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Improving Operating Room Efficiency

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Abstract

Purpose of Review Operating rooms are critical financial centers for hospital systems, with surgical care representing about a third of all health care spending. However, not all of the costs are appropriate or necessary, as there are sometimes significant inefficiencies in how operating rooms are utilized.

Recent Findings Recent innovations utilizing patient-centered data, systems principles from manufacturing industries, and enhanced communication processes have made significant improvements in improving operating room efficiency.

Summary By focusing on improving communication, standardizing processes, and embracing a learning health system with innovations, significant improvements in operating room efficiency can be seen to improve outcomes and costs for the health system and patient.

Keywords Operating room efficiency · Operating room costs · Six sigma · Lean · Cost efficiency

Introduction

Operating rooms are critical financial centers for hospitals and for many patients are important interaction points with the healthcare system. More than 48 million ambulatory procedures [1] and 51 million inpatient procedures were performed in 2010 [2]. Surgical care accounts for about one third of all health care spending [3], and about one half of aggregate inpatient hospital costs [4]. With reported operating room costs ranging from $30 to more than $100 per minute [5, 6, 7••, 8, 9], it is essential to maximize efficiency in the operating room to improve the value of surgical care provided.

The operating room is a complex and often unpredictable environment, with multiple factors driving inefficiency. There are complex social interactions involving multiple stakeholders, including patients, caregivers, anesthesiologists and surgeons, nurses, and administrative and facility staff. There is a wide variety of patients, surgical procedures, surgeon expertise, instrument, and staffing requirements. Emergency surgeries and traumas can occur that require appropriate flexibility in available staffing and operating room space. There are patient factors that can cause unexpected changes, such as violations of preoperative fasting periods or medical clearances that prompt last-second cancelations, or intraoperative findings that change the course of a procedure. There are staffing factors, such as start delays because of overlapping procedures, poor communication, or case flow problems from lunch and break coverage. There are system factors such as equipment supply chains and sterilization processes, patient transportation, and effective allocation and utilization of operating room block time for each individual patient, procedure, and surgeon.

In response to these challenges, there have been multiple innovations that have helped reduce waste and improve patient safety and outcomes with surgical care. In this article, we will evaluate operating room costs, define some of the metrics used to evaluate operating room efficiency, and examine some innovative techniques to improve the value of surgical care.

Costs of Care in the Operating Room

Understanding the costs of surgical care is essential to value-based care. Costs for inpatient hospital stays with surgical procedures totaled $187.1 billion in 2014, accounting for 48% of all aggregate hospital costs. Operating room costs

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are the second most expensive portion of surgical care, second only to room and board [10]. Previous studies have attempted to estimate the actual cost per unit time to run an operating room. However, there are few standardized estimates available, as most studies are from single institutions reporting charges and not costs [5], which represent what the hospital bills for medical care and are often confounded by differing negotiated contracts and profit margins. This explains some of the large variation in reported estimates of operating room time from $30 to more than $100 per minute [5, 6, 7••, 8, 9].

One recent study helped to provide a standardized estimate of operating room costs to better understand high-yield targets for cost-savings. Childers et al. [7••] evaluated the cost statements sent from the 302 hospitals across California to the Office of Statewide Health Planning and Development. They found that the average cost for the operating room was $36–37 per minute. Almost half of the total costs were from indirect costs from non-clinical expenses, such as parking and security that would likely not change with any improvement in operating room efficiency. Of the $20–21 per minute of direct costs, about two-thirds were for salaries and benefits, including the wages of operating room staff (nurses, circulators) and administrators, managers, and technicians. This helps identify potential interventions that could bring significant cost savings, and conversely, identify low-yield areas that are unlikely to provide value. For example, although multiple studies have found that different suture and wound closure techniques can decrease the wound closure time, there were minimal differences in the total operative time and therefore no changes in the cost savings [11–13].

This is of particular importance in urology, where robotic assisted surgeries have become increasingly utilized for an increasing number of diseases and treatments despite questionable benefit [14, 15]. In 2017, 644,000 robot-assisted procedures were done in the USA, accounting for $2.3 billion in revenue, or approximately $3568 per robot-assisted procedure $1701 for purchasing and maintaining the robot per procedure [16]. These are important considerations in improving operating room efficiency, as there is significant investment in staff training, infrastructure, and equipment management, and because robot-assisted surgeries can significantly increase operating room time [14, 17]. Potential decreases in the inpatient length of stay may help to offset these initial upfront costs; however, the benefit in length of stay and complication rates has been limited in large studies and randomized controlled trials [14, 15, 17, 18]. It is therefore essential to identify areas to improve efficiency and decrease unnecessary costs throughout the continuum of surgical care, from the preoperative, intraoperative, and postoperative management.

Operating Room Efficiency Metrics

There is no single metric or series of measures that have been standardized and tested to best evaluate efficiency in surgical care. However, there are several multiple proposed metrics that have been frequently reported and measured. Common measures include [19]:

- Procedure cancelation rate: usually defined as same day cancelations, but can include any unexpected cancelation or delay. Includes patient factors such as sudden illness, poor communication about fasting status, or missing medical clearance forms
- First case start time: measuring operating room and patient readiness
- Operating room utilization: use of operating room time for planned surgical procedures
- Percentage of unplanned closure: including unanticipated equipment malfunction, unanticipated staff or equipment problems
- Case duration accuracy: accurately allocating appropriate staffing scheduling to predicted time required for each procedure for each surgeon
- Operating room turnover time: measuring the interval between patient exit to the next incoming patient to clean the operating room, prepare the necessary equipment and staff for the next procedure
- Excess staffing costs: providing enough staffing needs to cover unexpected emergent procedures or unexpectedly prolonged cases, while avoiding unnecessary underutilization
- Off hours surgery: representing emergent add-on surgeries or procedures that are longer than the expected time

We will briefly review some of the most commonly evaluated metrics and provide an overview of some of the innovations that are being implemented to address these inefficiencies.

Unexpected Surgical Cancelations

One of the most successful ways of improving operating room efficiency has been to decrease the rate of unexpected delays and surgical cancelations. Unexpected cancelations of elective surgical procedures can result in significant potential losses for hospital systems. In 2007, hospitals in the UK lost almost $88 million for canceled operations [20]. Major tertiary hospitals, such as Cincinnati Children's Hospital, reported losses of 5.7 h of lost operating room time each day from day of surgery cancelations [21]. Day of surgery cancelations is a global problem, with estimates varying widely from around 2 to 20% [22, 23••, 24, 25], depending on patient population, surgical procedure, and hospital factors. Many of these unexpected cancelations are not preventable, especially for pediatric populations where more than a third of the cancelations are due to upper respiratory infections [26]. However, a large proportion of the cancelations are often preventable, in some institutions accounting for as much as 50–70% of the cancelations [21, 22, 25–27]. In a review of ambulatory urologic procedures, more than 75% of the cancelations were due to lack of adequate work-up or medical clearance, or facility factors [28]. For ambulatory ophthalmology procedures, a study found that up to 20% of the cancelations occurred because the patient did not show up for the procedure [29].

Cancelations are generally placed into three categories: representing hospital-related causes, patient factors, or surgeon/staff factors. Hospital-related factors include missing or failed equipment, prioritizing emergent surgeries, or lack of hospital beds. Patient-related factors include inadequate preoperative assessments or medical clearances, patient absenteeism, self-cancelation, improper nil per os (NPO) instructions, or financial constraints. Surgeon/staff-related factors include unavailability of required essential staff, surgeons, or anesthesiologists.

There have been many interventions published in the literature to address the wide variety of root causes of surgical cancelations, ranging from establishing a formalized preoperative anesthesia clinic [30], to phone calls from nursing staff [21], to machine learning algorithms to identify patients that are high risk for cancelations [31]. Despite the wide variety of possible interventions, there are several key factors that are shared by many of these innovations.

- Identify the root causes for the particular institution: There can be substantial differences in the most common causes of surgery cancelations for each health system, given the differences in patient population, procedure types and hospital resources. Hospital systems serving large immigrant communities may need bilingual instructions or translators present. Older patients may not have ready access to mobile phones or computers, and health literacy may make printed material difficult to understand [32]. In a root cause analysis of their surgical cancelations, Pratap et al. [21] found that about 20% of patients did not show up for their scheduled surgery and that more than 40% of the time the hospital staff were not able to get in contact with the patient or caregivers. This led to quality improvement initiatives to update the contact information within the electronic health record, an automated texting platform to remind the patient caregivers of their scheduled procedures, and a systems improvement initiative to contact the caregivers earlier before the planned procedure to allow more time to establish contact. Identifying the unique circumstances for unexpected cancelations can lead to large improvements in operating room utilization
- Leveraging the electronic health record: The electronic health record (EHR) provides a unique platform to measure patient-centered data and provide automated feedback. Most of the current analyses of surgical cancelations utilize the available patient-level data to identify potential patient risk factors for surgical cancelations. Higher risk patients and higher-risk surgical procedures can then be identified with machine learning techniques to help identify areas that may require specific interventions to reduce day of surgery cancelations [31]. Many different health systems now provide a patient portal or text messaging system that can then be utilized as a platform to communicate with the patient directly, send reminders, or relevant information, and improve patient activation in their own care [33].
- Clear communication: Failure to maintain NPO status is a common reason for unexpected operating room cancelations. In their root cause analysis, Pratap et al. [21] reported that about 15% of the total surgical cancelations were from NPO status and that a failure to clearly communicate the NPO instructions accounted for about 80% of the root causes of NPO violations. They then implemented a multi-modal intervention, with a standardized sheet with infographics that clearly listed the times to stop oral intake, the types of food that are allowable, and the phone numbers to call. They also utilized text messaging services to send automated reminders of the times to start being NPO and the scheduled arrival times. With these improvements among others, they were able to achieve a 17% improvement in operating room utilization. In a similar fashion, Haufler et al. [34] showed that a simple intervention with a phone call by a nurse to the patient to review a pre-scripted 14 question survey helped reduce the rate of unexpected surgical cancelations by 53%.

First Case Start Time

First procedure start time is a key target to improve operating room efficiency and reduce unnecessary costs. Retrospective reviews have found that 50–80% of first cases at tertiary care hospitals were delayed by as much as 30 min on average [35–37], which represent significant preventable costs. The most common causes for delays in the first case include surgeon/staff unavailability, delayed patient registration, congestion in the preoperative areas, and transportation issues [38].

Several innovations have been implemented to improve the rate of on-time first procedure starts, many of which were adopted from industrial processes. Six sigma was developed in 1986 by the Motorola Corporation to utilize statistical methodology to reduce process variability [39, 40]. This process involves an iterative process termed DMAIC (D = Define, M = Measure, A = Analysis, I = Improvement, C = Control). Lean describes a process developed by Toyota to eliminate wasteful steps to increase efficiency [39, 40]. The Lean process includes five main steps: identify value, map the process to eliminate steps that do not create value, create flow for the product to the consumer, establish flow to allow the customer to pull value from the activity, and create perfection by repeating the steps in an iterative process. TeamSTEPPS (Team Strategies and Tools to Enhance Performance and Patient Safety) is a process that was based off of the aviation industry and designed by the Agency for Healthcare Research and Quality and the Department of Defense to improve perioperative communication and reduce errors.

Several studies have used the Lean and Six sigma process to identify sources of delay and implement changes. Phieffer et al. [35] mapped the process to bring the patient to the operating room, and identified all the relevant stakeholders. Using the DMAIC process, they identified barriers to bringing patients on time for a first start procedure, detailing the potential problems for transport staff, surgeon, anesthesia, the preoperative area, and registration. Using these processes, they were able to almost double the percent of on-time first starts from 49 to 92%. A large part of the success of the implementation was due to information technology tools that allowed continuous measurement and feedback to the relevant stakeholders in a daily report. Several other investigations have found similar benefits to first case starts using Lean and Six sigma methodology [6, 41]. Using a TeamSTEPPS approach, with preoperative and postoperative briefing, Weld et al. [42] were able to show a 21% improvement in on-time first case starts, while decreasing patient safety issues from 16 to 6%.

Other strategies have proven successful in improving first case start rates. St. Jacques et al. [43] showed that minimal financial incentives to physicians (up to $500 per month) could improve the rate of first case starts from 19 to 61% in as little as 6 months. Improved communication between the operating room team, including surgeons, anesthesiologists, technicians, and nurses has been shown to significantly improve the rates of first case on-time starts. Bethune et al. [44] found that operating team briefings before each operative case was able to significantly decrease first start delays. Mathews et al. [45] similarly introduced team huddles before surgeries to identify the goals of the surgery and potential delays, and found that the percentage of on-time first case starts doubled from 33 to 68%. A study by Martin et al. [46] combining a preoperative checklist and team huddle with a modest financial incentive (up to $2000 per year if metrics were met) showed significant improvement in on-time first case starts from 15 to 72%, with an estimated cost savings of over $750,000. Multimodal approaches using methodology from industry, such as Six sigma and Lean, and financial incentives with improved communication can significantly reduce delayed first case starts.

Case Duration Accuracy

Operating room utilization is a key metric for improving efficiency; however, inadequate estimation of case duration can lead to both under and over utilization of operating room time. Some methods rely on surgeons to predict the case duration based off of the surgical approach, patient comorbidities, and clinical expertise. However, almost 75% of the time, surgeons will inaccurately predict the case length, overestimating case duration by 32% and underestimating case length 42% of the time [47]. One novel innovation to address this problem is the use of machine learning and artificial intelligence. By leveraging the available patient demographic data, pre-surgical milestones, and hospital logistics available through the electronic health records, a machine learning algorithm can reduce overall scheduling inaccuracy by 70% [48]. This approach needs to be validated across multiple hospital systems, but provides a possible solution to a challenging problem.

Operating Room Turnover Time

One of the most common complaints from surgeons is the amount of time waiting to operate. During a standard operative day, a surgeon may spend less than 50% of the time actually operating [49–51]. Prolonged operating room turnover times can lead to increased overtime staffing costs, wasted opportunity costs for potential revenue, and decreased patient satisfaction [52]. A major barrier to improving operating room turnover time is misaligned incentives between relevant stakeholders. Surgeons are incentivized by surgery volume, whereas anesthesiologists, nursing, and custodial staff are paid hourly [53].

Several novel innovations have been able to show drastic improvements in operating room turnover time. Using the Lean process, Cerfolio et al. [6] identified key areas that helped improve the operating room turnover time. They identified a process to allow the anesthesiologist to meet the next patient earlier and start their intravenous line and consent process. They identified a workflow issue with the circulator and eliminated unnecessary travel time to retrieve supplies by stocking the case cart for the day with the required supplies. By engaging different stakeholders in the Lean process, they were able to decrease median operating room turnover time from 37 to 14 min, resulting in a savings of 70 min of operating room time and an estimated return on investment of $19,500 daily.

These are particularly important findings in urology, since the turnover time for robotic procedures is significantly longer than traditional open procedures [54]. By modeling concepts from motor racing pit stops, to detail tasks and allocate specific responsibilities for all the relevant stakeholders, Souders et al. [55] was able to decrease average operating room turnover time from 99 to 53 min.

Another important consideration for turnover time is the availability of the post-anesthesia care unit (PACU) to recover. If the PACU does not have enough staff or beds available to receive a patient, the patient may be held in the operating room for an extended period of time. Just as planning and predicting the length of operations is important for operating room efficiency, predicting the length of time required in the PACU for each surgical procedure is essential. In one investigation, the utilization of a machine learning algorithm to predict the PACU time for each type of procedure was able to reduce total PACU holds by 76%, leading to significant cost savings [56]. In order to improve operating room turnover time, it is essential to involve all the relevant stakeholders, align the proper incentives, and eliminate wasteful steps as much as possible.

Intraoperative Interventions

Redesigning Operative Workflow

In addition to the pre-operative and peri-operative improvements in efficiency, there have been multiple investigations to improve intraoperative efficiency and value in surgical care. Redesigning the intraoperative surgical workflow to improve efficiency and reduce wasted time and resources can have a significant impact. Krasner et al. [57] implemented a standardized case cart and surgical setup, with parallel task completion for coronary artery bypass surgeries, and was able to reduce the total operating room time by 21%. Bender et al. [58] used a Six sigma process to include all the relevant stakeholders to address operating room utilization and was able to increase the number of surgical procedures by 9%, reduce personnel costs by 14%, and increase overall revenue by 19%.

Process mapping of surgical procedures can improve intraoperative efficiency by outlining every step of the procedure with the whole surgical team to decrease staff uncertainty and improve anticipatory involvement. By using process mapping, the overall operative time can be reduced by up to 12–20% and reduce operative costs by 5–12% [59–61]. These studies also helped implement "no-handoff" times, which represent critical times during the surgical procedure where a change in nursing staff or technician can potentially alter the surgical flow and increase complications. The number of handoffs and the size of the operating room team was found to be independently predictive of operative time [62]. Implementing a "no-handoff" time during critical moments, such as a flap harvest [60], or while clamping the renal hilum during a partial nephrectomy, may improve operating room efficiency and decrease operative complications.

Standardizing Surgical Trays

Standardizing and reducing surgical instruments for each procedure can improve operating room efficiency by reducing operative costs, setup and counting time, processing costs, and turnover time. Across specialties, only 13–22% of instruments on given surgical trays are utilized, representing wasted sterilization costs and time spent counting and processing unnecessary items [63]. Using various methodologies, including the Lean process, several investigators were able to reduce the number of instruments for each procedure by 19–70% [64–67]. The streamlining of surgical trays translated into decreased total operative times [64] and estimated savings of $41,000 per year [65].

In addition, educating surgeons on the price of disposable tools can decrease the total costs of a surgical procedure. By reviewing costs of disposable surgical instruments with surgeons for cholecystectomies, Gitelis et al. [68] were able to decrease the disposable costs by 10%.

Standardizing Surgical Teams

Having the same operating room staff that is familiar with the particular procedures and surgeon preferences can improve operating room efficiency and decrease operative times. Several studies have found that having standardized teams can reduce operative times, for a wide variety of cases from

Table 1 Common problems causing operating room inefficiencies, and examples of how those problems are solved

Key metric	Examples of innovative solutions
Cancelation rate	Root cause analysis, leverage electronic health record, clear communication, and patient education
First case start time	Six sigma/Lean principles to identify sources of delay and address problems, TeamSTEPPS approach for preoperative and postoperative briefings
Case duration accuracy	Machine learning and artificial intelligence
Operating room turnover time	Six sigma/Lean principles to identify sources of delay and address problems, TeamSTEPPS approach for preoperative and postoperative briefings

complex head and neck surgeries to hernia repairs, by approximately 9 to 47 min [67, 69, 70].

Real-Time Locating Systems

Real-time locating systems with radiofrequency identification (RFID) or Bluetooth technology, among others, can be used to track and visualize operating room flow and process in real-time. These can then be used to identify inefficiencies or bottlenecks, and could ideally provide automated responses or interventions in real-time to address those inefficiencies. In one study, Al-Hakim et al. [71] found that preventable disruptions intraoperatively, mainly caused by poor communication, increased the operative time by 25% and that 60% of those disruptions could have been resolved preoperatively. Utilizing the real-time locating system to provide automated messages and alerts for when the patient was ready for anesthetic induction, Yeoh et al. [72] were able to significantly decrease the duration between patient arrival and anesthesia induction, and therefore decrease the overall operative time (Table 1).

Large-Scale Interventions

Several large-scale interventions have been proposed to maximize operating room efficiency. Improvements in supply chain management can significantly reduce unnecessary costs and waste. The utilization of RFID can be used to track the quantity and location of specific supplies so that specific items can be delivered at the right time for the right procedure. This can also reduce costs by providing information on inventory and preventing excess supply, and reduce delays due to missing instruments or supplies [73].

Physical redesigns of the operating room itself can help improve patient flow and reduce inefficient transfers. Massachusetts General Hospital redesigned its operating room as a physical and functional learning health system to evaluate best practices to improve patient throughput and efficiency while improving patient outcomes. One important factor was to place an induction room and early recovery rooms so that the preparation for anesthetic induction could be done in parallel to the termination of a previous surgical case. This process can help improve patient flow, utilizing real-time sensors to monitor patient flow and location. Using time-driven activity-based costing (TDABC), this parallel induction design can reduce operative times by 55 min at a margin increase in personnel costs (1.6%), with the potential additional revenue of $2818 per day and $730,000 per year [74].

Conclusion

In this era of value-based care, it is essential to maximize surgical care efficiency while minimizing unnecessary costs. There have been multiple innovations in the perioperative and intraoperative space to help decrease cancelations, improve first time starts, increase operating room utilization, reduce turnover time, and streamline intraoperative processes. Data-driven approaches and clear communication between all the relevant stakeholders are essential to improving the efficiency and quality of care given. As we continue to push the frontiers of surgical treatment for our patients, we will need to be continuously vigilant about how we can improve the operating room experience to improve the value and quality of care that patients receive.

Compliance with Ethical Standards

Conflict of Interest Daniel J. Lee, James Ding, and Thomas J. Guzzo each declare no potential conflicts of interest.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by any of the authors.

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