Improved Operating Room Efficiency via Constraint Management: Experience of a Tertiary-Care Academic Medical Center

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BACKGROUND: Suboptimal operating room (OR) efficiency is a universal complaint among surgeons. Nonetheless, maximizing efficiency is critical to institutional success. Here, we report improvement achieved from low-cost, low-technology measures instituted within a tertiary-care academic medical center/Level I trauma center.

STUDY DESIGN: Improvements in preadmission testing and OR scheduling, including appointing a senior nurse anesthetist to help direct OR use, were instituted in March 2012. A retrospective review of prospectively maintained OR case data was performed to evaluate time periods before and after program implementation, as well as to assess trends over time. Operating room performance metrics were compared using Mann-Whitney and chi-squared tests. Changes over time were analyzed using linear regression.

RESULTS: Data including all surgical cases were available for a 36-month period; 10 months (6,581 cases) before program implementation and 26 months afterward (17,574 cases). Dramatic improvement was seen in first-case on-time starts, which increased from 39.3% to 83.8% ($p < 0.0001$). Additionally, the percent utilization of available OR time demonstrated a steady increase ($p < 0.001$). After an initial lag, case volume also improved, evident by an increase observed in the 12-month rolling average of cases per month ($p < 0.001$). The increase in case volume occurred during peak OR time (7 AM to 5 PM), and did not result from adding cases after hours (5 PM to 11 PM).

CONCLUSIONS: After many years of what seemed an insoluble problem, simple changes fostering collaboration among services, including active management of the OR schedule and transparent data, have resulted in substantial improvement in OR efficiency and case volume. (J Am Coll Surg 2015;221:154−162. © 2015 by the American College of Surgeons)

Decreasing reimbursements and an increasing have forced health care organizations to become more efficient providers of care. Operating room (OR) performance has come under particular scrutiny. As one of the largest contributors to a hospital's financial success, a productive OR is critical to institutional viability. Beyond financial considerations, suboptimal OR efficiency also decreases physician satisfaction and can result in low workforce morale.

Improving OR efficiency can be a challenging task. The OR is a very complex environment, and multiple factors have been identified that contribute to inefficient care delivery. These factors encompass a broad spectrum, including patient scheduling, preoperative care pathways, OR management, and postoperative recovery.[1,2] Additionally, the human element comes into play, with physician availability, nurse staffing, and other ancillary personnel contributing to the complexity of the OR environment. To improve efficiency, multiple strategies have been described in the literature.[3-7] Many authors have evaluated interventions

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Abbreviations and Acronyms

CRNA = Certified Registered Nurse Anesthetist
FCOT = first-case on-time
OR = operating room
QI = quality improvement
TOC = Theory of Constraints

aimed at isolated problems: turnover time, percent on-time starts, case volume, and OR utilization have all been popular metrics for study.[4,8-10] Although many of these studies show positive results, there has been no consensus as to the best strategy to improve efficiency. In addition, several require investment in expensive new technologies, with the assumption that any cost incurred will be balanced by gains in productivity.[11,12]

In recent years, there has been a rising emphasis on management strategies that target inefficiencies by focusing on the overall process of care delivery.[13] Many of these quality improvement (QI) strategies are adapted from the business and manufacturing sectors. For example, Lean and Six Sigma methodologies frequently are applied to health care and surgery.[14] In general, these strategies aim to standardize care in an effort to eliminate any wasteful steps that decrease overall quality and efficiency. These complex methods generally require investment in staff training or data collection, and can involve hiring additional project managers or consultants.[15] Although many studies have reported success across a variety of metrics with these strategies, they can be difficult to implement and detailed cost-effectiveness data are lacking.[16] The cost and complexity intrinsic to implementing these advanced QI measures can be unrealistic for some institutions.

Given the heterogeneity of the literature, no predominant QI strategy has emerged and clear recommendations have yet to be defined.[17] This has led some authors to apply the Theory of Constraints (TOC) to health care. According to this philosophy, systems can be held up at bottlenecks (ie, constraints) and process improvements occur by concentrating efforts on these areas.[18] The theory outlines a simple, logical approach to these problems. After identifying the constraint, there is a stepwise progression from improvements through the use of existing resources, to realigning the overall system to alleviate the constraint, to considering entirely new actions that might be necessary to address the constraint. Importantly, the process should be repeatable to avoid inertia, and inherent to TOC methodology is the ability to address constraints as they arise.[19] This aspect is particularly appealing, given the complexity of the OR system.

In this study, we hypothesized that application of TOC techniques could result in improved performance in our OR. Here we report the results of straightforward initiatives undertaken by an academic medical center aimed at improving OR performance and efficiency. These measures were driven by low-cost, low-technology solutions, and were derived from simple, common-sense approaches that addressed system constraints in real time.

METHODS

Setting

The University of Louisville Hospital is a tertiary-care academic medical center located in Louisville, KY. The hospital includes close to 400 beds and a Level I trauma center. As the principal provider of indigent care in the region, the hospital serves a relatively large uninsured population in addition to insured patients. There are 14 main ORs, with an annual volume of approximately 8,000 cases. One OR is reserved principally for acute trauma, and the remaining 13 are mixed use and accommodate elective, urgent, and emergency cases. Rooms are not strictly service based, although block time is proportioned by service and use is regularly reviewed. No major changes in block time allocation occurred during the study period. Typically, one room is reserved to accommodate overflow and add-on cases. The end result is that most rooms are available for use by all services, allowing a degree of flexibility in scheduling cases.

Quality improvement initiatives

The principal campaign to improve OR efficiency was launched in March 2012. Initially, the primary focus of the campaign was to improve first-case on-time (FCOT) starts and OR throughput. However, preliminary groundwork with additional improvements was performed before March 2012.[20] These initiatives included improved data collection and dissemination, changes in OR governance, and new procedures in preoperative scheduling and testing.

Operating room governance

Initially, the OR manager began working with leaders from different sections of the OR and perioperative care units to identify areas where change was necessary. Several areas were subsequently addressed to help improve workflows (see Perioperative initiatives section, below). In addition, a new perioperative management team consisting of multiple stakeholders from different parts of the hospital was created. The team consisted of department chairs from anesthesia and the surgical services; administrators, including OR managers and perioperative nursing managers; a representative from quality and patient safety; and a few interested senior-level surgeons and anesthesiologists.

To help identify areas for improvement, data information systems, including collection of performance metrics, were upgraded. Metrics including total cases, FCOT starts, OR utilization, and turnover times were routinely shared among the management team and filtered down through the associated departments. This allowed ongoing evaluation of progress and helped initiate a data-driven culture of efficiency.

Perioperative initiatives

After review of the performance metrics, the initial QI focus became FCOT starts and OR utilization. As a starting point for these QI projects, changes were made in several perioperative care pathways. At first, members of the OR improvement team monitored the preoperative unit and determined reasons that cases were not starting on time. Common reasons included missing documentation, incomplete testing, or absent surgeons and residents. Consistent with TOC methodology, resources were first reallocated to address these constraints. For instance, several nurses were shifted to admissions and preoperative testing to help improve bottlenecks in these areas. Additionally, emphasis was placed on improving patient compliance with preadmission testing before the OR date, with informed consents as well as history and physicals obtained before the day of surgery when possible. Parallel processing pathways were introduced whereby select patients began to receive anesthesia procedures, such as epidural or regional blocks, before entering the operating room.[5] These procedures were performed by Anesthesia soon after all consents were obtained to avoid any delay in case starts. Outside of the preoperative area, preference cards and case carts were updated for surgeons to ensure that ORs were prepared with the appropriate equipment. Overall, a common theme shared by these various initiatives was that they primarily involved reallocation or restructuring of our existing resources, and did not require the hiring of additional personnel or investment in new infrastructure.

Certified Registered Nurse Anesthetist operating room charge nurse

Once the groundwork was in place, a major push for improved efficiency was begun in March 2012. Central to this effort was empowering a dedicated Certified Registered Nurse Anesthetist (CRNA) to coordinate the daily schedule and serve as an intermediary between the OR staff, anesthesiology, surgeons, and the perioperative care units. Overall, the CRNA served as a nodal point between the multiple different services involved in moving patients through the operating room, and from this position he could address any new constraints or bottlenecks as they arose in real-time. Due to this wide range of responsibilities, we selected a seasoned CRNA with extensive experience in our ORs and perioperative care areas. He was well respected by both physicians and the nursing staff, had good working knowledge of the different components of the OR team, and was a hard worker who led by example.

A key component of the CRNA's role is facilitating communication. Using a cell phone with the number of nearly every surgeon, anesthesiologist, and resident, the CRNA is in constant communication with these services (often by text messaging) to help prevent delays and negotiate obstacles in real time. As an example, residents are notified (multiple times if necessary) well before a case's planned start time if any of the preoperative documentation needs completion. In addition, the CRNA plays a key role in coordinating the daily schedule. When procedures run long or time gaps appear in the schedule, cases are often moved to other rooms or into earlier time slots. Overall, this serves to prevent bottlenecks and improve patient flow. As the person in contact with all of the various components of the OR team, the CRNA is in a key position to initiate and facilitate these day of surgery changes to the OR schedule. The OR schedule was maintained in a highly visible area outside of the entry to the ORs, and consisted of movable magnetic strips on a large white board. Rather than consider the daily schedule in each room as inviolable, or that one OR belongs to a single surgeon for the day, the CRNA plays a strategic chess game with the magnetic strip board, moving cases from room to room, time slot to time slot, depending on availability of surgeons, patients, and other factors.

Data and statistics

Data including key time points was electronically documented at the time of surgery for each case. Subsequently, case data was uploaded to the OR Benchmarks Collaborative server (McKesson). This third-party collaborative performs standardized calculations and provides monthly summary data including case numbers, total OR minutes used, total available OR minutes, percentage of FCOT starts, and multiple different case duration measurements (turnover time, total room time, total operative time). Data were available for a 36-month period, from May 2011 to April 2014. This covered a time period from 10 months before our QI rollout, and up to 26 months afterward. Cases included surgical operations from multiple services: General Surgery and subspecialties (Surgical Oncology, Vascular, Cardiothoracic, Plastics, and Colorectal), Otolaryngology, Orthopedics, Neurosurgery, and Obstetrics/Gynecology.

Table 1. Operating Room Metrics: Case Totals, On-Time Starts, and OR Utilization

OR metric	Pre-QI changes (10 months)	Post-QI changes (26 months)	p Value
Overall OR use			
Total cases, median (IQR)	650.5 (626.5–683.75)	671.0 (640.75–715.25)	0.433*
Total used OR hours, median (IQR)	2,093.6 (2,030.8–2,178.6)	2,148.0 (2,070.1–2,305.5)	0.286*
Total available OR hours, median (IQR)	2,911.5 (2,867.6–3,012.3)	2,943.0 (2,791.3–3,118.0)	1.000*
OR utilization, %†	71.7	72.2	0.142‡
First case on-time starts			
Total first start cases, median (IQR)	217 (209.25–227.75)	224 (218.75–233.5)	0.126*
Cases early or on-time, median (IQR)	88.5 (79–94)	186 (175.7–193)	<0.001*,§
Early or on time, %	39.3	83.8	<0.001*,§
Peak hours, 7 AM to 5 PM			
Total cases, median (IQR)	590.5 (574.5–617.5)	619.5 (589.0–653.5)	0.177*
Used OR hours, median (IQR)	1,799.0 (1,780.0–1,873.5)	1,911.5 (1,812.9–2,017.1)	0.049*,§
Available OR hours, median (IQR)	2,476.8 (2,413.8–2,578.8)	2,516.5 (2,403.3–2,669.0)	0.849*
OR utilization, %†	73.2	76.7	<0.001‡,§
After hours, 5 PM to 11 PM			
Total cases, median (IQR)	38.0 (32.0–43.0)	35.0 (31.3–37.5)	0.201*
Used OR hours, median (IQR)	277.2 (246.0–308.7)	255.6 (231.9–291.8)	0.155*
Available OR hours, median (IQR)	440.0 (428.5–459.5)	429.0 (400.0–458.0)	0.227*
OR utilization, %†	63.4	62.5	0.289‡

*p Value calculated with Mann-Whitney test.
†Percent of summed used OR time divided by the total OR time during each period.
‡p Value calculated using chi-square test.
§Statistically significant.
IQR, interquartile range; QI, quality-improvement initiative; OR, operating room.

The initial QI efforts were focused on peak OR use, so analysis was limited to weekdays when the schedule was actively managed by a CRNA. Operating room time periods were split between peak hours (7 AM to 5 PM) and after hours (5 PM to 11 PM). Percent OR utilization was defined as total used OR time divided by total available OR time. Used OR time represented the total sum of individual case times, where case time was defined as the time from when the patient entered the room to when they left the room. Operative time was from initial incision to closure. Turnover time was calculated between successive elective cases where there was not more than a 1-hour scheduled delay, and was counted from when the first patient left the OR to the when the next patient entered.

Statistical analysis was performed using SPSS software, version 21 (IBM SPSS). Descriptive statistics for the different time periods are reported as the median with interquartile range, and were compared using the Mann-Whitney test. Comparison of frequencies between categorical variables was performed using the Pearson chi-squared test. To characterize trends over time, analysis of scatter plots was performed with linear regression to determine best-fit lines. To control for seasonal variation, a 12-month prior moving average was applied to smooth data points. When a rolling average was not used, or if data did not fit a linear regression model, the locally weighted scatterplot smoothing method (LOESS) was applied to graphically display trends over time within a 95% CI. Graphs were generated using SAS software, version 9.4 (SAS Institute).

RESULTS

Overall totals

A total of 24,155 cases were included during the 36-month study period. The mean number of cases per month was 671 (median of 658), and ranged from 568 to 783 cases per month. Early or on-time starts (within 5 minutes of the scheduled OR time) occurred in 70.9% of the 8,079 cases that were classified as a first case. Overall OR utilization was 73.9%, but was higher during peak hours (7 AM to 5 PM) at 75.7% compared with 62.8% after hours (5 PM to 11 PM).

Impact of quality-improvement measures

Several QI initiatives were introduced over time, culminating in the appointment of a CRNA to enforce and actively manage the schedule in March 2012. Comparing the time periods before and after the QI rollout demonstrates several significant differences (Table 1). The largest improvement was in the percentage of FCOT starts, which increased from 39.3% to 82.7% per month ($p < 0.001$). The increase in FCOT starts occurred almost immediately on implementation of the QI measures (Fig. 1).

Although there was an increase in the total number of cases, this was not significant as a direct comparison between the 2 time periods overall (Table 1; 650.5 vs 671.0; $p = 0.433$). To better characterize changing trends over time, comparison of 12-month rolling averages for monthly case volume was performed (Fig. 2). Overall, the total number of cases demonstrated a significant increase. The 12-month rolling average of cases per month increased to 701 in April 2014 from a nadir of 647 in January 2013. In terms of individual months, case totals ranged from 568 to 783. Broken down into time periods, the number of cases performed during peak hours increased and after hours cases demonstrated a slight decrease (Fig. 3).

Increases in OR utilization correlated with the increase in total case volume. These improvements in OR utilization were largely driven by an increase in utilization during peak hours. As a direct comparison between time periods, there was a small, but significant increase in OR utilization (72.6% vs 75.9%; $p = 0.007$). However, once viewed over time, utilization during peak hours demonstrated a steadily increasing trend and was >80% for the last 5 months of the study period (Fig. 4). The increase in OR utilization coincided with an increase in the amount of OR time with a patient in the room (1,799.0 vs 1,911.5 hours/month; $p = 0.049$). There was no change in the total amount of OR time available (2,476.8 vs 2,516.5 hours/month; $p = 0.849$), suggesting that the increase seen in percent utilization was a result of an increase in the numerator (used OR time), and did not result from a decrease in the denominator (available OR time).

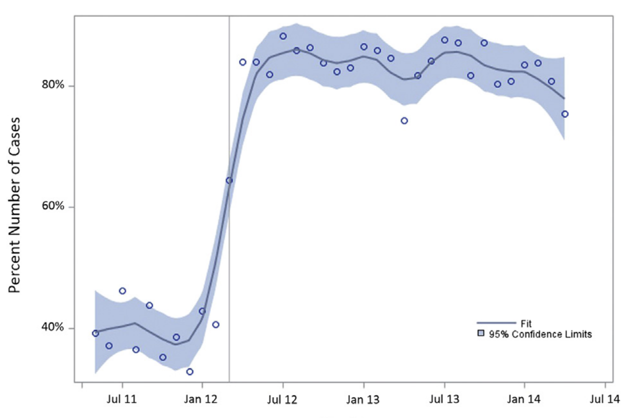

Figure 1. Percent of first-start cases that were either early or on time (within 5 minutes of the scheduled start) for each month during the 36-month study period. A LOESS fit line demonstrates the general trend for first-case on-time starts; the shaded area represents a 95% CI for the line estimate. March 2012 is indicated by the solid vertical line.

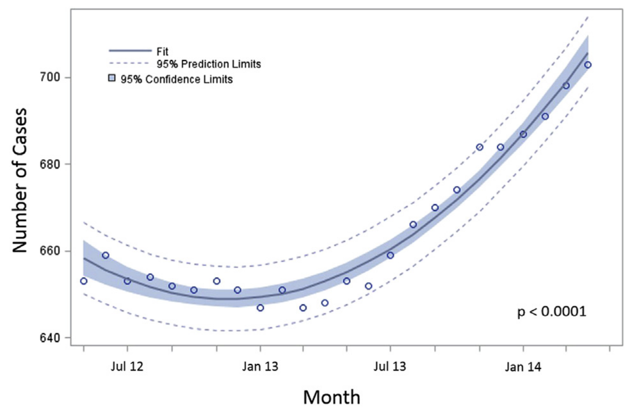

Figure 2. Overall increase in the total number of cases performed each month. Each data point represents the mean number of cases per month for the previous 12 months. Regression yields a best-fit line that closely approximates the data points ($p < 0.0001$), with the shaded area representing the 95% CI. Given that 12 months of data is needed each point, analysis is limited to the final 24 months of the study period (May 2012 to April 2014).

No major differences were observed among multiple room-time measures, including turnover time, total room time, operative time, or time related to anesthesia (Table 2). In addition, these times demonstrated little month-to-month variation during the study time period. Importantly, total case time was no different between the 2 time periods, indicating that the increase in the number of cases seen during the later study months likely did not result from a collection of shorter cases.

DISCUSSION

In this study, we describe our results using a combination of measures to improve operating room efficiency in a tertiary-care academic medical center. Interventions centered on identifying system constraints and then devising low-technology, practical solutions to address these problems. These included assigning a CRNA to actively manage the OR schedule and help enforce our quality initiatives. In addition, performance metrics were transparently distributed among stakeholders to foster a culture of efficiency and accountability. Our principal findings included a dramatic increase in FCOT starts, as well as a more gradual increase in OR utilization and total case volume.

No clear recommendations exist to guide the use of QI methods to improve the efficiency of health care processes. Multiple different strategies have been described.

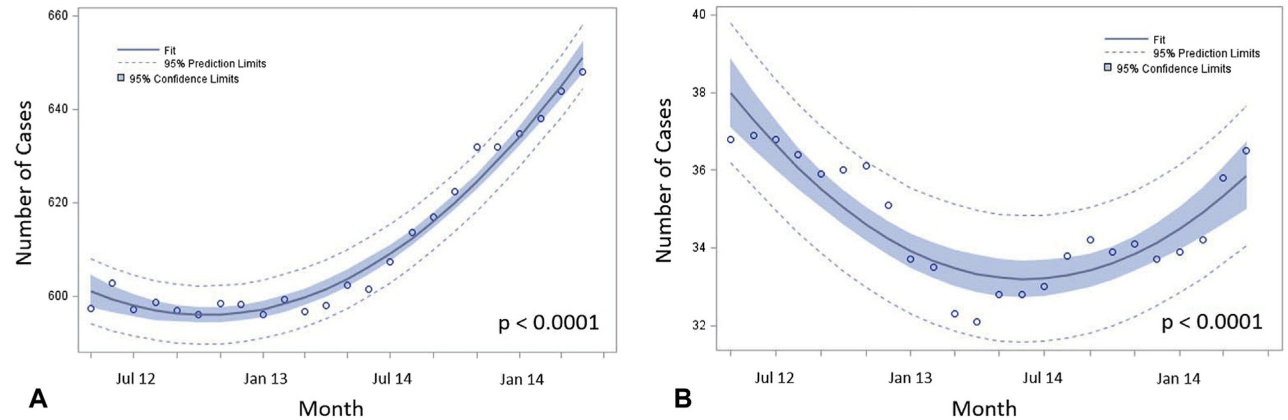

Figure 3. Number of cases per use period. The 12-month prior moving average of the total number of cases between (A) peak hours (7 AM to 5 PM) and (B) after hours (5 PM to 11 PM) time periods. Although the number of cases per month increased during peak hours ($p < 0.0001$), case volume did not increase after hours, and might have shown a slightly decreasing trend ($p < 0.0001$).

In addition, successful initiatives using "bottom-up" approaches, whereby stakeholders including surgeons, anesthesiologists, and hospital administrators actively institute and manage the reform process, have been reported previously.[21,22] Such solutions require ground-level participation of local health care providers and administrators, not just external consultants or the application of standardized QI models.[23] The simple reality is that situations can differ greatly between hospitals, and solutions require adaptation to local environments and institutional cultures.

Along these lines, to facilitate new efficiency initiatives, we developed an OR governance team composed of multiple stakeholders, including surgeons, anesthesia, nursing, OR managers, and other administrators. Analysis of different OR and perioperative processes identified performance-limiting steps. Specifically, FCOT starts were identified as an area needing improvement. Once initiatives were underway, performance metrics were shared weekly among stakeholders to track our results. Although these data served to emphasize any efficiency gains or areas in need of additional improvement, tracking individuals to recognize the best early starters or to punish poor performers was not performed.

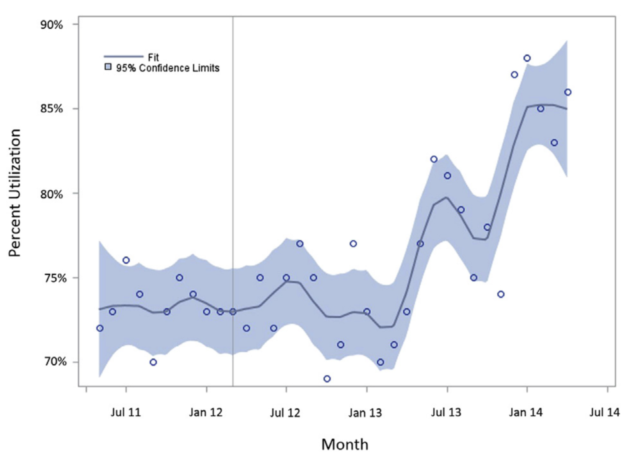

Figure 4. During the second half of the study period, operating room utilization during peak hours demonstrated a steady increase. During the final 5 months, percent use ranged from 81% to 87%. A LOESS fit line estimates the general trend, with the shaded area representing a 95% CI. March 2012 is indicated by the solid vertical line.

As a framework for guiding QI initiatives, the TOC has been described as a simple, logical approach to improving performance.[18,24] The underlying philosophy rests on a continual process of identifying core bottlenecks or constraints, and improvements in overall system performance occur once these constraints are addressed.[19] A strength of this method is that it is easy to use, widely applicable, and much of it is simply "common sense."[18] Broadly speaking, the thinking process behind TOC simply asks that one decide what needs change, decide what to change to, and decide how to cause the change.[19] A stepwise approach includes reallocating resources or restructuring current systems to alleviate the constraint, and the process must be ongoing to prevent inertia from reducing any productivity gains.

Looking at our results in this context, the initial dramatic improvement in FCOT starts likely reflects that the common constraints leading to delayed case starts (missing documentation, unprepared patients, or absent surgeons/residents) were quickly correctable. Comparable experiences leading to improved first-case starts are reported in the literature.[1,8,9,21,22,25] In one report, use of a dedicated facilitator (similar to the CRNA role in our study) and a checklist to ensure that all necessary preoperative work had been completed resulted in a 50% decrease in late starts.[8] Along the same lines, others have reported that holding surgeons accountable for late arrivals increases FCOT starts.[25] Moving anesthesia procedures out of the OR and into the preoperative area, including tasks like induction or epidural placement, has also been reported to increase efficiency.[5] Although it is difficult to separate the individual contribution of various initiatives, changes involving preoperative scheduling, improved communication, and increased accountability led to an approximately 110% increase in the number of FCOT starts in our study.

Although FCOT starts improved almost immediately, a longer period elapsed until we saw improvements in OR utilization or an increase in total case volume. This might reflect that gains in OR efficiency result from an interplay of short, intermediate, and long-term strategies.[21] Although improved FCOT starts are an important component in improving OR use throughout the day, taking advantage of these gains with additional cases requires a longer-term increase in the number of cases scheduled, as well as other changes involving the optimal use of block time.[2,6] Regardless, over time, we saw a clear increase in the number of cases performed, particularly during peak hours. Although we saw a slight decrease in the number of cases performed after hours, this was a relatively small decrease of only a few cases per month, and likely not clinically relevant. In reality, the number of cases performed after hours remained relatively static. For instance, there was no perceived decrease in the need for after-hours staffing. However, it remains important to point out that the increase in total case volume observed in our study was achieved without a concomitant increase in the number of cases performed after hours. Instead, the percent utilization of peak OR time increased, indicative of improved efficiency.

Although several QI strategies rely on new technology, a key component of our initiatives is that they largely occurred within our existing infrastructure: outside of early improvements to our data collection, no major capital or technology investments were required. Alternatively, others describe efficiency gains with electronic OR boards, automated pager systems, or complex computer models that assist with making scheduling decisions on the day of surgery.[26] A recent article even demonstrated that implementing financial incentives for OR staff improved efficiency.[27] However, improvements from technology might not always translate into efficiency gains. For instance, if increasing OR throughput does not save enough time to schedule an additional case, investing in technologies to do so might not be worthwhile.[28] Depending on the details of a particular OR's needs and case-mix, expensive technologies might have little to no impact.

Table 2. Operating Room Metrics: Breakdown of Case Time

Metrics	Pre-QI changes, min	Post-QI changes, min	Impact, %
Total room time	156.4	158.1	+1.0
Patient in to anesthesia ready	18.7	17.3	−7.4
Patient in to incision	36.6	37.6	+2.7
Incision to close	104.6	104.1	−0.5
Close to patient out	15.5	16.6	+7.0
Turnover time	43.7	41.4	−5.3

QI, quality-improvement initiative.

Our successful experience using a white board with magnetic strips in conjunction with a dedicated manager for the daily schedule underscores this point. A study evaluating the role of coordination systems as they relate to OR schedule management identified 5 key attributes of any new technology system; it must serve as a common referent, provide communal memory, serve as a basis for collaboration, allow for manipulation by multiple groups, and allow flexible reconfiguration. All 5 criteria were easily satisfied by a simple whiteboard.[29] Along the same lines, humans can perform as well or even better than prediction systems in some instances. For example, experienced surgeons outperformed statistical models in predicting elective surgery time in one study.[30] Certainly, there are variables difficult to quantify within a prediction algorithm that a surgeon or other human might be better suited to evaluate. Interestingly, personality might also matter; a study looking at the role of nurse anesthetists as OR coordinators found that there was a significant increase in OR utilization with non—risk-averse (ie, aggressive) CRNAs managing the schedule.[31]

In addition, although multiple different groups and processes contributed to the OR efficiency gains, placing a single individual in charge of administering the OR schedule provided a focal point for effecting change. The job responsibilities included reviewing the daily schedule, moving cases to take advantage of empty space, and communicating directly with anesthesia/surgery to handle any unforeseen schedule changes or other obstacles. In effect, this constant monitoring of OR throughput did not allow inertia to set in, and permitted the CRNA and other OR stakeholders to deal with new bottlenecks or constraints as they emerged in real time. In addition, our CRNA served as a clear contact point for any issues about OR cases, and efficiently communicated with most providers directly via cell phone or text message. There was generally clear communication and collaboration among providers, and, as an indirect result, physician satisfaction improved.[20]

One area in which we did not see substantial improvement was turnover time, which remained just over 40 minutes throughout the study period (Table 2). Reducing turnover time is a substantial challenge, and successful interventions might require a mix of complex interventions aimed at improving workflows and OR organization.[10] We instituted several changes that could impact turnover time, including updating surgeon preference cards and case carts, as well as instituting parallel processing pathways to have patients ready for surgery before going back to the OR. However, reducing turnover time was not a principal goal of our initial efforts and, as we move forward, additional interventions are clearly necessary to see improvement in this area.

This study does contain limitations that are common to the QI literature.[17] Due to the format of the third-party OR Benchmarks software, most data were available only as summary statistics and not as case-by-case observations. As a result, it is difficult to draw any conclusions about case-specific features or certain patient subgroups. For instance, we cannot separate out patients who received epidurals and compare them with patients who did not. Although our results demonstrate improvement across several efficiency metrics, it is not possible to establish a causal relationship between any single intervention and these results. In addition, as a retrospective study, our results could be influenced by confounding variables that are not accounted for within our analysis. During the study period, there was a merger involving our hospital system, associated with staff turnover and reduction in available OR support personnel. For this reason, we did not look at staffing costs or variables, such as personnel overtime.

Finally, these QI methods might not be applicable to all institutions. Our experience is suitable for a 400-bed hospital with 14 ORs; larger institutions might require more advanced systems to deal with their increased complexity. In addition, our success depended heavily on the role played by our CRNA. Although he is an individual well suited to our system, other systems might require equally unique individuals to match their institutional culture and working environment. Additionally, the position requires certain intangibles, including toughness; a strong work ethic; aggressiveness in managing the OR schedule; and a knack for frank, effective communication. Maintaining continuity over time might become an issue moving forward; although we do have other personnel that occasionally fill this role, there is no "succession plan" for our current CRNA OR manager.

CONCLUSIONS

In this study, simple changes fostering collaboration among services, including active management of the OR schedule and transparent data, were associated with substantial improvement in FCOT starts, OR efficiency, and case volume. The use of a dedicated CRNA as an OR manager was a successful and popular strategy to improve efficiency through real-time management of bottlenecks in the OR schedule and throughput.

EPILOGUE

Since the conclusion of this study, we have collected an additional 9 months of OR performance data. Although it is not uncommon to see QI projects decay once left alone, so far our results have proven durable. Over the last 9 months, the percentage of first-case on-time starts has remained >80%, with a range of 76% to 89%. Operating room utilization during peak hours has continued to improve, and has been close to 89% (range 84% to 93%) during the same timespan. As we have approached these high levels of utilization, the previously seen increase in the 12-month rolling average of cases per month has leveled off, but now consistently remains at >700 per month (704 to 710 cases/month). On the other hand, turnover time still has not improved, and has increased slightly to 43.3 minutes.

A tenet of the TOC is that the process is ongoing, otherwise QI succumbs to inertia. Accordingly, the durability of our results likely depends on increased accountability from continual re-evaluation and sharing of our data, as well as the daily presence of a CRNA OR manager to enforce our QI initiatives.

Author Contributions

Study conception and design: Kimbrough, McMasters, Jackson, Farah, Boswell, Scoggins

Acquisition of data: Kimbrough, Canary, Jackson, Farah, Kim

Analysis and interpretation of data: Kimbrough, McMasters, Canary, Jackson, Boswell, Scoggins

Drafting of manuscript: Kimbrough, McMasters, Scoggins

Critical revision: Kimbrough, McMasters, Canary, Jackson, Farah, Boswell, Kim, Scoggins

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Discussion

DR RIFAT LATIFI (Tucson, Arizona): The authors report the results of what they call "straightforward" and "common sense approaches," supported by low-cost, low-technology solutions to improve operating room (OR) performance and efficiency in a tertiary care academic medical center with a level I trauma center. Its importance is obvious to all of us who struggle to start the case on time, to make sure that preoperative testing and documentation are done properly and the patient is moving effortlessly to the operating room, that the anesthesiologist has seen the patient and has asked the right questions, that the Coumadin and aspirin and other anticoagulants were stopped on time, and that there will be no surprises in the minutes before cutting time.

The authors have accomplished a considerable feat. They report on the process of reengineering of the OR governance at their institution by establishing accountability, the metrics of transparency, and creating a culture of data-driven efficiency. In other words, they took full responsibility for the grave situation at their institution and changed it. In the business world, this is commonplace. But, for some reason, we in health care tolerate significant delays for starting the first case, tolerate long delays between cases, and tolerate if the patients are not ready for the operating room, even when we have already scheduled the operation. Can you imagine a shop or factory—or any other business office for that matter—that opens on time only 39% of the time? Surely if they did, they would not remain in business for very long.

I congratulate the authors for taking the required steps to change the status quo of their OR patient flow. In fact, what they did is simple. They took the steps that we surgeons should take to change and innovate the process if it does not work or