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Deliberate Perioperative Systems Design Improves Operating Room Throughput

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Background: **New operating room (OR) design focuses more on the surgical environment than on the process of care. The authors sought to improve OR throughput and reduce time per case by goal-directed design of a demonstration OR and the perioperative processes occurring within and around it.**

Methods: **The authors constructed a three-room suite including an OR, an induction room, and an early recovery area. Traditionally sequential activities were run in parallel, and nonsurgical activities were moved from the OR to the supporting spaces. The new workflow was supported by additional anesthesia and nursing personnel. The authors used a retrospective, case- and surgeon-matched design to compare the throughput, cost, and revenue performance of the new OR to traditional ORs.**

Results: **For surgeons performing the same case mix in both environments, the new OR processed more cases per day than traditional ORs and used less time per case. Throughput improvement came from superior nonoperative performance. Nonoperative Time was reduced from 67 min (95% confidence interval, 64–70 min) to 38 min (95% confidence interval, 35–40 min) in the new OR. All components of Nonoperative Time were meaningfully reduced. Operative Time decreased by approximately 5%. Hospital and anesthesia costs per case increased, but the increased throughput offset costs and the global net margin was unchanged.**

Conclusions: **Deliberate OR and perioperative process redesign improved throughput. Performance improvement derived from relocating and reorganizing nonoperative activities. Better OR throughput entailed additional costs but allowed additional patients to be accommodated in the OR while generating revenue that balanced these additional costs.**

This article is accompanied by an Editorial View. Please see: Dexter F: Deciding whether your hospital can apply clinical trial results of strategies to increase productivity by reducing anesthesia and turnover times. ANESTHESIOLOGY 2005; 103:225–8.

OPERATING room (OR) time is expensive, with an estimated cost of $10–30/min.[1,2] Concomitantly, minimally invasive surgery is increasingly prevalent, with longer setup times for the technology required to support minimally invasive procedures in multipurpose ORs. At the same time, changes in reimbursements and increasing costs create tremendous pressure to maximize surgical productivity from valuable OR space. Considerable recent effort has been applied to optimizing the use of OR time to improve access for patients, reduce costs, and improve patient and personnel satisfaction. However, emphasis on reduction of turnover time has not been rewarding. The achievable reduction in time between operations is likely to be too small to accomplish additional cases during regular OR hours.[3] Alternatively, the reductions in total case time that must be achieved to reliably accommodate an additional case within scheduled hours vary as a function of the total case time but are probably too large to be obtained by incremental improvements in standard perioperative processes.[4] Against this backdrop, we decided to change the basic paradigms by which one of our ORs functions, seeking to achieve increased throughput.

We[5,6] and other groups[7] are seeking to define the characteristics of the ideal OR for minimally invasive surgery. Our Operating Room of the Future (ORF) Implementation Project was designed for optimal support of advanced minimally invasive surgery, to allow technology assessment and development in a live, patient-care environment, and as a test environment to explore redesigning perioperative patient movement and work processes. Technologically intensive surgery requires extensive setup, and ORs at our institution do not have separate sterile setup areas. Furthermore, anesthesia induction is always conducted in the OR and is always preceded by room setup, creating an obligate serial processing workflow. Postoperatively, transfer to the postanesthesia care unit (PACU) entails another serial process, with time spent on (1) transferring the patient from the OR table to the gurney, (2) anesthetist-accompanied transportation to the PACU, (3) providing a report to the PACU nurse, and (4) occasional delays while waiting for PACU space. These serial perioperative processes incur Nonoperative Time (*i.e.*, time not spent performing surgery) and hence decrease the utilization of OR space and resources.

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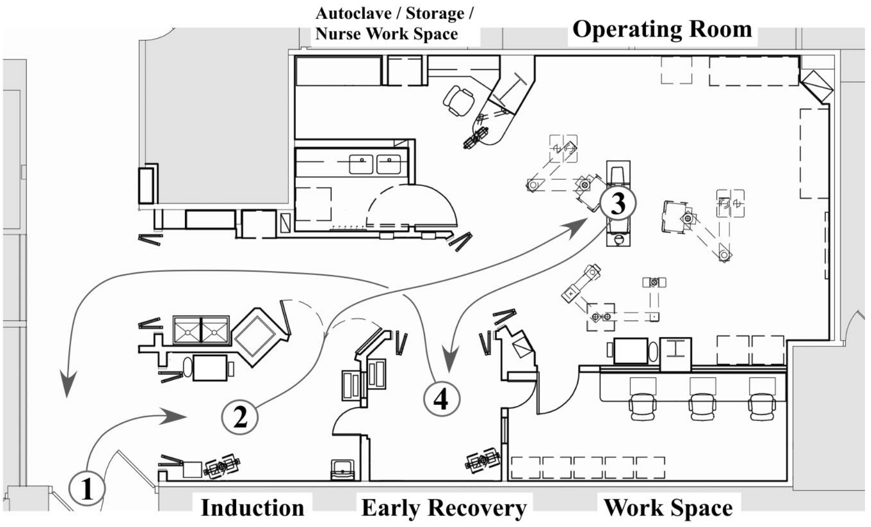

Fig. 1. Ground plan and flow diagram of patient movement through the Operating Room of the Future. Patients are brought from the main registration area (*1* and *arrow*) to the induction area (*2*). Preoperative preparation and induction of anesthesia occur in the induction area (*2*), concomitantly with instrument setup taking place in the operating room (*3*). The sequence is timed so that anesthetized patients are transferred to the operating room (*2*, *arrow*, and *3*) for surgery as instrument setup is completed. At the conclusion of surgery, patients emerge from anesthesia in the operating room and are promptly transferred to the early recovery area (*3*, *arrow*, and *4*), or emergence occurs in the early recovery area. After approximately 15 min of recovery, patients are transferred to the postanesthesia care unit (*4* and *arrow*) by the perioperative nurse. The work space provides access to the hospital information system. It is used by surgeons between cases for dictation, order writing, and teleconsultation with patients' families and by the anesthesia team during surgery for preoperative planning for subsequent cases.

We hypothesized that the barrier precluding additional productivity in conventional ORs could be overcome by a more radical redesign of OR processes than has heretofore been reported. To achieve this redesign, we undertook a multidisciplinary approach to reorganizing perioperative patient flow and work processes for maximum OR productivity, as assessed by increased throughput. In our ORF Implementation Project, we applied (1) advanced technology, (2) changes in OR architecture, and (3) reengineered work processes to enhance OR productivity. We sought to redesign the space and the processes it supports so that wherever possible, activities that do not require the OR were off-loaded to other locations, and whenever possible, activities that occurred serially in a typical OR setting were made to run in parallel in the new model.

We developed the following hypotheses for testing as outcomes of the ORF project: 1. The redesigned OR configuration and perioperative patient flow would increase throughput, reduce overtime, or possibly achieve both changes. 2. Not all surgeon/case type dyads would benefit equally from the new system, so that in some instances there would be no performance improvement. 3. The improvement in throughput would be due to improvements in ergonomics (*i.e.*, usability and layout of equipment in the OR), nonoperative process efficiency, or both. 4. Within our hospital's cost, compensation, and reimbursement structure, the incremental revenue from additional throughput would offset both the increased costs of running the redesigned OR and the additional costs associated with caring for more patients.

The purpose of this article is to describe the implementation of our ORF project and to test the hypotheses enumerated above by analysis of data obtained during routine patient care. Throughput and financial performance of the ORF relative to our hospital's standard ORs are reported.

Materials and Methods

Design and Implementation of the ORF

The ORF was constructed in 1,315 ft^2 (gross) of space constrained in all directions by the existing structure. This space had previously been a large rectangular storeroom surrounded on all but one of the short sides by other ORs. A multidisciplinary team solicited input from hospital OR personnel about what constituted an ideal OR. Next, they surveyed other "best-of-breed" ORs (*i.e.*, ORs thought to embody one or more of these ideals) in the United States and Europe and used the accumulated experience to inform the initial designs of the ORF. After several rounds of design refinement, including full-scale mock-ups and walk-throughs of patient flow in the space, a multiroom design was chosen. We constructed an OR suite with a functioning induction room and a room for early recovery, both attached to the OR (fig. 1). The specific arrangement and sizes of the rooms in figure 1 was strongly influenced by the walls and supporting columns of the surrounding building and so represents a compromise between the ideal OR and what was possible given the available space. Construction of a self-contained, three-room suite created an extra 120 ft^2 of patient care space (early recovery area) compared with a typical OR at our institution. In addition, the ORF suite contains 150 ft^2 of work space for surgeons to use between cases (fig. 1), with the goal of encouraging them to remain in the OR suite. Equipment in the ORF was chosen to facilitate throughput and improve working conditions for surgeons, anesthesiologists, and nurses. The OR table is a transporter/OR tabletop/fixed

Fig. 2. Mobile operating tabletop, transporter, and fixed base column used to facilitate rapid movement of anesthetized patients between areas in the Operating Room of the Future. The operating tabletop and transporter with patient can be easily moved between areas by a single person. No surface-to-surface transfers occur in the operating room. At the start of each case, anesthetized patients are brought into the operating room, the tabletop is docked to the fixed base column seen in the *right side* of the photograph, and the transporter is removed. All bed functions (*e.g.*, elevation, Trendelenburg position) are manually actuated on the transporter but electric on the fixed column. The physiologic monitor data acquisition unit is mounted to the operating tabletop (*arrow*), with a single cable connection to the monitor controller and display. A transport display is used to monitor patients traveling on the tabletop to and from more distant hospital units such as the intensive care unit.

column system (Maquet, Rastatt, Germany; fig. 2) that eliminates OR table-to-gurney surface-to-surface transfers in the OR. Monitoring is nearly continuous (without cable swapping) from suite arrival through discharge. This is accomplished by attaching the monitors to the under-bed surface (fig. 2, arrow). Patients may be transferred directly between ORF spaces or other hospital units (*e.g.*, intensive care unit) on the OR tabletop while fully monitored. The ORF itself contains a dedicated, integrated endosurgical equipment package (OR1; Karl Storz Endoscopy, Goleta, CA) that is mounted on ceiling booms to improve surgical viewing angles during laparoscopy and to facilitate room turnover between cases. The integrated OR system is specifically designed to minimize the number of devices that need to be individually connected and powered up at the start of each case and also allows the circulating nurse to control equipment and lighting without leaving the nursing station.

Comparator rooms, *i.e.*, "standard" ORs (SORs) were the same size as the ORF, *i.e.*, roughly 625 ft^2. ORF surgical and anesthesia equipment (other than the integrated endosurgical system) were equivalent to our typical institutional ORs and were consistent with the typical OR installations found throughout the United States. The ORF and SORs both included a dedicated induction area (roughly 130 ft^2 in each environment) used for patient preparation consisting of preoperative evaluation, vascular access, and transfer to the OR table. The ORF differs from the SORs in that the induction area is further used for application of monitors and induction of anesthesia to create the new anesthesia workflow described below.

Anesthesia Workflow

The obligate sequential processing at the beginning and end of each case and the PACU transfer process seemed to be obvious first targets for change to achieve improved throughput. Hence, in the ORF, induction of anesthesia runs in parallel with room setup. This is shown as a process flow diagram in figure 3. Similarly, at the end of the case, PACU transfer time is minimized by giving a report to ORF-stationed PACU personnel in parallel with the last stages of surgery (fig. 3). In both instances, surface-to-surface transfers are eliminated to facilitate the rapid transfer of patients between locations. The provision of an early recovery area in the ORF eliminates the need for anesthesia personnel to travel to the PACU.

The serial-to-parallel conversion of work processes is supported by a restructured perioperative care team including additional personnel. Specifically, the ORF care team includes a "perioperative" nurse who admits patients to the suite and provides early recovery care (including transport to the main PACU after early recovery is complete), allowing anesthesia personnel to move promptly to induction of the next patient. The ORF also has extra attending anesthesiologist resources. The attending supervision ratio in the ORF was maintained at 1:1 during the study, while 1:2 supervision was common but not exclusively the norm in SORs.

Outcomes Measurement

This study was conducted with the approval of the Massachusetts General Hospital Institutional Review Board (Boston, Massachusetts). The study design was a

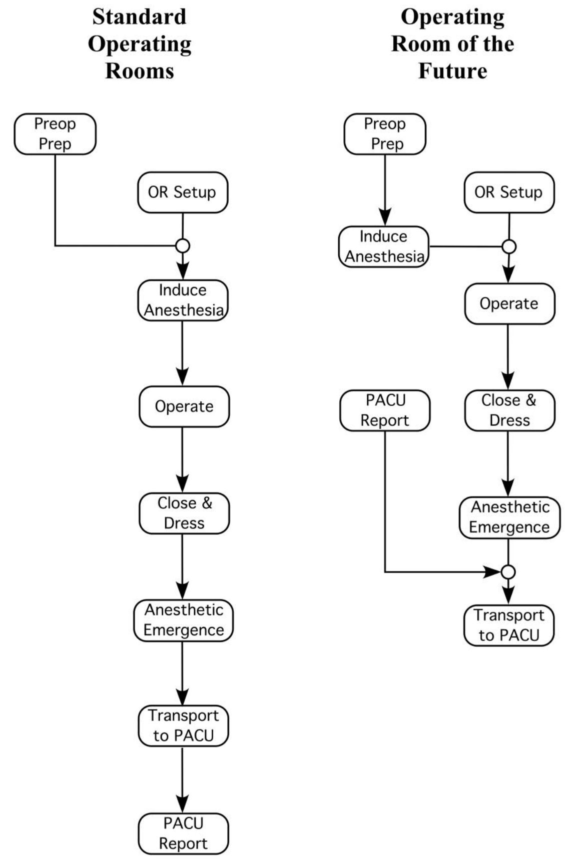

Fig. 3. Flow diagrams of the surgical process in standard operating rooms and the Operating Room of the Future. Anesthesia induction and the transfer-of-care report to the postanesthesia care unit (PACU) occur in parallel with other perioperative processes in the Operating Room of the Future. The main-line process is shorter in the Operating Room of the Future, and the impact of this reorganization is translated directly to reductions of the total process time, *i.e.*, the time from when a previous patient leaves the operating room after surgery until the current patient leaves the room. OR = operating room.

retrospective, case-matched comparison of the performance of the ORF with standard OR controls. Three general surgeons, a gynecologic surgeon, and a urologist used the ORF. All personnel worked in both the ORF and the SOR.

We obtained the data for this study by integrating three sources. Our institution uses an internally developed computerized system called the Nursing Perioperative Record (NPR) for perioperative documentation. This includes time stamps for key milestone events. The definitions of the relevant milestones and the intervals calculated from them are given in table 1. We also use an Anesthesia Information System (Saturn; Draeger Medical, Telford, PA), which replicates some of the milestone time stamps in the NPR and provides anesthetic milestones as well as demographic data. Cost information was obtained from the hospital cost accounting system (Eclipsys, Boca Raton, FL). We searched all three databases to create a new master database integrating all data elements needed for the study. The master database included all cases performed by each surgeon who had worked in both the ORF and SOR environments during the period encompassing September 1, 2002, to October 31, 2003. These dates were chosen because they encompassed all cases performed at the time of our institutional review board submission. The master database was the main source of information for the study. We also conducted a similar search of the NPR, Anesthesia Information System, and cost accounting databases for the period encompassing September 1, 2001, to August 31, 2002, for selected surgeons to obtain retrospective control data.

We validated the NPR time stamps by comparison with data collected prospectively by an expert observer. Prospective time data were collected using a personal digital assistant (PDA)–based system that automatically entered a time stamp when the field corresponding to each milestone was tapped by the observer. The PDA clock was synchronized with a network time server. Corresponding milestone time stamps entered by OR workers (who were unaware of the purpose of the prospective data collection) were extracted from the NPR. For each instance of an event, the difference (in minutes) between the PDA time stamp and the NPR time stamp was calculated. Then, for each milestone of interest, the mean difference (PDA − NPR) was calculated. These data were used to assess the precision and accuracy of the NPR time stamps that serve as primary data for this study.

The throughput characteristics of the ORF were assessed using a matched, retrospective design, with data extracted from the master database. For each surgeon, only completely blocked OR days (*i.e.*, same surgeon all day, last case is finished no earlier than 14:30) in which they performed the same repertory of procedures on the same patient population were considered in the throughput analysis. For the throughput analysis, we tabulated the number of cases per day and the total OR hours used (total hours from the time the first patient entered the OR until the last patient of the day left the OR), segregated by surgeon.

For analysis of case-level differences between the ORF and the SOR, we extracted from the master database all instances in which the same case was performed by a given surgeon in both environments. We used these data to assess the impact of the ORF on three major time intervals: the OR Total Process Time, the Nonoperative Time, and the Operative Time (table 1 and fig. 4). Where standard terms are available in the American Association of Clinical Directors Procedural Times Glossary,†† they are used in this report. We defined the OR Total Process Time as the time (in minutes) between a previous patient's departure from the OR and the current patient's

†† American Association of Clinical Directors Procedural Times Glossary. Available at: http://aacdhq.org?Glossary.htm. Accessed December 25, 2004.

Table 1. Summary of Milestones and Intervals Used

Name	Definition
Milestone	
Start of Anesthesia Care	Anesthesia clinician toggles event in Anesthesia Information System, denoting the beginning of billed activities
Anesthesia Induction	Anesthesia clinician begins administration of anesthesia and toggles event in Anesthesia Information System
Patient in Room	Patient crosses OR door threshold into OR
Ready for Surgical Prep	Patient is deemed ready for surgeon to begin positioning and skin prep
Surgery Start Time	Surgical instrument contacts patient
Surgery Finish	Dressing applied or drapes off if no dressing
Patient Out of Room	Patient crosses OR door threshold out of OR
Interval	
OR Total Process Time	Previous Patient Out of Room to current Patient Out of Room
Operative Time	Ready for Surgical Prep to Surgery Finish
Nonoperative Time	Previous Patient Out of Room to current patient Ready for Surgical Prep *plus* Surgery Finish to Patient Out of Room
Turnover Time	Previous Patient Out of Room to current Patient in Room
Total Preoperative Anesthesia Time	Start Anesthesia Care to Ready for Surgical Prep
OR Anesthesia Time	Patient in Room to Ready for Surgical Prep
Induction Time	Anesthesia Induction to Ready for Surgical Prep
OR Emergence Time	Surgery Finish to Patient Out of Room

Where standard terms are available in the American Association of Clinical Directors Procedural Times Glossary (http://aacdhq.org?Glossary.htm, accessed December 25, 2004), they are used in this report.

OR = operating room.

departure from the OR because departure time was the closest milestone to the beginning of OR setup that was available from any of the databases. The OR Total Process Time was divided into Nonoperative and Operative Times (table 1 and fig. 4). The Nonoperative Time was further subdivided into OR Anesthesia Time, OR Emergence Time, and Turnover Time (table 1 and fig. 4). Additional times considered were the Total Preoperative Anesthesia Time and the Induction Time (table 1).

We assessed the impact of the new process flow on nonoperative times using a case-matched design, controlling for surgeon and case type. From the master database, we extracted all instances of the same procedure performed by the same surgeon in both environments. First cases of the day were not included because the first milestone time defining the Nonoperative Time (previous Patient Out of Room) does not occur in the first case of the day. We controlled for any effects of the identity of the surgeon or the procedure (*e.g.*, appendectomy) on the global average nonoperative times as follows: (1) Only surgeon–procedure combinations occurring in both environments were included, and (2) equal numbers of each surgeon–procedure combination were considered in each environment by random culling of cases from the larger of each group. Next, the cases were collapsed over surgeon and procedure within each environment, and differences between group nonoperative time intervals for the ORF and SOR environments were assessed by direct comparison.

We tested for effects of the ORF environment on operative times relative to operative times for identical cases performed in the SOR as follows: We again extracted all instances of the same procedure performed by the same surgeon in both environments from the master database, but without excluding first cases. Because the proportions of each procedure performed in the two environments by the various surgeons were not balanced, equal numbers of each surgeon–procedure combination were established in each environment by randomly culling cases from the larger of each group. Surgeon identity[8] and procedure are major determinants of operative time. To remove procedure and surgeon effects from the comparison of operative times between the ORF and the SOR, we computed a standardized operative time (*z* score) for each case. For each procedure k (*e.g.*, appendectomy) performed in both environments by a given surgeon j, we computed a global average operative time, $AvgOpTime_{k,j}$, for all instances of procedure k in both environments. Next, for each instance i of procedure k (*e.g.*, appendectomy) performed in both environments by surgeon j, we computed a standardized operative time score, $ssOpTime_{i,k,j}$, given by $((Operative\ Time_{i,k,j} - AvgOpTime_{k,j})/\mathrm{SD}_{AvgOpTime_{k,j}})$. These were then collapsed over surgeon and procedure to make comparisons between the two environments for all cases, and for laparoscopic and open cases in separate groups.

In addition to analyzing the throughput differences between the ORF and SOR, we sought to evaluate the financial impact of running the ORF. For the purpose of this comparison, we assumed that the ORF functioned as an established OR with all capital and construction costs depreciated to the same extent as SORs. Therefore, we analyzed differences in (1) hospital costs, (2) costs and revenue for the anesthesia department, and (3) global

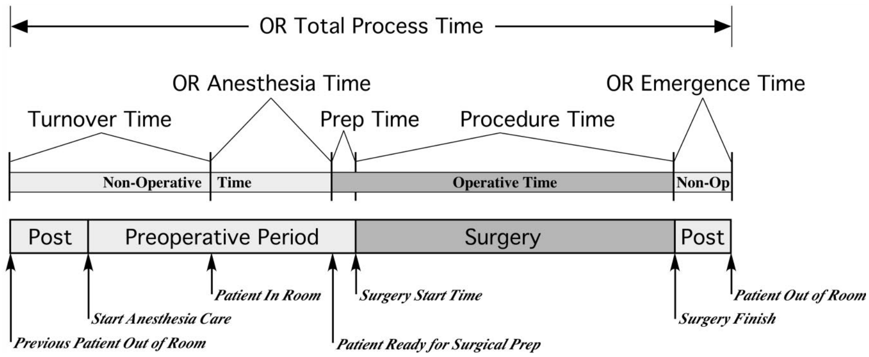

Fig. 4. Graphic illustration of operative and nonoperative time definitions and time intervals described in this report. Nonoperative Time encompasses preoperative and postoperative activities, including room cleanup after the departure of the previous patient, operating room (OR) setup, OR anesthesia time, and emergence from anesthesia. Operative time encompasses those activities (surgical prep and the operation itself) that must occur in the OR. Post = postoperative period.

net margin in each of the two environments. To perform these analyses, we collected the financial results for the cases used to compare operative times between environments above. Anesthesia costs and revenues for these cases were obtained from our department's payroll, billing, and revenue databases for the calendar period of the study. Revenue to the hospital for the entire hospitalization (excluding surgical professional fees) surrounding each case was obtained from the hospital cost accounting system. To quantify changes in OR costs due to the ORF, a modification of the standard cost accounting methodology used in the Eclipsys system was used. All of the cost centers relevant to the preoperative, intraoperative, and postoperative periods (including postoperative hospitalization) were included. Costs were adjusted within 12 months of the data extraction. As described below, we quantified the resources required to run the ORF and compared these to the expenses for running the SOR, controlling for surgeon and procedure.

We assumed that the cost of supplies would not vary between cases that are matched by surgeon and procedure. Therefore, we quantified the staffing portion of hospital costs for all perioperative care, starting from day-of-surgery preoperative care and extending to the end of the PACU recovery period. We assumed that the ORF would consume extra hospital resources relative to an SOR. For example, we judged that the technology-intense environment of the ORF requires more biomedical engineering resources. Hence, the expense associated with additional biomedical engineering resources should be reflected in the cost for OR time. To accomplish this adjustment for resource intensity in the ORF, all staff positions that support the ORs were reviewed to determine the magnitude of their involvement with the project. The contributions of all personnel involved in the ORF were quantified relative to their contributions to the SOR. Adjustments were made to reflect increased efforts by nursing, biomedical engineering, anesthesia technician, and OR administrative personnel, and these relative contributions (expressed as percentage of full-time employee effort) were then allocated to the downstream OR costs. These downstream costs are reflected in quantities known as Intermediate Products (IPs).

An IP is the cost accounting term used to define a given service provided to the patient. IPs can be both services and supplies. Examples of IPs include 1 MOR Hour, Team = 3; Level 1 Patch; and Admission to Recovery. Costs associated with the patient care experience and the resulting hospital charges are translated into IPs.

The IP associated with delivery of nursing care, *e.g.*, 1 MOR Hour, Team = x, deserves a fuller explanation. Patients at our hospital are billed in 30-min increments for their use of an OR. The costing methodology then consolidates these 30-min increments into 1-h IPs. One or two 30-min use increments are translated into a 1-h cost IP, three or four 30-min use increments translate into two 1-h IPs, and so on. MOR is an abbreviation for the Main Operating Room, the business unit in which both the ORF and the SORs are found. Team = x (where x is an integer) indicates the Team Count, *i.e.*, how many nursing and scrub personnel were required for a particular case. The team count is factored into the patient charge and, ultimately, the patient cost. There may be instances when another staff person is needed for part of the case, in addition to those required for the duration. If these additional staff are required for more than 50% of the surgery, they are included in the team count.

Summarizing the cost per IP unit and the IPs received by patients, the total OR costs for each case in the balanced group of cases used in the operative time analysis above were calculated. Next, the non-OR hospital costs for each case were combined with the OR costs. These data were combined with net revenue data for each case to derive the impact of the ORF on the net margin to the hospital. Costs to the anesthesia department (salaries, benefits, insurance, and fees) were calculated for each case using current (at the time) salary data for listed personnel. These were combined with payment data for the corresponding cases. Finally, hospital and anesthesia department financial data for each case were combined to calculate the "global" net margin. All financial data are reported relative to SOR performance.

Statistical Analysis

Process time data in healthcare settings frequently have rightward skewed distributions, arising from the fact that no procedure can be done in zero or negative time, whereas a few procedures take very long. Logarithmic transformation of time data before comparisons creates a data set that more closely approximates a normal distribution.[9]‡‡ Group means of logarithmically transformed continuous variables were compared using the two-tailed Student *t* test. For tests of significance on logarithmically transformed time data, the value of *P* reported is for the transformed data. Results were transformed back to units of time and reported as mean and 95% confidence interval (CI). Group means of financial variables were compared using the two-tailed Student *t* test on untransformed data. Financial results are reported as mean ± SD. Categorical variables, including the number of cases performed per day, were compared by chi-square analysis. In all comparisons, a *P* value of less than 0.05 was considered to be significant.

Results

ORF Throughput Analysis

Four of the five surgeons whose patients were included in the ORF study had blocked full days of equivalent case mix in both the ORF and SOR environments, either contemporaneously with the period of study or in the preceding year. One surgeon had no blocked full days in the SOR environment, neither contemporaneously with the period of study nor in the preceding year, and this surgeon's patients were not included in the throughput analysis. For each of the four surgeons included in the throughput analysis, a different pattern of cases per day and OR time usage was observed. The results are presented in table 2. For each surgeon shown in table 2, average patient age, sex distribution, American Society of Anesthesiologists physical status classification, and surgical case mix were not statistically significantly different between the two environments (not shown).

Surgeon 1 (table 2), performing laparoscopic prostatectomies and nephrectomies (operative time approximately 3.5 h), did not realize any increase in throughput when working in the ORF, nor was there a decrease in the OR time used during the period of the study. This surgeon was able to perform two cases per day in 8 h of OR time, regardless of the environment.

Surgeon 2, performing thyroid and parathyroid procedures (table 2), was able to perform five cases per day in each environment. Before moving to the ORF, Surgeon 2 incurred an average of 1 h of overutilized time per OR day in the SOR. After moving to the ORF, Surgeon 2 was able to accomplish the same five-case-per-day workload without overutilized time. Alternatively, Surgeon 3 (table 2) was able to accomplish additional cases in the same number of utilized hours in the ORF environment as compared with the SOR. Contemporaneous full-day comparison between environments was difficult for this surgeon because he had only 11 full-day blocks for this case mix in the comparator ORs after moving to the ORF. Therefore, Surgeon 3's case days from the year before moving to the ORF environment were matched to full days of the same case mix in the subsequent 14 months in the ORF environment.

Finally, Surgeon 4 (table 2) performed full days of mixed laparoscopic and brief open general surgery cases. Contemporaneous full-day comparison between environments was not possible for this surgeon because he no longer had full-day blocks for this case mix in the comparator ORs after moving to the ORF. Surgeon 4's case days from the year before moving to the ORF environment were matched to full days of the same case mix in the subsequent 14 months in the ORF environment. After moving to the ORF environment, Surgeon 4 was able to perform two extra cases per day while at the same time finishing the day's cases 1 h earlier than had previously been possible in the SOR environment. Examination of staff deployment records reveals that Surgeon 4 routinely enjoyed 1:1 staffing for anesthesia in the SOR environment, suggesting that improved

Table 2. Throughput Summary: ORF and SOR

	ORF	SOR	*P* Value
Surgeon 1			
Days	45	30	
Cases/day	2 (2–3)	2 (2–3)	NS
Total hours	8.5 (8.2–8.8)	8.9 (8.5–9.3)	NS
Surgeon 2			
Days	6	28	
Cases/day	5 (4–6)	5 (4–6)	NS
Total hours	8.7 (7.8–9.7)	9.9 (9.5–10.4)	< 0.02
Surgeon 3			
Days	60	67	
Cases/day	4 (3–5)	3 (2–4)	< 0.001
Total hours	9.1 (8.8–9.4)	9.1 (8.7–9.5)	NS
Surgeon 4			
Days	42	38	
Cases/day	7 (6–8)	5 (3–6)	< 0.001
Total hours	8.6 (8.3–9.0)	9.4 (8.9–9.8)	< 0.02

Data for the same group of surgeons performing the same case mix on matched patient populations (age, sex distribution, and American Society of Anesthesiologists classification not different between groups) in the Operating Room of the Future (ORF) and standard operating room (SOR) environments. Comparisons for Surgeons 1 and 2 were contemporaneous. The SOR data for Surgeons 3 and 4 were from the previous calendar year.

Cases/day data are presented as median and interquartile range. Cases/day is not a continuous variable, so comparisons were done using chi-square analysis, and the value of *P* reported is for this test.

Total hours data are presented as mean (95% confidence interval). Group means of total hours data were logarithmically transformed and then compared using two-tailed Student *t* tests. The value of *P* reported is for the transformed data.

NS = not significant.

‡‡ Although we present transformed data here, the mean differences and their significances were similar for comparisons of nontransformed time data, despite the fact that the distributions were skewed. We also computed the means and 95% confidence intervals for the log-transformed data according to the method of Zhou and Gao[10] and obtained similar results.

Table 3. Validation of Timestamps in the Nursing Perioperative Record

Time Point	Mean Difference (PDA − NPR)
Patient in Room	−0.4 ± 2.1
Ready for Surgical Prep	−0.8 ± 5.2
Surgery Start Time	0.5 ± 2.5
Surgery Finish	−1.4 ± 2.8*
Patient Out of Room	−0.5 ± 1.0*

Data (in minutes) are reported as mean ± SD. Where standard terms are available in the American Association of Clinical Directors Procedural Times Glossary (http://aacdhq.org?Glossary.htm, accessed December 25, 2004), they are used in this report.

* Mean difference statistically significantly different from 0.

PDA = personal digital assistant; NPR = Nursing Perioperative Record.

throughput in the ORF is not simply a result of additional anesthesia resources. During the study period, as many as 10 cases were done per workday in the ORF during Surgeon 4's regular hours.

Sources of Increased Throughput

We next examined whether the improvements in throughput and efficiency observed in the ORF were due to reductions in Operative Time, reductions in Nonoperative Time, or both. To accomplish this, we validated the accuracy of the OR milestone time stamps recorded in the NPR, which contain fields dividing the total case time into portions devoted to nonoperative and operative activities. Validation was performed by expert observation of OR process milestones, with automatic time stamping using PDA-based software. Interobserver reliability (reported elsewhere) for prospective time data collection was excellent. There was also excellent agreement between expert observation and the entries in the NPR (table 3). Therefore, the times in the NPR are reliable for the purpose of attributing reductions in OR process time to nonoperative or operative periods.

To examine the relative contributions of changes in nonoperative and operative performance to the increased throughput observed in the ORF, we first present a detailed analysis of an example case: Surgeon 4 performing laparoscopic cholecystectomy (fig. 5). We performed a contemporaneous comparison (SOR *vs.* ORF) of the OR Total Process Time (defined as Previous Patient Out of Room to Current Patient Out of Room, surgeons following themselves) for laparoscopic cholecystectomy. OR Total Process Time was reduced from 100 min (95% CI, 90–110) in the SOR (n = 27) to 66 min (95% CI, 63–70) in the ORF (fig. 5; n = 113, $P < 0.0001$). In this example, three such cases could theoretically be performed in the ORF in the time required for two in the SOR environment.

Operating Room Total Process Time for the example case is graphically broken down into its constituent intervals in figure 5. Operative Time is reduced from 42 min (95% CI, 38–47) in the SOR to 36 min (95% CI, 33–38) in the ORF. However, the reduction of the Nonoperative Time is much larger, going from 56 min (95% CI, 49–64) using SOR workflow to 29 min (95% CI, 26–31) in the ORF parallel workflow (fig. 5). Each of the measured intervals is meaningfully reduced in the new workflow, and all contribute to the reduction in OR Total Process Time.

Next, we examined all Operative Times as a group to determine whether the reduction in Operative Time seen in the example above was a general feature. We standardized Operative Times to remove the effects of surgeon identity and procedure (see Materials and Methods). For all cases in the ORF as a group, Operative Time is reduced by 5 min (table 4). The mean Operative Time for all cases included in table 4 is 105 min, so the observed difference between the ORF and SOR is approximately 5% of the total. When the cases are separated into laparoscopic/endoscopic and open groups (still collapsed over surgeon identity and case description), it becomes evident that open cases are accomplished more quickly in the ORF environment than in the SOR. On the other hand, laparoscopic cases have the same Operative Times in both environments.

Finally, we examined changes in the Nonoperative Time and its constituent intervals collapsed over a broad range of cases performed in the ORF and SOR. Surgeon and case identity effects were controlled as described in the Materials and Methods section. The results are shown in table 5. The average Nonoperative Time over all ORF cases considered in this analysis was 38 min (95% CI, 35–40), *versus* 67 min (95% CI, 64–70) in the SOR. There were no major differences in Nonoperative Time between open *versus* laparoscopic cases in either environment. For open cases in the ORF, the Nonoperative Time was 38 min (95% CI, 35–42), *versus* 64 min (95%

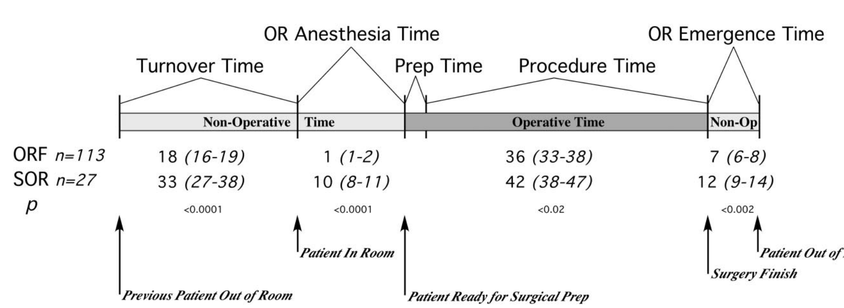

Fig. 5. Comparison of Operating Room of the Future (ORF) *versus* standard operating room (SOR) process times for the same surgeon performing laparoscopic cholecystectomy in the two different environments. Times (in minutes) are reported as average (95% confidence interval). Both the operative and nonoperative times are reduced, but the largest gains are found in the intervals comprising the Nonoperative Time. OR = operating room.

Table 4. Operative Times in the ORF and SOR

Standardized Operative Times	ORF, Mean ± SD	SOR, Mean ± SD	*P* Value
All cases			
Cases in each environment	372	372	
Standardized Operative Time, SD units	−0.08 ± 0.92	0.07 ± 0.94	< 0.05
Mean SD of Average Op-Time, min	32		
Op-Time Difference, ORF − SOR, min	−5		
Open cases			
Cases in each environment	175	175	
Standardized Operative Time, SD units	−0.15 ± 0.86	0.14 ± 0.97	< 0.005
Mean SD of Average Op-Time, min	29		
Op-Time Difference, ORF − SOR, min	−8		
Laparoscopic cases			
Cases in each environment	197	197	
Standardized Operative Time, SD units	−0.03 ± 0.97	0.02 ± 0.90	NS
Mean SD of Average Op-Time, min	35		
Op-Time Difference, ORF − SOR, min	None		

Mean Operative Times for the same group of surgeons performing the same case mix on matched patient populations (age, sex distribution, and American Society of Anesthesiologists classification not different between groups) in the Operating Room of the Future (ORF) and standard operating room (SOR) environments.

NS = not significant.

CI, 61–68) in the SOR. For laparoscopic cases, the Nonoperative Time was 37 min (95% CI, 34–39), *versus* 69 min (95% CI, 65–74) in the SOR.

Table 5 also summarizes the differences in the constituent intervals of the Nonoperative Time between the ORF and the SOR. Although it is tempting to attribute the reduction in Nonoperative Time solely to the higher anesthesia staffing ratio, examination of the constituent

Table 5. Total Process Times and Nonoperative Times

Nonoperative Times	ORF Mean (95% CI)	SOR Mean (95% CI)	*P* Value
All cases			
Cases in each environment	219	219	
OR Total Process Time	118 (109–128)	156 (147–166)	< 0.0001
Nonoperative Time	38 (35–40)	67 (64–70)	< 0.0001
Turnover Time	22 (21–23)	36 (34–38)	< 0.0001
Total Preoperative Anesthesia Time	20 (19–21)	24 (22–26)	< 0.001
OR Anesthesia Time	3 (3–3)	13 (13–14)	< 0.0001
Induction Time	11 (10–12)	7 (6–8)	< 0.0001
OR Emergence Time	9 (8–10)	14 (13–15)	< 0.0001
Open cases			
Cases in each environment	108	108	
OR Total Process Time	104 (95–114)	138 (129–147)	< 0.0001
Nonoperative Time	38 (35–42)	64 (61–68)	< 0.0001
Turnover Time	23 (21–25)	34 (31–36)	< 0.0001
Total Preoperative Anesthesia Time	20 (18–22)	23 (20–26)	NS
OR Anesthesia Time	3 (2–3)	13 (12–15)	< 0.0001
Induction Time	10 (8–11)	6 (5–8)	< 0.0005
OR Emergence Time	10 (9–11)	13 (12–15)	< 0.002
Laparoscopic cases			
Cases in each environment	111	111	
OR Total Process Time	134 (118–152)	177 (160–195)	< 0.001
Nonoperative Time	37 (34–39)	69 (65–74)	< 0.0001
Turnover Time	21 (19–23)	38 (35–41)	< 0.0001
Total Preoperative Anesthesia Time	20 (18–22)	25 (23–28)	< 0.005
OR Anesthesia Time	3 (3–4)	13 (12–15)	< 0.0001
Induction Time	12 (11–14)	8 (7–9)	< 0.0001
OR Emergence Time	9 (7–10)	15 (13–16)	< 0.0001

Mean OR Total Process Times and Nonoperative Times for the same group of surgeons performing the same case mix on matched patient populations (age, sex distribution, and American Society of Anesthesiologists classification not different between groups) in the Operating Room of the Future (ORF) and standard operating room (SOR) environments. Data are presented as mean (95% confidence interval [CI]), in minutes. Group means of time data were logarithmically transformed and then compared using two-tailed Student *t* tests. The value of *P* reported is for the transformed data. First cases of the day were excluded because Previous Patient Leaves OR, the milestone event beginning the OR Total Process Time and contributing to Nonoperative Time, does not occur for first cases.

NS = not significant; OR = operating room.

intervals of the Nonoperative Time in table 5 suggests that this is not the case. For example, the Turnover Time, which is minimally impacted by the anesthesia staffing ratio, is reduced from 36 min to 22 min in the ORF. All of the Nonoperative Time constituent intervals in the ORF environment are reduced relative to the SOR, with the exception of the Induction Time. The Induction Time in the ORF is actually longer (by approximately 50%) than in the SOR, suggesting that ORF anesthesia personnel are afforded a more leisurely induction process by performing this step off-line (figs. 1 and 3). Therefore, "velocity" of anesthesia care is not increased in the ORF, negating the notion that the increased anesthesia staffing ratio is the sole source of the reduced Nonoperative Times.

Cost and Revenue Analysis

We expected that the ORF would be more costly to run than the SOR based on cost estimates from our hospital cost accounting system, and this proved to be the case. Differences were found in both the cost per IP and in the sum of IPs used. The cost for 1 MOR Hour, Team = 2 was higher in the ORF than in the SOR, because the cost of more intense supporting resources is allocated to the nursing charge for the room. Besides having a higher cost per IP, we found that many ORF patients utilized more costly IPs (*e.g.*, 1 MOR Hour, Team = 3 instead of 1 MOR Hour, Team = 2). In each comparison (*i.e.*, cost, revenue, or margin), the data are presented with the quantity for the SOR mean value set equal to 1. All other quantities for that comparison are then scaled accordingly. Financial data are presented as mean ± SD. The OR cost of performing a case in the ORF as conceived and organized at our institution incurred a premium of 13% (SOR = 1 ± 0.58 *vs.* ORF = 1.13 ± 0.56; $P < 0.005$) relative to the cost of performing the same case in the SOR. The increased OR cost is driven largely by the additional personnel used to run the ORF.

Running the ORF also impacted the results for the anesthesia department, mainly because of additional personnel costs incurred by staffing the ORF at a 1:1 ratio. One-to-one anesthesia staffing in the ORF cost the department an additional 21% per case relative to the SOR (SOR = 1 ± 0.35 *vs.* ORF = 1.21 ± 0.87; $P < 0.0001$), assuming consistent 1:2 staffing in the SOR. Anesthesia net revenues per case for the ORF were similar to the SOR (SOR = 1 ± 0.70 *vs.* ORF = 0.97 ± 0.70; P = not significant). The net margin per case to the anesthesia department was negative in the ORF relative to the SOR (SOR = 1 ± 0.95 *vs.* ORF = −6.1 ± 0.70; $P < 0.0002$), reflecting the impact of the increased salary costs for 1:1 staff anesthesiologist coverage.

The ORF generates enough extra revenue (by virtue of the extra throughput it generates) to offset the additional costs relative to the SOR. We calculated the "global" net margin per case (for the entire admission) for the ORF and SOR cases considered in this study by subtracting total costs (SOR or ORF OR costs plus the remaining hospital costs and anesthesia costs) from the anesthesia and hospital net revenue. The average global net margin generated by ORF patients is statistically indistinguishable from the global net margin for SOR patients. We calculated the global net margin per day in each environment by combining the global net margin per case with the average number of cases per day performed in the ORF or the SOR. The additional throughput from the ORF generates sufficient revenue to offset increased total (anesthesia plus hospital) costs. The daily global net margin generated by the ORF due to additional throughput was not different from the global net margin generated in the SOR (SOR = 1 ± 3.1 *vs.* ORF = 1.12 ± 2.4; P = not significant).

Discussion

We have redesigned the OR workspace and anesthesia workflow for enhanced throughput. Other successful approaches to improving OR performance have focused on team training and emphasizing personal accountability,[11] interventions that may require ongoing reinforcement to maintain effectiveness. In contrast, the interventions in our ORF project are structural and permanent and have had a lasting impact without the need for reinforcement. Given that the interventions (*i.e.*, introducing parallel processing and improved in-OR ergonomics) were aimed at all parts of the OR process (*i.e.*, operative and nonoperative times), it was unclear at the outset of the project where the largest improvements in performance would occur. Our results clearly indicate that restructuring the perioperative processing model had the larger impact, although operative times were also slightly reduced. Regardless of the source, we expected more benefit from doing many short cases than from doing a few long ones. Our results support this hypothesis. Surgeons performing longer cases were unable to accomplish extra cases during the allotted time, whereas those performing shorter cases did extra cases in fewer hours.

Because the ORF uses additional nursing, biomedical engineering, administrative, and anesthesiology resources, we expected that it would be more expensive to run than the SOR. In this analysis, we have omitted surgical professional expenses and revenues because these are not expected to change based on the environment in which the case is performed. As expected, running the ORF costs the hospital more per case relative to the SOR. Similarly, staffing the ORF at a ratio of 1:1 and using a certified registered nurse anesthetist as the medically directed provider is a costly arrangement. For the anesthesia department, payer mix and staff compensation influence financial performance.[12] In our setting, intensive staffing raises compensation costs so that, on average, the anesthesia department loses money on every case. However, in exchange for the added cost per case, the institution is able to accommodate additional cases in the available OR space during regular business hours. Revenue from the additional cases apparently balances the added operational expenses, making the additional throughput capacity cost-neutral to the institution as a whole.

The cost estimates for running the ORF are subject to the limitations of our cost accounting system. Costs are accumulated in 1-h increments, regardless of the actual duration of effort required to complete a case. Therefore, using the detailed example of the laparoscopic cholecystectomy, 2 h of costs are accumulated in both environments (at a 20% higher cost per hour in the ORF) despite the fact that the ORF accomplishes the case in two thirds of the time, *i.e.*, 69 min *versus* 103 min in the SOR. The ORF also makes efficient use of fixed costs (such as personnel) by running a full schedule, *i.e.*, all allocated hours used, so that the full benefit of the costs is realized.

A discrete event simulation (performed before ORF implementation) based on a somewhat different anesthesia and nursing staffing model and using national average financial data indicated that parallel processing in the ORF would be cost effective.[6] The financial results presented in our current study, based on the actual ORF performance within our particular institutional setting, are less clear-cut. ORF costs are statistically significantly higher than SOR costs. In our analysis, we biased costs against the ORF. Also, our cost data are from a single cost structure, resulting in smaller variances for the cost data than for our revenue data. Taken together, these factors enhanced the likelihood of finding a significant increase in costs for the ORF. In contrast, revenue data (and hence margin data) for both ORF and SOR had large variances due to heterogeneity in our hospital's payer mix. Therefore, the revenue and margin samples have large variances, and our sample size is too small to adequately test for differences between the ORF and SOR.

It should be pointed out that the ORF Implementation Project was conceived and designed as a research space, rather than being optimized for cost-effectiveness. This makes it difficult to achieve a fair comparison of the financial performance of the room with the SOR, because the extra personnel resources allocated to the ORF to support the research mission are not always necessary for routine operations. Since the conclusion of the study, nursing resources have been adjusted downward, and the attending anesthesiologist is on many days available to cover a second OR. Throughput and nonoperative performance are unchanged despite the staff reductions. Furthermore, Surgeon 1 is now routinely able to accomplish three cases per day in the ORF but is still only able to accomplish two such cases in the SOR. However, none of these changes is captured in the reported financial impact analysis.

Another limitation of our study is that it encompassed many interventions at once: (1) a new workflow emphasizing minimal in-OR nonoperative activities, supported by (2) a new (for the United States) OR floor plan including a working induction area and a dedicated early recovery space, (3) additional personnel to allow parallel processing, and (4) mobile OR tabletops with integrated monitoring to facilitate rapid patient transfer between the spaces. Each of these features contributes to the enhanced function of the new system, which involves a complete redesign of the near-OR perioperative process. Therefore, it is difficult to attribute the observed improvement in performance to any one of the deployed interventions. However, some speculations are possible.

Considering all case types together, the ORF Implementation Project described here was able to save 38 min/case (roughly 25% of the original OR Total Process Time), largely by reducing the Nonoperative Time. The Nonoperative Time includes Turnover Time, OR Anesthesia Time (before the case), and OR Emergence Time. Reductions in each of these intervals contributed meaningfully to the overall reduction in Nonoperative Time, and potential contributors to each of these improvements can be identified. Turnover Time was reduced from 36 min to 22 min, and this could alternately be attributed to the presence of an integrated surgical system (obviating the need to acquire, configure, and connect the equipment between cases), the presence of extra personnel in the OR, or both. Dedicated minimally invasive surgery teams experienced in laparoscopic techniques can contribute to OR process efficiency.[13] Similarly, permanently deployed endosurgical equipment may reduce costs associated with setup and breakdown times.[14] Personnel and locations in our study were equally likely to be utilized for laparoscopy, but only the ORF had fully integrated laparoscopic equipment.

It is likely that the parallel flow achieved at the beginning of each case is responsible for the reduction of the OR Anesthesia Time from 13 min to 3 min/case. This is comparable to the effect seen by adding additional staff to induce anesthesia for following patients during current cases.[15] In both instances, activities were moved out of the OR (and off of the main process path in fig. 3), thus allowing them to occur at a natural pace while shortening the main process duration. At the end of surgery, the mobile OR tabletop and integrated monitors eliminated a surface-to-surface transfer in the OR, facilitating room exit. Furthermore, adding the perioperative nurse to the team enabled parallel processing of the PACU sign-out during the end of each case (fig. 3). The impact of this intervention is not fully captured in the current study. Separate prospective observation revealed that the process of traveling to the PACU and giving sign-out takes 13 min in the SOR, compared with

1.5 min for OR-to-recovery transfer and sign-out in the ORF. The ORF anesthesia provider then immediately joins the attending anesthesiologist to begin induction of the subsequent case. Therefore, the ability to run PACU sign-out in parallel with the end of the case and to eliminate transport saves approximately 11 min/case relative to the SOR work flow. Because the ORF Turnover Time is also reduced (by approximately 14 min), this reduction in sign-out time allows the ORF anesthesia team to remain in parallel synchrony with the OR setup team, fully capturing the benefit of the improved room setup time.

Each of the observed improvements in between-case performance of the ORF relative to the SOR is due to the summation of many linked improvements in perioperative processes owing to new technology, OR configuration, and changes in staffing patterns. In our setting, achieving parallel flow was dependent on having a working induction area, extra staff, and the ability of the mobile OR tabletop with integrated monitors to support rapid transfers of the patient between locations. Using this constellation of modifications, the ORF accomplishes extra cases, reduces overutilized time, or does both on most days.

Parallel processing models have been tried in other settings with mixed results. For example, providing extra personnel to induce regional anesthesia in a block room reduced the time between cases by 8–12 min.[16] The authors concluded, based on deterministic modeling, that this per-case time saving would not be sufficient to add another case but might reduce overtime personnel utilization.[16] In another example that was more directly comparable to the ORF, increasing staffing to allow induction of general anesthesia during the completion of a preceding case reduced between-case time by 13 min.[15] Time spent by surgeons in the OR increased, and the surgeons began their ward work later, resulting in longer surgical work hours. The authors concluded that although their intervention had reduced OR turnover time, the overall impact on the system did not justify the intervention. Anecdotal reports from the surgeons using our ORF reveal no such complaints, perhaps because our ORF Implementation Project included a work space with dictation, communication, and computer resources to allow the surgeons to work between cases without leaving the OR.

Operative times in the ORF are slightly but statistically significantly reduced for the same surgeon doing the same case, relative to the SOR. Again, no single cause for this effect can be readily identified. Other studies have shown that the composition of the surgical team affects OR times. The presence of surgical trainees during laparoscopic cholecystectomy significantly prolongs the procedure time[17] and can increase the operating time for common surgical procedures by 20–50%.[17,18] However, the presence or absence of trainees is unlikely to have influenced our results, because trainees worked in both environments. On the other hand, the composition of the rest of the OR team may have impacted operative times. All nurses and scrub technicians who worked in the ORF also worked in the SOR, but not all nurses and scrub technicians worked in the ORF. The ORF nursing and scrub technician team consisted of volunteers who may have been particularly motivated. However, the improved performance has been sustained over the entire period of the study. Alternatively, the improved operative time performance may have been attributable to improved surgical ergonomics from the dedicated endosurgical package, but this cannot be determined from the available data.

The ORF Implementation Project creates nontraditional clinical knowledge that is not completely captured by typical measurement tools. For example, experience reveals that the induction and early recovery spaces, although apparently small, are adequately sized for their purposes. In the induction and early recovery areas, every needed item is immediately at hand, but there is sufficient room for regional anesthesia and invasive monitor placement. In each room, the effective space can be significantly enlarged by opening the folding doors comprising one end of the room, allowing additional personnel to have access to the patient if necessary. Furthermore, improving the longitudinal aspect of care by adding the perioperative nurse cannot be quantified by time data. Similarly, an anesthesiologist who works in a standard OR may be under some pressure to anesthetize patients quickly because they are motivated to make productive use of the OR. By performing the induction— or any part of it—in parallel with OR preparation, some of that pressure may be relieved. The Induction Time (interval from Anesthesia Induction to Ready for Surgical Prep; table 5) is longer in the ORF than in the SOR. On the other hand, the Total Preoperative Anesthesia Time is reduced in the ORF, without any reduction in anesthesia task demands between the two environments. This suggests that the Total Preoperative Anesthesia Time difference between the ORF and the SOR is time in which the anesthesia team the SOR environment is waiting for release from other parts of the system to proceed, followed by expeditious induction of anesthesia. That is, establishing a parallel processing workflow may smooth the task demands on the anesthesia team.

One consequence of the increased throughput has been additional strain on preoperative and postoperative resources, illustrating the importance of considering the global effects of local changes to perioperative processes.[5] However, addition of the dedicated emergence area to this particular ORF Implementation Project buffers the effects of delays due to limited postoperative resources and allows the ORF to continue processing patients.

The ORF has improved perioperative throughput by a concerted group of interventions aimed at improving surgical ergonomics and reorganizing the perioperative workflow. Operating times (*i.e.*, interval from Patient Ready for Surgery to Surgery Finish) are only slightly impacted for the same surgeon doing the same case in SOR and ORF environments. In contrast, the nonoperative times (all other intervals) are markedly reduced in the ORF, where wholesale changes in the perioperative process were introduced. The reductions in nonoperative time alone are large enough to allow extra cases to be performed during regular work hours, with a neutral overall financial impact. In our setting, the reduction in nonoperative time is approximately 30 min/case, or approximately 40% of the preintervention nonoperative time, regardless of the case type. Therefore, if the average total OR process time is 2 h or less before a successful ORF implementation, additional cases can be performed in 8 h of scheduled OR time.

To meet the increased demands for surgical care in the current healthcare crisis, simply asking providers to work harder is not sufficient. We have shown that redesign of the perioperative, intraoperative, and early postoperative processes and architecture to support these functions can improve the effectiveness with which we provide surgical care. Viewed as a business proposition, the cost of added ORF staff is leveraged to produce markedly improved throughput with preserved net revenue. In conclusion, our work demonstrates that improving the effectiveness of surgical/perioperative care is feasible by working smarter without placing an additional burden on an already overworked operating room staff.

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