Use of Lean and Six Sigma Methodology to Improve Operating Room Efficiency in a High-Volume Tertiary-Care Academic Medical Center

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BACKGROUND: Operating rooms (ORs) are resource-intense and costly hospital units. Maximizing OR efficiency is essential to maintaining an economically viable institution. OR efficiency projects often focus on a limited number of ORs or cases. Efforts across an entire OR suite have not been reported. Lean and Six Sigma methodologies were developed in the manufacturing industry to increase efficiency by eliminating non−value-added steps. We applied Lean and Six Sigma methodologies across an entire surgical suite to improve efficiency.

STUDY DESIGN: A multidisciplinary surgical process improvement team constructed a value stream map of the entire surgical process from the decision for surgery to discharge. Each process step was analyzed in 3 domains, ie, personnel, information processed, and time. Multidisciplinary teams addressed 5 work streams to increase value at each step: minimizing volume variation; streamlining the preoperative process; reducing nonoperative time; eliminating redundant information; and promoting employee engagement. Process improvements were implemented sequentially in surgical specialties. Key performance metrics were collected before and after implementation.

RESULTS: Across 3 surgical specialties, process redesign resulted in substantial improvements in on-time starts and reduction in number of cases past 5 PM. Substantial gains were achieved in nonoperative time, staff overtime, and ORs saved. These changes resulted in substantial increases in margin/OR/day.

CONCLUSIONS: Use of Lean and Six Sigma methodologies increased OR efficiency and financial performance across an entire operating suite. Process mapping, leadership support, staff engagement, and sharing performance metrics are keys to enhancing OR efficiency. The performance gains were substantial, sustainable, positive financially, and transferrable to other specialties. (J Am Coll Surg 2011;213:83–94. © 2011 by the American College of Surgeons)

Operating rooms (ORs) are often the largest contributors to a hospital's financial success. However, ORs also represent one of the most costly units within a hospital. As the health care economic environment becomes increasingly more challenging, increasing OR productivity represents a high priority. Efforts to increase OR productivity need to be counterbalanced against the impact on patient and staff satisfaction and, most importantly, patient and staff safety and ultimately patient outcomes. OR efficiency efforts that attempt to address many or all of these goals in a unified approach have not been widely reported.

A number of authors have reported on factors and processes that contribute to OR inefficiencies.[1-4] Numerous factors constrain OR productivity and efficiency, including infrastructure, human resource management issues, scheduling variation, process flow, technology issues, and infor-

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Abbreviations and Acronyms

Gen/CRS = general and colorectal surgery
GYN = gynecologic oncology surgery
LSS = Lean and Six Sigma methodologies
MCR = Mayo Clinic, Rochester
OR = operating room
RMH = Rochester Methodist Hospital
SPI = surgical process improvement
TS = general thoracic surgery

mation management limitations. Perhaps the greatest challenge for a high-efficiency OR environment is accounting for the variability in patient problems, operations types, and unexpected events that occur in any surgical practice. Most published reports have focused on minimizing variability in the procedure types or development of a small number of high-throughput ORs.[1,5] No reports have attempted to describe a process that can be applied across an entire surgical specialty or entire OR suite in an economically viable and sustainable manner.

The manufacturing industry has developed and managed their processes to maximize efficiency. Increased efficiency results in enhanced productivity, decreased personnel costs, reduced waste, and increased financial performance. Recently, the focus has shifted from efficiencies gained at the production level to efficiencies gained across the entire organization. Lean and Six Sigma are 2 methodologies that can be used at both the work unit and organizational level.[6-8] Both methods encompass a number of principles and tools designed to increase the efficiency of a process by reducing wasteful steps. The Lean process strategy is attributed to Taiichi Ohno, as reflected in the Toyota Production System.[9] In the Toyota Production System, specific types of manufacturing "waste," which absorb personnel, resources, or time but do not add value to the overall process or to the end user of the service or product are eliminated. Lean is a process that continually reduces waste and improves workflow to efficiently produce a product or service that is perceived to be of high value to those who use it.[10] Six Sigma is a different method to reduce process variation through the rigorous application of process metrics collection and statistical analysis.[11] The successful application of Lean and Six Sigma (LSS) and other similar management tools is not limited to manufacturing, but has been applied in the customer and financial service industries and the government.[12-14]

Increasingly, Lean and Six Sigma are being used in the health care industry. Similar to other industries, the use of these tools can be applied to several aspects of health care, including finance, inventory management, information processing, outpatient clinics, and inpatient setting.[15,16] However, reports of the effectiveness of using these management tools in the OR environment is quite limited.[17] Therefore, we report the use of a combined LSS methodology to improve OR efficiency across multiple surgical specialties in a large academic surgical practice.

METHODS

Setting

The Mayo Clinic, Rochester (MCR) is a tertiary-care academic medical center located in the upper Midwest. The 88 main ORs are divided between 2 acute care hospitals located on the MCR campus: Rochester Methodist Hospital (RMH) and Saint Marys Hospital. All ORs are staffed exclusively by MCR physicians, residents, nurses, and allied health staff, which totals approximately 4,000 people. The staff are employed under one organizational leadership structure with a unified policy and procedure manual for OR conduct. On average, 53,000 to 56,000 operations are performed annually.

Aim

In 2008, an institutional initiative was undertaken to improve OR efficiency. However, rather than focusing on one aspect of the OR process, it was decided to initiate a global assessment of patient flow from the surgical consult through postoperative recovery. An LSS approach was selected as the process improvement methodology. The initial step in the surgical process improvement (SPI) effort was to develop a value stream map of patient flow that detailed the event location, personnel, and information technology requirements, alternative pathways, key performance elements at each step, and bottlenecks (Fig. 1)

A multidisciplinary leadership team including surgeons, anesthesiologists, certified registered nurse anesthetists, registered nurses, administrators, systems and procedure experts, financial analysts, and information technology programmers analyzed the value stream map. Five work streams were identified that contributed to the flow of surgical patients. Smaller multidisciplinary teams were tasked to redesign these 5 work streams using LSS methodology. The objectives for each of the work streams included:

1. Unplanned surgical volume variation: Design scheduling processes that support improved OR use (ie, decrease both under- and overuse of OR resources).
2. Streamlining the preoperative process: Ensure appropriate preoperative patient testing and evaluation before surgery and reduce the redundancy of provider activity.
3. Reducing OR nonoperative time: Improve the efficiency of nonoperative processes (eg, surgical turnover times).

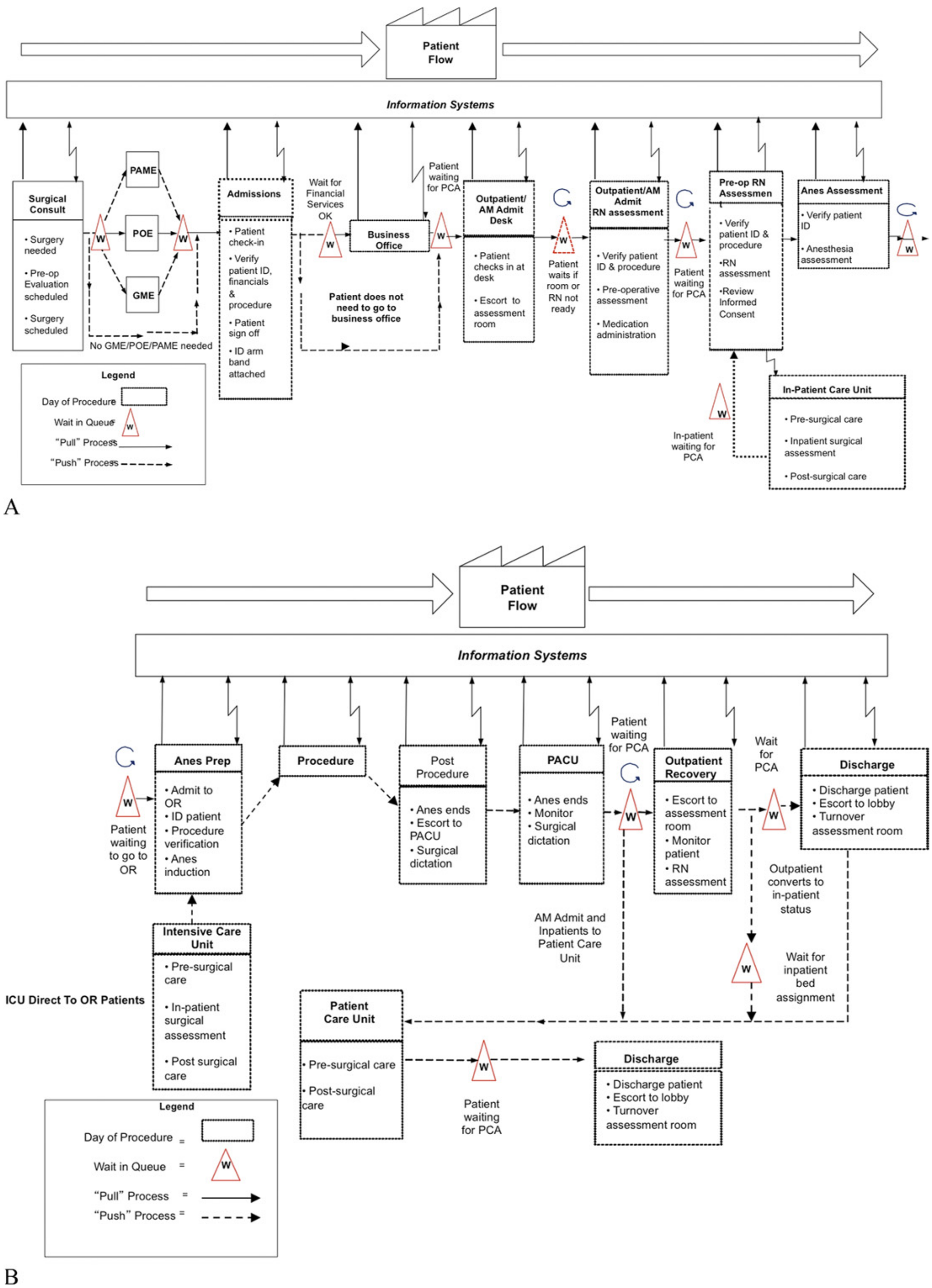

Figure 1. Current state value stream map of patient flow from (A) the time of the surgical consultation and (B) surgery and then discharge for a surgical patient at Saint Marys Hospital (SMH). GME, general medical examination; ID, identification; OR, operating room; PACU, post-anesthesia care unit; PAME, pre-anesthetic medical evaluation; PCA, patient controlled anesthesia.

4. Reducing the collection and documentation of redundant patient information: Reduce redundancy in the capture, entry, and reporting of patient information.
5. Employee engagement: Improve employee engagement and satisfaction across all surgical service constituencies.

Key findings and interventions

Each work stream team identified non−value-added steps and/or barriers to improving efficiency along the value stream map of the surgical process. Using a Define, Measure, Analyze, Improve, Control approach, interventions were designed and evaluated that addressed the issues identified as barriers to efficiency. Table 1 provides examples of identified barriers and implemented solutions. Key findings that were thought essential to the process improvement are described here.

1. Unplanned surgical volume variation: A key finding was that daily OR capacity was not adequately matched to demand. Daily volume variation was attributed to insufficient OR use/capacity information provided to the surgeons as they plan their operative schedule. This lack of coordination within a specialty interfered with developing an appropriate OR allocation strategy. To assist surgeons in scheduling, all prescheduled cases, estimated case durations, percentage OR use, and surgeon absences in each specialty were made available to the surgeons to improve decision-making when scheduling elective cases. In addition, there was considerable variability identified within specialties and among surgeons with regard to case listing descriptors. This variation interfered with standardized collection and use of procedure- and surgeon-specific case durations and equipment requirements. This limitation made prospective evaluation of OR use and case scheduling difficult. As reported previously, each surgical practice was required to develop standardized case listing descriptors.[18] Implementing Six-Sigma methodology resulted in a 60% and 53% decrease in surgical listing errors for colorectal and gynecologic oncology surgery, respectively. Standardized procedure descriptions facilitated development of a surgeon-specific procedure database that could be analyzed for pertinent procedure-related variables, such as case duration. Estimated duration by surgeon, including time between cases based on historical operative and prospective moving averages, was then displayed in the daily surgical list. This provided OR staff more accurate time estimates for individual surgeons and specific cases and, once pooled for entire specialties, enabled them to develop the daily OR use plan for the specialty. This knowledge facilitated sequencing of cases and helped to manage the need to open or close ORs within the specialty.
2. Streamlining the preoperative process: Numerous preoperative factors were identified that impacted OR throughput. The preoperative clearance of patients was found to be performed by more than 2 dozen specialty groups at MCR. This resulted in inconsistent preoperative patient evaluation, which contributed to day of surgery delays and cancellations. To address this problem, standardized preoperative assessment criteria based on procedural and patient risk factors were developed by partnering with the Department of Medicine and were implemented across MCR. The value stream map for the day of surgery preoperative process demonstrated an average time from patient arrival at the hospital to OR entry of 2 hours. To facilitate on-time OR starts, staggered OR start times (7:30 AM, 7:45 AM, and 8:00 AM) were implemented. Each OR had an assigned time that did not change, which allowed consistency of planning for surgeon and staff. Staggering OR starts allowed patient arrival times to the hospital to be varied. Rather than having a single report time for all first-case patients, 3 distinct hospital reporting times based on a formula (OR start time minus estimated admission time) were defined (5:30 AM, 5:45 AM, 6:00 AM). Patient entry into the Surgical Admissions area was accomplished through 3 separate self-triaging check-in lines based on report time. This change also facilitated scheduling intake personnel arrival to work-load demand.

   An important performance metric was achieving a high percentage of on-time starts. Common patient and procedural barriers to on-time first-case starts were identified and communicated to surgeons in the form of a checklist. To avoid altering hospital reporting times for the multiple support services (pacemaker service, radiology, interpreter services), cases that were identified as having any of these barriers and others, such as isolation requirements, were strongly discouraged as first cases.
3. Reducing OR nonoperative time: nonoperative time includes time in the OR required for anesthesia and nursing services to safely prepare a patient for surgery, as well as the time it takes to prepare the OR for a subsequent case. To decrease nonoperative time for subsequent (nonfirst) cases, parallel processing was implemented. For subsequent surgical cases, nonsurgical tasks normally performed in the OR were completed concurrent with the ongoing case. Preoperative procedure rooms (eg, placement of intravenous lines, arterial catheters, regional anesthesia) and induction rooms (eg, induction of general anesthesia and central line placement) were used for parallel processing in select pa-

Table 1. Objectives of the Five Work Streams, Findings, and Process Improvements

Work stream	Objectives	Process improvements
Unplanned surgical volume variation	To design scheduling processes that will support improved OR use (decrease under- and overused times)	Developed surgical case scheduling system that provides: Standardized procedure descriptions Required laterality by procedure Automated site marking indicator Required initial patient positioning Historical case durations and turnover times by procedure and surgeon Developed daily use threshold alerts (minimum and maximum) to smooth daily volumes, reduce variation, and improve OR use Ability to view scheduled hours, available capacity, and planned use across days, weeks, or months by surgeon and summarized by specialty Developed surgical scheduling/OR assignment guidelines to reduce scheduling variation
Streamlining the preoperative process	To ensure appropriate preoperative patient testing and evaluation, complete as many steps as possible before the day of surgery, and reduce redundancy of activity	Mapped existing clinical and financial preoperative processes to identify redundancies and waste Implemented triage guidelines to ensure patients receive the appropriate level of preoperative evaluation before the day of surgery Implemented staggered day of surgery report times Defined process step milestones based on historical preoperative process times Isolated administrative functions and designed administrative preoperative tasks to occur before the day of surgery Redesigned the admissions processes to ensure appropriate prioritization and on-time delivery of patient to OR Developed first-case scheduling checklist to eliminate barriers to on-time OR starts Consolidated and streamlined OR nursing assessment documentation
Reducing nonoperative time	To improve the efficiency of the nonoperative processes and patient flow	Evaluated current nonoperative time performance variance Mapped existing processes to identify redundancies and waste Established process definitions and metrics, such as case start and end activities Standardized preoperative OR RN nursing activities Provided consolidated view/print of all preoperative verification information to facilitate nursing activities Redefined roles and responsibilities to facilitate on-time starts Implemented parallel processing of anesthesia preparation tasks reducing wheels out to next wheels in time Instituted OR turnover task standards to reduce nonoperative time Provided transparency of monthly performance metrics to all staffs
Reducing redundant information collection	To reduce redundancy in the capture, entry, and reporting of patient information	Completed patient documentation analysis of every data element captured or viewed across the entire perioperative process Identified 10 application enhancements. Implemented automated transfer of information from clinic-based application to nursing-based application to eliminate redundant data entry Consolidated the inpatient and outpatient nursing record to share information Initiated effort to consolidate multiple nursing applications used within the OR to a single source system
Employee engagement	To improve employee engagement and satisfaction across all surgical service constituencies	Completed staff survey and results analysis Evaluated 21 key drivers of employee engagement Identified key drivers to focus on: Promotion of shared goals Encouragement of continuous professional growth Frequent recognition of individual employee contributions Executive demonstration of values; commitment to mission Timely communication of "newsworthy" information Active reinforcement of the value of employee input Implemented OR briefings with OR team Implemented preprocedure checklist Implemented use of SBAR (Situation, Background, Assessment, Recommendation) communication tool for hand off of patient information Initiated use of surgical safety checklist and preoperative OR staff briefings Created a Communication Council to effectively disseminate information throughout all levels of staff Initiated Town Hall meetings for leadership to meet with staff to discuss current issues, gather input, and feedback Designed and implemented critical language to open lines of communication

OR, operating room.

tients. Targets for time between cases were established for each specialty, and expectations were reviewed and responsibilities assigned to all surgical and anesthesia staff to achieve these time goals. Weekly performance metrics for each surgeon and OR team were posted monthly outside each OR. The metrics included percentage on-time, median turnover time, anesthesia OR preparation time, percentage OR closed by 5 PM, starts, incision to close time, minutes OR went past 5 PM.

4. Reducing the collection and documentation of redundant patient information: A complete review of all the electronic applications used from the surgical consult visit through the patient recovery was performed. Limited integration of the electronic applications resulted in staff inefficiencies and dissatisfaction. During the preoperative period from surgical listing to OR entry, 500 data elements were entered and viewed multiple times across the process. In addition, nomenclature was inconsistent and multiple naming conventions were present within the different electronic applications. Working with our information technology programmers, 10 major application enhancements were developed to standardize the data terminology and collection across the electronic applications. For the preoperative period, a line-by-line review of all information entered and viewed was performed. With the exception of information required by the Universal Protocol, collection of redundant information was removed. Information collected earlier in the preoperative process was autopopulated into applications further downstream. A comprehensive single-source application that encompasses the entire preoperative process is currently being developed with planned implementation in 2011.
5. Employee engagement: A major barrier to process change is ensuring agreement and active participation by all stakeholders. Staff satisfaction can substantially influence the long-term success of an efficiency initiative. A communication council was formed with representatives from all the stake-holder groups (surgeons, anesthesiologist, OR nurses, pre/post nursing staff, certified registered nurse anesthetist, certified surgical technicians, surgical assistants, resident staff, and OR administration). This group resolved concerns or differences between providers and set clear expectations for staff roles and responsibilities. The communication council formulated consistent communication plans to all stakeholders. A staff satisfaction survey was conducted and 21 drivers of staff satisfaction were identified. The 7 major elements of staff satisfaction were targeted as improvement initiatives. The communication council evaluated and implemented interventions based on the 7 major determinants of staff satisfaction within the overall process change (Table 1). Surgical leadership met with allied health staff in scheduled town hall meetings to facilitate information exchange. An important staff satisfaction driver and efficiency element is the daily preoperative briefing. Each OR has an assigned briefing time, which is typically 10 minutes before the scheduled start time. All members of the OR team (the surgeon, residents, anesthesia providers, nurses, surgical technicians, and assistants) attend the briefing. After introducing new team members or any visitors to the OR, the surgeon reviews all of the cases assigned to the OR. During the briefing, specific medical/surgical/anesthetic issues, the operative plan, personnel, or equipment needs are discussed. In addition, it provides an opportunity to discuss specific milestones that prompt activation for calling the next patient down to the operating suite. Also, during the initial implementation of the new system in each specialty, daily debriefings at the end of the day were conducted to identify opportunities for improvement. These were quickly communicated to leadership, evaluated, and implemented.

All work stream teams were given 6 months to complete their analysis and coordinate activities with other work streams. During this time, baseline data for 3 surgical specialties (ie, gynecologic oncology-RMH [GYN], general thoracic-Saint Marys Hospital [TS], and general/colorectal CRS-RMH [Gen/CRS]) were collected. These specialties were selected because of their high surgical volumes and diversity of case types. Implementation of SPI process improvements was done sequentially across the specialties. The process began with TS, followed by GYN-RMH, and finally Gen/CRS-RMH.

The financial performance metric was a normalized number calculated by average daily OR financial yield corrected for fixed (daily operational cost) and variable (overtime) personnel costs.

RESULTS

An important factor for on-time OR starts is ensuring that patients arrive in the preoperative area in a timely fashion. Changes in the admission process were measured in aggregate for all of the specialties during the study period. Patient wait times at the surgical admissions desk of longer than 10 minutes were significantly decreased after implementation of SPI (42% versus 12%; $p < 0.0001$). Similarly, on-time arrival (within 30 minutes of scheduled report time) to the preoperative area was significantly improved (81% versus 52%; $p < 0.0001$). Standardization of preoperative patient evaluation, elimination of barriers to first-case scheduling, and improved admissions processes resulted in a substantial improvement in on-time starts for each surgical specialty (Table 2).

Efforts to reduce nonoperative time between subsequent cases for a given OR were successful across all specialties. Parallel processing significantly improved overall turnover times (TS, 40 minutes versus 30 minutes; GYN, 35 minutes versus 20 minutes; Gen/CRS, 34 minutes versus 23 minutes; $p < 0.05$ for all) (Table 2). Although there were no specific efforts directed at reducing operative times (ie, incision to close time), there was a trend toward decreased operative times in 2 of the 3 specialties in the absence of any noticeable change in procedure mix (TS, 133 minutes versus 115 minutes; Gen/CRS, 128 minutes versus 117 minutes; NS for both).

Improved on-time starts, standardized room allocation guidelines, and parallel processing led to enhanced efficiency of the entire operative suite for the specialties. Overall, increased OR efficiency resulted in significant increases in the percentage of ORs closed by 5 PM for GYN and Gen/CRS (GYN, 42% pre-SPI versus 36% post-SPI; Gen/CRS, 37% pre-SPI versus 31% post-SPI; $p < 0.05$). Although thoracic surgery did not experience a change in the percent of time ORs were in use after 5 PM (34% pre-SPI versus 36% post-SPI), this finding was offset by a reduction in the number of ORs used by thoracic surgery per day by nearly an entire OR.

A basic assumption of the SPI initiative was that improved OR efficiency would result in improved financial performance. Despite a static or slightly unfavorable change in payer mix, improved efficiency did lead to improved OR financial performance (operating margin/OR/day) in all 3 specialties (TS, 22% positive; GYN, 16% positive; Gen/CRS, 50% positive). In addition, efficiency efforts have increased daily OR capacity (saved ORs per day: TS, 0.75; GYN, 0.55; Gen/CRS, 0.4). This increased OR capacity can accommodate incremental surgical case volume or reduce personnel costs by planned OR closures. In addition, an unexpected consequence of the SPI initiative was a reduction in the number of nursing and allied health staff required for daily operations despite an increase in surgical volumes. Additionally, the number of late shifts and overtime obligation (minutes/specialty/month) has decreased for surgical nursing and certified registered nurse anesthetist evening shifts by 30% and 50%, respectively.

Although OR efficiency might have improved considerably, sustainability of this process is contingent on continued staff support. Staff satisfaction was assessed before and after implementation of the SPI processes. In voluntary surveys electronically distributed to OR within the 3 specialties (86% response rate), the majority of care givers responded that they agree or strongly agree that communi-

Table 2. Key Performance Metrics for the 3 Surgical Specialties before and after Process Improvements

	Thoracic surgery			Gynecologic surgery			General/colorectal surgery		
Metric	**Pre-SPI (n = 735)**	**Post-SPI (n = 2,430)**	**Impact**	**Pre-SPI (n = 1,740)**	**Post-SPI (n = 2,430)**	**Impact**	**Pre-SPI (n = 1,685)**	**Post-SPI (n = 1,907)**	**Impact**
On-time starts (%)	50	80	$p < 0.05$	64	92	$p < 0.05$	60	92	$p < 0.05$
Operations past 5 PM (%)	34	36	$p = 0.34$	42	36	$p < 0.05$	37	31	$p < 0.05$
Average turnover (min)	40	30	25% reduction	35	20	43% decrease	34	23	32% reduction
Average staff overtime (min/specialty/mo)	109	92	16% reduction	106	87	18% reduction	87	41	53% reduction
Operating rooms saved/d/specialty	0	0.75	0.75 ORs saved	0	0.55	0.55 ORs saved	0	0.4	0.4 ORs saved
Change in operating margin/OR/d (%)	1.00	1.25	25% increase	1.00	1.16	16% increase	1.00	1.51	51% increase

OR, operating room; SPI, surgical process improvement.

cation and teamwork has improved as a result of the SPI process (TS, 90%; GYN, 77%; Gen/CRS, 90%). Although teamwork and communication among the specialties improved, 76% of respondents believed their individual efforts were increased compared with before the SPI initiative. At the time of implementation, resistance from members of the staff to SPI was common. The reasons for resistance were varied and diverse. One area of resistance centered on job security. Efficiency gains can be seen by surgical support staff as a threat to their position and livelihood. Despite an overall reduction in nursing and allied staff required for daily operations, no active employee was laid off or involuntarily reassigned to an alternative work area as a result of SPI. Nursing and allied health positions held by individuals who retired during the SPI process were not filled. Additionally, reduction in after-hour surgery has allowed reallocating late-shift personnel to earlier positions to facilitate the SPI initiative. The overall support by the staff for the SPI initiative has resulted in a sustainable performance for all 3 specialties (Fig. 2).

DISCUSSION

In the current health care environment, improving the efficiency of hospital ORs is an essential element of financial viability. Here we report on the use of LSS methodology to improve the efficiency of the surgical process across several surgical specialties and case types at an academic medical center. Using LSS management tools, a complete mapping of our surgical admissions and OR process was performed. Process changes resulted in substantial improvements in OR efficiency and financial performance as well as staff satisfaction. In addition, these gains were sustainable and applicable to other surgical specialties.

Previous reports have addressed OR efficiency focusing on a specific element of OR process, such as dynamic scheduling, turnover time, on-time starts, or intraoperative delays.[1-5] These efforts target individual or select elements of the surgical process or on a limited number of ORs or case types. Friedman and colleagues evaluated the impact of parallel processing on OR turnover for outpatient inguinal hernia repair (n = 138).[1] They found that when using a specially designed OR, turnover and anesthesia time could be reduced by the surgeon administering the local anesthesia in an induction room adjacent to the OR as it was being readied for the patient. In previous studies using this specially designed OR, parallel processing was mainly effective for a few selected case types or short operations.[3] Use of an induction room in a traditional OR environment was evaluated in 335 cases.[19] Anesthesia time was substantially reduced and the number of cases per OR increased. However, this increase in productivity required incremental anesthesia staff to achieve it. Our report differs in that we directed process improvements at the entire surgical trajectory from decision for surgery to leaving the OR. There are multiple components of the surgical process. Each component has built-in obstacles to efficiency. Efforts focusing on a single component of the process are unlikely to have a substantial or sustainable impact on the trajectory of the surgical process.

Both Lean and Six Sigma methodologies are quality improvement tools that have their origin in the manufacturing sector. Each is designed to improve quality and efficiency of a given process. Lean focuses on reducing wasteful or non−value-added steps in a process, and Six Sigma reduces process variation through the application of statistical methods. In many quality improvement projects, these different tools are complementary, which has led to merging them into a single strategy, ie, LSS.[17] LSS methodology has been applied to improving OR efficiency on a limited scale. Adams and colleagues predominately used a Six Sigma process to decrease turnaround time between general surgery cases.[20] Similar to our findings, they demonstrated that a decrease in turnaround time resulted in increased surgical throughput with a resulting positive financial return. In a study focusing on improving on-time starts, using LSS achieved an improvement from 12% on-time starts to 89%.[21] Despite successful implementation of LSS in the surgical environment, there remains a limited evidence base in the literature that applications of LSS are beneficial in the health care environment. In a systematic review of the literature, 177 articles on LSS use in health care have been published during the last decade.[17] However, only 34 report any process outcomes and less than one third included any statistical analysis confirming actual improvement in the measured process. In our experience, ongoing collection and analysis of performance metrics combined with feedback to all staff were essential in sustaining the gains. After 18 months, the 3 surgical specialties described in this report continue to meet their performance metrics, all of which are substantially improved when compared with baseline performance before the SPI initiative. More importantly, we have been able to spread this process across our entire surgical practice with similar improvements.

There are limitations to our study that might interfere with general implementation within most surgical suites. These limitations are not related to the LSS, which is easy to learn and implement. Rather, they are related to the organizational and infrastructure capabilities of our institution. MCR is a completely integrated practice under one organizational structure and leadership. All physicians and staff are employees of the institution. In addition, we have substantial OR capacity with 88 ORs available for daily use

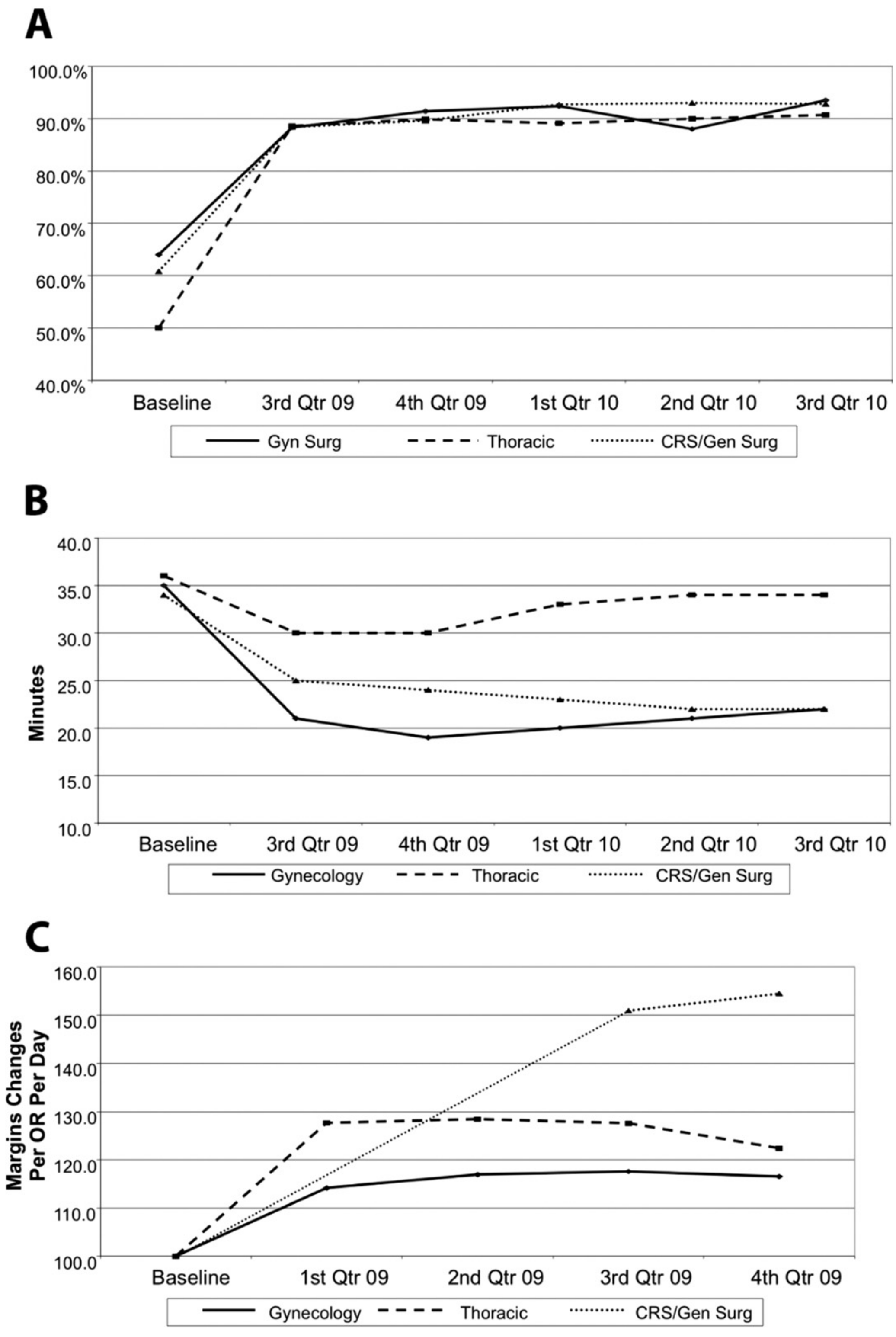

Figure 2. Durability of the process improvement is demonstrated by sustained performance on 3 major metrics. (A) Percent on-time starts, by specialty; (B) median room turnover, by specialty; and (C) margin changes per operating room (OR) per day, by specialty, baseline = 100. Solid line, gynecology; dashed line, thoracic; dotted line, colorectal surgery and general surgery.

and >20 additional outpatient OR/procedural areas available. Another unique practice is direct surgeon OR scheduling based on assigned rooms as opposed to traditional block scheduling. The majority of our surgeons operate on an every other day schedule, which also provides the patient the option of having next-day surgery. Next-day surgery increases variability in the system and a more dynamic scheduling system. In some practices, such as colorectal surgery, next-day operations can account for up to 60% of the daily schedule. Despite these differences, the primary finding of this study is that LSS methodologies can be used across a diverse high-volume surgical practice without increased expenditure of resources or infrastructure, resulting in substantial OR efficiency and financial gains. Many of these findings can be applied to other institutions.

CONCLUSIONS

We report application of a comprehensive LSS analysis and associated process improvement to increase OR efficiency at MCR. Using LSS methodology, multidisciplinary teams consisting of anesthesiologists, surgeons, nurse anesthetists, nurses, allied health staff, hospital administrators, financial analysts, systems and procedures and information technology personnel, identified multiple modifiable points across the surgical process. Process improvements based on these findings were applied to 3 different surgical specialties and resulted in substantial and sustainable increases in OR efficiency and financial performance. Based on our performance, we have introduced these processes across our entire surgical practice with comparable positive results. The success of LSS methodology combined with active and visible support from institutional and surgical leadership at all levels has made it our preferred approach to quality improvement projects at MCR.

Author Contributions

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