

Review Article

Data Driven Insights to Operating Room Inefficiencies: What's next? Part 2

Jason Cholewa, Ph.D.^a, Arjun Kaneriya^b, Mike B. Anderson^c

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We previously discussed the methodologies for improving operating room efficiencies including lean and six sigma methods, the use of scheduling algorithms, and even direct observations. Additionally, we demonstrated the effects of pre-operative factors on efficiency in the operating room and noted that inefficiencies in the operating room are multi-factorial. In the second part of this paper, we discuss intra- and post-operative opportunities for improvement. We recognize that inefficiencies within the intra- and post-operative periods are often similar between institutions (e.g., environmental services, surgery technicians, and nurses responsible for turning over the OR), while the specific causes of inefficiency are unique to each individual institution or department. Given the variability and burden that exists in an efficiency program, there is a substantial opportunity for the development of technologies capable of automating the measuring and analysis of actionable data to transform OR efficiencies.

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INTRODUCTION

In the U.S., hospital care expenditures were \$1.3 trillion in 2021 and are expected to rise 43% by 2031 (Centers for Medicare & Medicaid Services 2023). Additionally, health-care costs have also outpaced inflation by approximately 25% over the last decade (U.S. Bureau of Labor Statistics 2023). This surge in costs, coupled with the push for value

in medicine, has led to initiatives to reduce unnecessary costs and improve efficiency in healthcare, particularly in operating rooms (ORs) (Healey, El-Othmani, et al. 2015; Healey, Peterson, et al. 2015). Operating rooms (OR) account for a significant portion of hospital costs and revenue, with operational costs averaging around 36\$ USD/min (Childers and Maggard-Gibbons 2018) and reported as high as \$133 USD/min (Ting et al. 2012).

^a Jason Cholewa holds a Ph.D. in Applied Exercise Physiology and is Medical Senior Writer at Zimmer Biomet. His research interests include monitoring functional recovery following joint arthroplasty and robotics in arthroplasty.

[Connect with Jason Cholewa on LinkedIn](#)

[Conflicts of Interest Statement for Jason Cholewa](#)

^b Arjun Kaneriya is an undergraduate student at the College of William and Mary studying computer science and physics on the pre-medical track.

[Connect with Arjun Kaneriya on LinkedIn](#)

[Conflicts of Interest Statement for Arjun Kaneriya](#)

^c [Connect with Mike Anderson on LinkedIn](#)

[Conflicts of Interest Statement for Mike B. Anderson](#)

Operational inefficiencies stem from diverse factors including personnel availability, surgical scheduling, operative workflow, and OR turnover (D. J. Lee, Ding, and Guzzo 2019). Despite extensive research, there is still opportunity for improvement in these areas by leveraging data and technological solutions. In Part 1 of this two-part article, we described OR efficiency as the culmination of maximizing OR utilization and optimizing productivity. We then reviewed the limitations of current scheduling practices in maximizing OR utilization and discussed the potential for the combination of automated data acquisition and machine learning algorithms to maximize OR utilization without overbooking. The current review will identify sources of intra- and post-operative inefficiencies and propose potential data and technological solutions.

INTRA-OPERATIVE ACTIVITIES AFFECTING EFFICIENCY

CHECKLISTS & PROCESS MAPPING

Checklists standardize protocols, serve as cognitive aids, and mitigate the impact of stress and fatigue, thereby reducing errors, enhancing team cohesion, and potentially improving OR efficiency (Gaba and Howard 2002; Kanich and Byrd 1996; McConnell, Fargen, and Mocco 2012; Verdaasdonk et al. 2009; S. W. Wong, Smith, and Crowe 2010). Studies have shown that implementing checklists throughout the peri-operative period can significantly reduce late starts (Panni et al. 2013), surgery and OR room time (Bettarelli et al. 2023; Batista et al. 2023; Bliss et al. 2012), and costs associated with disposables and surgical complications (Cadman 2016; Papaconstantinou et al. 2013). The World Health Organization (WHO) Surgical Safety Checklist ranks communication as the most critical out of fifteen key influences of intra-operative efficiency (Sotto, Burian, and Brindle 2021). Pre-operative checklists employed during team briefings have been reported to reduce miscommunication events by up to 50% (Pugel et al. 2015). A recent systematic review found surgical safety checklists to improve OR staff's perceptions of teamwork and communication while diminishing observable errors related to poor team skills (Russ et al. 2013).

By process mapping each step within the surgical workflow, potential inefficiencies can be identified and rectified, creating standardized procedures (Lalys and Jannin 2014). Several studies have reported reduced OR times with process mapping and procedure standardization in breast reconstruction surgery (B. T. Lee et al. 2008a, 2008b), laparoscopic cholecystectomy (von Strauss und Torney et al. 2018), esophagectomy (Iannettoni et al. 2011), head and neck reconstruction (Chalian et al. 2002), and hand surgery (Casaletto and Rajaratnam 2004). A recent systematic review calculated the cost savings per case based upon eight procedure standardization studies and reported a mean cost savings of 38.1% with a range of 9.9% to 87.9% (von Schudnat et al. 2023). The greatest cost savings based upon multiple studies were reported for general and visceral, orthopedics, and pediatric surgeries.

CHECKLIST AUTOMATION AND DIGITIZATION

Automation of checklists has led to significant efficiency improvements in various industries, including aviation (Linskens et al., n.d.) and automotive repair (Jackson and Schneider 2015), with potential applicability in medicine. In a Veterans Affairs medical center, Nissan and colleagues (Nissan et al. 2014) reported an automated checklist system reached 95% compliance, increased first-case on-time starts by 40%, and reduced median timeout duration by 13 seconds. Digital support systems, providing data elements such as checklists, preference cards, or process maps, may further improve OR efficiency by reducing unnecessary variations and resource use. Digitization of data acquisition and procedural optimization was shown to reduce functional endoscopic sinus surgery by approximately 6 minutes (14.3%) and improve process reliability by approximately 49% per case (Feige et al. 2017). Similar findings have been reported for OR time in laparoscopic surgery (Athanasiadis et al. 2021), costs in total knee arthroplasties (Millet et al. 2020), and downstream reductions in recovery room and hospital stay in hip endoprosthesis surgery (Lahmann and Hampel 2020). Although these findings are encouraging, fully realizing the potential efficiency gains in the OR will require automated data acquisition, aggregation and registration, along with expedient means of analysis, prediction and validation (Lalys and Jannin 2014; von Schudnat et al. 2023).

COORDINATION OF STAKEHOLDERS

COMMUNICATION

Healthcare delivery is a complex process that requires effective coordination and communication to ensure efficient resource allocation and maximize care (Moss and Xiao 2004). The transfer of information between OR staff members occur at a rate of about 32 to 74 communications per hour, with approximately 30% of communications failing (Lingard et al. 2004; Garosi et al., n.d.; Nagpal et al. 2010). Communication failures are one of the main causes of medical error (Nagpal et al. 2010; Donchin et al. 1995; Leape et al. 1995), accounting for almost twice as many adverse events as clinical inadequacy (Wilson et al. 1995). Information transmission and resource request errors in the OR have been linked to delayed starts (Lingard et al. 2004; Gupta et al. 2011; Halverson et al. 2011) and perceivable inefficiency, team tension, resource waste, and patient inconvenience (Lingard et al. 2004). Poor communication is reported to result in a \$12 billion annual economic loss in US hospitals, with a 500-bed hospital estimated to lose approximately \$4 million annually as a result of communication insufficiencies (Agarwal, Sands, and Schneider 2010).

The etiology of communication errors is diverse, and can be categorized into occasion failures, content failures, audience failures, and purpose failures, with most surgical communications in failure attributable to occasion and content (Lingard et al. 2004). Surgeons and anesthesiologists report twice as many information transfer problems as nurses, citing missing and erroneous information related

to lab/test results and patient records as the most common failures (H. W. Wong et al. 2011). By lessening the need to leave the aseptic area, a central repository of accessible data within the OR is suggested to increase efficiency and reduce patient risk (H. W. Wong et al. 2011). Automating the tracking and transfer of information is further proposed to reduce communication failures, and by extension enhance workflow (Moss and Xiao 2004), thereby reducing medical errors (Felder 2003; Alotaibi and Federico 2017) and improving the quality of care (Ugajin 2023).

DISTRACTIONS WITHIN THE OR

Distractions within the OR, including irrelevant conversations and door openings, occur approximately every three to five minutes, and negatively impact surgical performance, potentially leading to errors and complications (Aouicha et al. 2021; Mentis et al. 2016; Wheelock et al. 2015; Wiegmann et al. 2007). Distractions are linked to higher stress levels in surgeons and perception of workload in nurses, and negatively affect leadership and coordination by anesthesiologists (Aouicha et al. 2021; Mentis et al. 2016; Wheelock et al. 2015). Auditory distractions (including door openings) have also been reported to negatively affect completion time and economy of motion (Mentis et al. 2016). The impact of distractions on surgical errors varies with the experience of the surgeon, with inexperienced surgeons slowing down their tasks to prevent errors while experienced surgeons did not slow, but recorded more errors (Mentis et al. 2016).

Operating room door openings occur approximately once every one to two minutes as personnel exchange information or supplies (Andersson et al. 2014; Panahi et al. 2012; Perez et al. 2018; Bédard et al. 2015; Lynch et al. 2009). In addition to being distracting, frequent OR door opening disrupts laminar air flow leading to the faster spread of airborne organisms (Salvati et al. 1982; Smith et al. 2013; Mathijssen et al. 2016; Rezapoor et al. 2018; Stauning et al. 2018; Teter et al. 2017) and an increased risk of intra-operative wound contamination (Persson 2019; Birgand, Saliou, and Lucet 2015). Because approximately 80% of OR door openings are unnecessary (Wheelock et al. 2015; Stauning et al. 2018), tracking door openings per case in conjunction with an educational intervention can effectively lessen door openings (Hamilton et al. 2018) and reduce environmental contamination (Parent 2021). However, significant resources are required to analyze video recordings or audit surgeries to measure door openings and the sustainability of such changes is unknown. Automating the measurement of door openings will allow OR teams to monitor not just the performance, but also the sustainability of quality improvement projects related to reducing OR traffic.

DISTRACTIONS OUTSIDE THE OR

High-quality peri-operative documentation is a responsibility of the OR team and facilitates communication across the continuum of care (Braaf, Manias, and Riley 2011; Brima et al. 2021). However, the documentation workload

of OR team personnel has risen continuously (Lamprecht, Kolisch, and Pfürringer 2019; Wolff et al. 2017). Several studies show documentation work consumes approximately 20-25% of a surgeon's workload (Arndt et al. 2017; Holzer et al. 2019), and administrative tasks have been reported to exceed the amount of time physicians spend with patients in some hospitals (Momenipur and Pennathur 2019). The adoption of documentation through electronic health records (EHR) has contributed to an increase in administrative workload, leading to increased staffing, intra-operative times (Sanders et al. 2014), and a transient reduction in first case on-time starts (Frazee et al. 2015). The documentation burden negatively impacts morale (Aouicha et al. 2021), makes resident physicians feel rushed (Christino et al. 2013), and is perceived as limiting the time surgeons can dedicate to important medical work (Holzer et al. 2019). This has been linked with limiting opportunities for continuing medical education, stress, dissatisfaction, and lower quality of life among surgeons (Holzer et al. 2019; Bohrer et al. 2011).

Although the direct economic effects of administrative burden are unknown, some research suggests that increased surgeon workload could lead to financial losses due to decreased quality and detail in discharge notes. Powell and colleagues (Powell, Savin, and Savva 2012) reported that as trauma surgeon workload increases, the likelihood of a patient receiving an accurate high-severity DRG code decreases, leading to a 1.1% annual hospital revenue loss. Technologies capable of automating these tasks will enable OR staff to concentrate on medical work, which in turn will increase patient trust, reduce health care worker psychological burden, reduce medical errors, and free-up time for continuing education (Ugajin 2023).

POST-OPERATIVE ACTIVITIES AFFECTING EFFICIENCY

TURNOVER TIME

Turnover time (TOT), the interval between one patient leaving the OR and the next entering, is a critical measure of OR efficiency with implications for hospital revenue, overtime reduction, and patient satisfaction (D. J. Lee, Ding, and Guzzo 2019; Fixler and Wright 2013; Warner et al. 2013). End-of-shift times after 2:00 pm, change in personnel between procedures, staff shortages, lack of managerial support, supply chain interruptions due to the Covid-19 pandemic, and communication breakdowns between sequential teams have all been associated with increased TOT (Kamande et al. 2022; Namisi, Karugu, and Gacil 2023; Norman and Bidanda 2014). These findings suggest that the causes for delays in TOT are highly variable, and dependent on region, hospital size and infrastructure, department, surgeon and staff, and the patient (Malhotra and Malhotra 2017).

Several studies have reported improvements in TOT following quality improvement projects (Norman and Bidanda 2014; Goldhaber et al. 2023; Kodali et al. 2014; Uddin et al. 2018). Though the specific interventions differed across

studies, each project measured TOT metrics to identify appropriate interventions and assess effectiveness. TOT was improved by 5 to 20 minutes per case through interventions targeting response time, cross-team communication, teamwork efficiencies, and workflow adjustments (Norman and Bidanda 2014; Goldhaber et al. 2023; Kodali et al. 2014; Uddin et al. 2018). Of note, the authors of these studies highlighted the importance of data to set goals and hold teams accountable (Goldhaber et al. 2023; Uddin et al. 2018), re-define roles and cross-train staff (Norman and Bidanda 2014), and facilitate buy in across teams (Kodali et al. 2014).

A common limitation to the studies described above includes the increased task load placed on nurses and/or staff to timestamp OR activities and record any reasons for delay. Regular measurement and analysis of TOT metrics, coupled with goal setting, can help identify bottlenecks and inefficiencies and drive improvements (Norman and Bidanda 2014; Goldhaber et al. 2023; Kodali et al. 2014; Uddin et al. 2018). However, long term monitoring may increase the burden on nurses and OR staff leading to recording errors or require additional resources to train new personnel. Given that the factors affecting TOT vary from hospital to hospital, TOT needs to be measured and analyzed on a per hospital (or even departmental level) basis to identify and implement inefficiency interventions. Automating data entry and improving IT communication and coordination could potentially reduce TOT and simultaneously reduce workload for OR staff (Uddin et al. 2018).

POST-OPERATIVE DEBRIEFS

Debriefing, a concept borrowed from military and aviation fields, provides meaningful learning opportunities and aids in achieving learning objectives and ensuring inclusivity (Salik and Paige 2023). By employing a “gather, analyze and summarize” model like that proposed by the American Heart Association (Cheng et al. 2012), data collected during cases or simulations can be used to solicit alternative clinical decisions and management options to facilitate safety and efficiency discussions. Porta and colleagues (Porta et al. 2013) reported a standardized post-operative team debriefing system improved OR efficiency by minimizing delays. Debriefing electronically was used to identify and address issues causing delays, resulting in a 9% reduction in delays and a monthly saving of 212 minutes of OR time.

Several studies emphasize the importance of teamwork and clinical leadership during debriefing to improve efficiency. Clinical leaders report successful debriefing programs should include education, piloting, stakeholder involvement, and feedback (Brindle et al. 2018). For example, Wolf and colleagues (Wolf, Way, and Stewart 2010) reported a program comprised of classroom learning, checklist-guided briefings and debriefings, and an Executive Committee for problem-solving resulted in a marked decrease in any-cause delays from 23% to 8%. A similar study found that regular debriefs improved OR staff's ability to handle interference and variability, leading to fewer cancellations and better utilization (van Veen-Berkx et al. 2015). These studies suggest that engaging multiple stakeholders in data

gathering and interpretation can create a valuable feedback loop for refining OR systems ([Figure 1](#)).

CONCLUSIONS

As healthcare expenditures continue to outpace inflation, improving the efficiency of operative processes have become critical to maintaining a balance between financial value and high-quality care. Previous work has shown that many of the factors related to inefficiencies within the intra- and post-operative periods share similarities between institutions (for example, environmental services, surgery technicians, and nurses are responsible for turning over the OR), while the specific causes of inefficiency are unique to each individual institution or department. Identifying and addressing these causes requires measuring the processes involved, while sustaining improvements requires ongoing measures. The studies referenced in this review demonstrate that quality improvement projects can enhance efficiency by refining processes, improving communication, and lessening TOT. While the methods highlighted in these studies may be difficult to scale due to increased documentation workloads, there exists a substantial opportunity for the development of technologies capable of automating and measure and analysis of actionable data to transform the OR.

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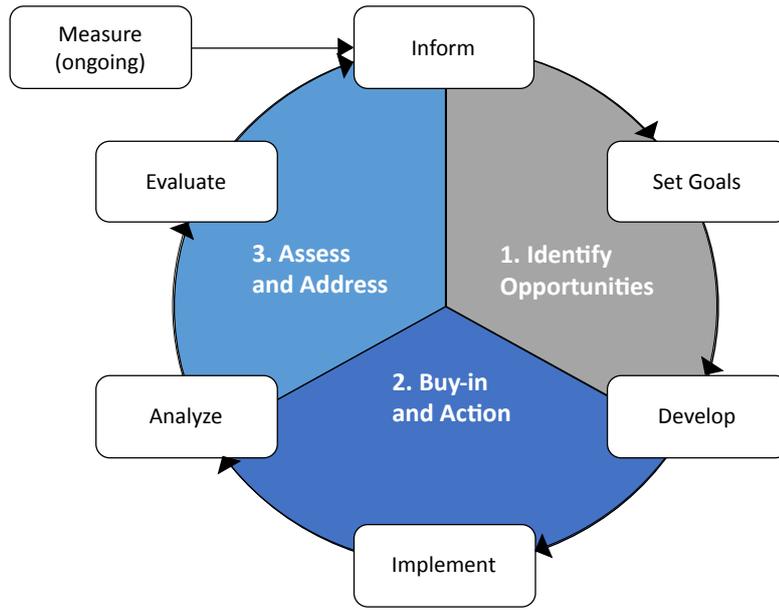


Figure 1. Schematic detailing the ongoing planning, implementation, and confirmation of a data-driven, OR efficiency quality improvement program

Ongoing:

Measure: Automated/Artificial Intelligence (AI) assisted sustainable and reliable measures (i.e.:Patient In to Anesthesia Start, Anesthesia Time, Anesthesia to Surgery Start, Surgical Time, Surgery Stop to Patient Out, Room Turnover by Process Step (Patient Out to Cleaning Start, Cleaning Time, Cleaning Stop to Patient In), Surgeon Turnover (defined as Surgeon Out to Surgeon In), Door Openings During Procedure, etc).

Phase 1:

Inform: Identify potential components slowing down processes.

Set Goals: Define and quantify intervention outcomes (i.e.: Reduce Patient Out to Cleaning Start from 5:00 to 0 minutes, reduce Door Opening During Procedure from 4 to 0).

Phase 2:

Develop: Identify and prioritize which processes to alter in quality improvement plan (QIP). Assign leaders/plan champions.

Implement: Discuss with staff tangible benefits of process alterations to institution, department, and individual (Buy-in). Implement QIP.

Phase 3:

Analyze: Automated/AI assisted systems display the results of the QIP for each metric

Evaluate: Team discussion of which processes improved, which metrics of OR efficiency were impacted, and new inefficiencies identified (return to Inform step and repeat)



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