late procedures and the differences in how OR staff are incentivized need to be systematically studied to better understand ways to improve how today’s ORs can run effectively and efficiently. Further, prospective, larger studies may be needed to determine the long-term implications of changes implemented to decrease organizational operational costs related to the OR.

Authors contribution SK and KS contributed to data analysis and writing and editing of the first draft of the manuscript in methods and results. JM and AA contributed to writing and editing of the first draft of the manuscript in results. ED and MNN contributed to critically revising the manuscript and study supervision. MNN contributed to conception and design. All authors read and approved the final manuscript.

Data availability statement All relevant data are published in the study. Further data used in this study are available upon reasonable request from the corresponding author.

Declarations
Conflict of interest The authors have no conflicts of interest to disclose in relation to this article.

Ethics and other permissions This study uses data from electronic medical records with Institutional Research Board approval from the corresponding institution.

References
1. Bowling B, Newman D, White C et al (2018) Provider reimbursement following the Affordable Care Act. Health Care Manag (Frederick) 37:129–135. https://doi.org/10.1097/HCM.0000000000000205
2. Li F, Gupta D, Potthoff S (2016) Improving operating room schedules. Health Care Manag Sci 19:261–278. https://doi.org/10.1007/s10729-015-9318-2
3. Dexter F, Epstein RH, Marcon E, Ledolter J (2005) Estimating the incidence of prolonged turnover times and delays by time of day. Anesthesiology 102:1242–1248; discussion 6A. https://doi.org/10.1097/00000542-200506000-00026
4. Overdyk FJ, Harvey SC, Fishman RL, Shippey F (1998) Successful strategies for improving operating room efficiency at academic institutions. Anesth Analg 86:896–906. https://doi.org/10.1097/00000539-199804000-00039
5. Sarpong K, Kamande S, Murray J et al (2022) Consecutive surgeon and anesthesia team improve turnover time in the operating room. J Med Syst 46:16. https://doi.org/10.1007/s10916-022-01802-6
6. Dexter F, Epstein RH, Schwenk ES (2019) Tardiness of starts of surgical cases is not substantively greater when the preceding surgeon in an operating room is of a different versus the same specialty. J Clin Anesth 53:20–26. https://doi.org/10.1016/j.jclinane.2018.09.027
7. Austin TM, Lam HV, Shin NS et al (2014) Elective change of surgeon during the OR day has an operationally negligible impact on turnover time. J Clin Anesth 26:343–349. https://doi.org/10.1016/j.jclinane.2014.02.008
8. Masursky D, Dexter F, Garver MP, Nussmeier NA (2009) Incentive payments to academic anesthesiologists for late afternoon work did not influence turnover times. Anesth Analg 108:1622–1626. https://doi.org/10.1213/ane.0b013e31819e7504
9. Andreata M, Faraldi M, Bucci E et al (2020) Operating room efficiency and timing during coronavirus disease 2019 outbreak in a referral orthopaedic hospital in Northern Italy. Int Orthop 44:2499–2504. https://doi.org/10.1007/s00264-020-04772-x
10. R Core Team (2020) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria
11. Jay, Matthew (2019) generalhoslem: goodness of fit tests for logistic regression models. R Package version 134
12. Rubin R (2015) Bill takes aim at nationwide shortage of nurses. JAMA 313:1787. https://doi.org/10.1001/jama.2015.3747
13. McGarry BE, Grabowski DC, Barnett ML (2020) Severe staffing and personal protective equipment shortages faced by nursing homes during the COVID-19 pandemic. Health Aff (Millwood) 39:1812–1821. https://doi.org/10.1377/hlthaff.2020.01269
14. Gupta A, Roth T, Roehrs T, Drake CL (2019) Shift work: a perspective on shift work disorder—is prevention the answer? J Clin Sleep Med 15:1863–1865. https://doi.org/10.5664/jcsm.8104
15. Cheng P, Drake C (2019) Shift work disorder. Neurol Clin 37:563–577. https://doi.org/10.1016/j.ncl.2019.03.003
16. Macario A (2014) Implementing operating room management science: from the bench to the scheduling office. Eur J Anaesthesiol 31:355–360. https://doi.org/10.1097/EJA.000000000000026
17. Dexter F, Abouleish AE, Epstein RH et al (2003) Use of operating room information system data to predict the impact of reducing turnover times on staffing costs. Anesth Analg 97:1119–1126. https://doi.org/10.1213/01.ANE.0000082520.68800.79
18. Cerfolio RJ, Ferrari-Light D, Ren-Fielding C et al (2019) Improving operating room turnover time in a New York City Academic Hospital via Lean. Ann Thorac Surg 107:1011–1016. https://doi.org/10.1016/j.athoracsur.2018.11.071
19. Leming-Lee T, “Susie”, Polancich S, Plon B (2019) The application of the Toyota production system LEAN 5S methodology in the operating room setting. Nurs Clin North Am 54:53–79. https://doi.org/10.1016/j.cnur.2018.10.008
20. Bouscsein W, Thum M (1997) Design of work/rest schedules for computer work based on psychophysiological recovery measures. Int J Ind Ergon 20:51–57. https://doi.org/10.1016/S0169-8141(96)00031-5
21. Kopardekar P, Mital A (1994) The effect of different work-rest schedules on fatigue and performance of a simulated directory assistance operator’s task. Ergonomics 37:1697–1707. https://doi.org/10.1080/00140139408964946
22. Norman BA, Bidanda B (2014) Operating room turnaround time analysis: a case study. Int J Collaborative Enterprise 4:101–114. https://doi.org/10.1504/IJCENT.2014.065056
23. Vassell P (2016) Improving OR efficiency. AORN J 104:121–132. https://doi.org/10.1016/j.aorn.2016.06.006

Publisher’s Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Springer Nature or its licensor holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.