CARDIOTHORACIC ANESTHESIOLOGY:
The Annals of Thoracic Surgery CME Program is located online at http://www.annalsthoracicsurgery.org/cme/home. To take the CME activity related to this article, you must have either an STS member or an individual non-member subscription to the journal.

Improving Operating Room Turnover Time in a New York City Academic Hospital via Lean

Robert J. Cerfolio, MD, MBA, Dana Ferrari-Light, DO, MPH, Christine Ren-Fielding, MD, George Fielding, MD, Nissa Perry, MA, Annette Rabinovich, MHA, Mark Saraceni, MBA, Maureen Fitzpatrick, MSN, Sudheer Jain, MD, and H. Leon Pachter, MD, FACS

Departments of Cardiothoracic Surgery, Surgery, Hospital Operations, and Anesthesiology, NYU Langone Health, New York, New York

Background. **Prolonged operating room turnover time erodes patient and employee satisfaction and value.**

Methods. **Lean and value stream mapping was applied to three operating room teams at an academic health center in New York City, and a solution called Performance Improvement Team (PIT Crew) was piloted.**

Results. **Overall, 10% of operating room turnover steps were considered nonvalued and were eliminated, and 25% of previously sequential steps were performed synchronously. Seven institutional dogmas were eliminated, and three hospital policies were changed. After 35 pilot turnovers, median operating room turnover time improved from 37 minutes (range, 26 to 167 minutes) in historic matched controls to 14 minutes (range, 10 to 45 minutes, $p < 0.0001$) for the PIT Crew. Cost of the PIT Crew was $1,298 daily, and estimated return on investment was $19,500 per day.**

Conclusions. **Lean and value stream mapping identifies nonvalued steps in operating room turnover and affords opportunities for efficiency. Once institutional rules and dogma are changed, culture and workflow improve and turnover time substantially improves. This process adds cost but is profitable. Scalability and sustainability are under further study, as is the "halo effect" on the culture in other non-PIT Crew operating rooms.**

(Ann Thorac Surg 2019;107:1011–6)

Operating rooms are perhaps the most expensive and potentially the most lucrative part of many health care systems. The estimated cost of 1 minute in our main campus operating rooms at New York University Langone Health is approximately $150 per minute. Some institutions allow selected surgeons to run multiple operating rooms sequentially, but this practice is politically and legally controversial, can be difficult to organize consistently and efficiently, and is not the most efficient use of expensive resources [1, 2]. A model that reduces the turnover time to less than 20 minutes and allows other surgeons to use their resources in the same manner is preferred.

Perhaps the most common complaint of surgeons is "the wait to operate." In a standard workday devoted entirely to surgery from 7:00 AM to 5:00 PM, the typical surgeon spends less than 50% of this time actually operating [3–5]. The median turnover time of an operating room depends on the setting (ambulatory versus inpatient center), the type of operation performed (endoscopy versus cardiac surgery with cardiopulmonary bypass), and many other complexities. However, the obstacles to efficiency and throughput are often the same.

"Lean" is the concept of eliminating wasteful parts of a process and has been applied successfully to many operating rooms and health care systems [6–10]. The goal of this study is to test the feasibility of streamlining and improving operating room turnover time by implementing lean and value stream mapping at a New York University Langone Health System.

Patients and Methods

We gathered a multidisciplinary stakeholder team designated as the Performance Improvement Team (PIT Crew)

Dr Cerfolio discloses a financial relationship with Bovie, Community Health Services, Covidien/Medtronic, C-SATS, Davol/Bard, Ethicon, Google/Verb, Intuitive Surgical, KCI/Acelity Company, Myriad Genetics, Pinnacle, ROLO-7 Consulting Firm, and TEGO Corporation; Drs Christine Ren-Fielding and George Fielding with Allergan and Novare.

Accepted for publication Nov 30, 2018.

Presented at the Poster Session of the Fifty-fifth Annual Meeting of The Society of Thoracic Surgeons, San Diego, CA, Jan 26–29, 2019.

Address correspondence to Dr Cerfolio, Department of Cardiothoracic Surgery, NYU Langone Health, 550 1st Ave, 15th Flr, New York, NY 10016; email: robert.cerfolio@nyumc.org.

Published by Elsevier Inc.

0003-4975/$36.00
https://doi.org/10.1016/j.athoracsur.2018.11.071

that consisted of general surgeons, anesthesiologists and certified registered nurse anesthetists (CRNAs), anesthesia technicians, preoperative nurses, circulating nurses, certified surgical technologists, housekeeping staff, sterile processing staff, patient transport staff, elevator operators, pharmacy representatives, supply chain staff, infectious disease specialists, and hospital administrators. Each stakeholder group was assigned to value stream map their entire process for a surgical procedure, beginning with patient admission in the preoperative area and ending with patient transfer to the postanesthesia care unit. After each group mapped out every step in their entire process, the PIT Crew met and reviewed all processes together. Each step of each process was determined as "valued" or "nonvalued" and the "nonvalued" steps were eliminated. Valued steps are those that generate a positive return on the investment of resources and cannot be eliminated without impairing a process; in contrast nonvalued steps are those that that generate a zero or negative return on the investment of resources and can be eliminated without impairing a process.

Importantly, the valued steps were further reviewed and streamlined by removing unnecessary or duplicate movements. In addition, we reviewed which steps could be performed in parallel with other teams. The PIT Crew then vetted each process improvement to ensure that there were no unintended safety consequences, regulatory issues, or collateral damage to the PIT Crew or more importantly to other nonparticipatory surgical teams. After identifying all barriers and obstacles, the PIT Crew then simulated five trials with the new process. The goal was to pilot 1 day of surgery per week, with a minimum of five operating room turnovers per day. This pilot testing ran from February to April 2018. During this time frame, seven different days of surgery were tested with a total of 35 operating room turnovers logged for 42 cases. Data was prospectively collected by an administrative team member after each turnover. The PIT Crew also met on a weekly basis to review the data from the trial that week, to discuss obstacles preventing efficiencies. and to ensure patient safety and quality standards were met. Pilot testing with the PIT Crew model was then compared with matched historic data from October 2017 to January 2018, using the same surgeons and identical operations (69 turnovers for 86 cases). Because this was a quality improvement project, institutional review board approval and individual patient consent were waived for inclusion this study; however, consent was required and obtained to enter patient data into the prospective database.

Statistical Analysis

Data was gathered and stored in Excel (Microsoft Corp, Redmond, WA), and data analysis was performed with Excel (Microsoft Corp) and GraphPad Prism 7 (GraphPad Software, LLC, La Jolla, CA). Descriptive statistics are shown by the use of means and medians as appropriate. Nonparametric continuous data were compared with the Mann-Whitney U test when indicated. A p value of less than 0.05 was considered significant.

Table 1. Operation Types for Surgeon 1 and Surgeon 2 for Historic and PIT Crew Operations

Operation Type	Historic Operations, n	PIT Crew Operations, n
Surgeon 1	50	31
Laparoscopic gastric band insertion	10	2
Laparoscopic gastric band revision	6	3
Laparoscopic gastric band removal	5	0
Laparoscopic cholecystectomy with cholangiogram	1	4
Laparoscopic hiatal hernia repair	3	2
Laparoscopic Roux-En-Y gastric bypass	3	2
Laparoscopic gastric resection (vertical sleeve)	17	17
Open ventral hernia repair	0	1
Laparoscopic biliopancreatic diversion with duodenal switch	1	0
Excision soft tissue mass	1	0
Diagnostic laparoscopy	1	0
Laparoscopic Heller myotomy	1	0
Laparoscopic inguinal hernia repair	1	0
Surgeon 2	36	11
Laparoscopic gastric band insertion	1	2
Laparoscopic gastric band revision	3	3
Laparoscopic gastric band removal	2	1
Laparoscopic cholecystectomy with cholangiogram	3	0
Laparoscopic hiatal hernia repair	2	0
Laparoscopic Roux-En-Y gastric bypass	3	0
Laparoscopic gastric resection (vertical sleeve)	21	5
Open ventral hernia repair	0	0
Diagnostic laparoscopy	1	0
Total number of cases	86	42

PIT = Performance Improvement Team.

Selection Criteria

We selected two general surgeons who historically had performed up to eight elective minimally invasive abdominal operations per day. In addition, these surgeons were chosen because they displayed a history of efficiency and performing short operations (median operative time, 50 minutes; range, 40 to 90 minutes).

Definitions

Operative time is defined as time from skin incision to skin closure. Operating room turnover time is defined as the time from when the wheels of a patient's bed exited the operating room to the time when the wheels of the next patient's bed entered the operating room.

Results

The operations for the two surgeons in this study are listed in Table 1. The streamlined processes for select PIT Crew members are illustrated Table 2. The operations, surgeons, and other team members (except for additional PIT Crew

Table 2. Streamlined Processes for Selected PIT Crew Members

Historic Tasks, n	Details of Historic Tasks	Tasks Removed, Streamlined, or Paralleled, n	Details of Tasks Removed, Streamlined, or Paralleled
Anesthesia (physician and CRNA)			
13	1. Preoperative assessment of patient in holding area 2. Obtain informed anesthesia consent from patient 3. Review and place medication orders 4. Order preoperative medications if required 5. Site marking if required (for anesthesia procedures) 6. Order preoperative antibiotic 7. Travel with patient from holding area into OR **8. Update anesthesia record during case** 9. Move patient from OR to PACU after case 10. Anesthesia emergency protocol postoperatively in OR **11. Give patient report to PACU nurse after case** **12. Assist anesthesia technologist with preparing room/ anesthesia equipment** **13. Evaluate next patient in holding area**	4	8. Now in parallel by CRNA 11. Now in parallel by CRNA 12. Now in parallel by CRNA 13. CRNA stays in OR to finish case while anesthesiologist leaves room to evaluate next patient
Anesthesia technologist			
12	**1. Prepare anesthesia machine/equipment before case** 2. Obtains and delivers specialty items (bronchoscopes, endoscopes, etc) to OR as needed for case 3. Set up transesophageal echocardiogram equipment 4. Deliver oxygen, pulse oximeter, and transport monitor to OR 5. Deliver patient transport monitor to OR 6. Move anesthesia machine (disconnect/reconnect) and ensure proper communication with electronic medical record 7. Restock anesthesia supplies and carts **8. Obtain anesthesiology medications from automated medication dispensing system** **9. Prepare intravenous medication drips** **10. Assist anesthesiologist as needed** **11. Obtain surgical, anesthesia, and specialty equipment from central sterile area and bring to OR** **12. Remove used anesthesia circuit tubing and trash/used linen from OR after case**	6	1. Removed; now prepped before first case of the day for all cases 8. Removed; now prepped before first case of the day for all cases 9. Removed; now prepped before first case of the day for all cases 10. Now in parallel with CRNA 11. Now in parallel with CST 12. Now in parallel with housekeeping
Circulating nurse			
13	1. Review patient chart for completion of documentation 2. Receive in-person patient handoff report from prep nurse 3. Deliver patient specimen after case to pathology department for processing 4. Add patient positioners (eg, arm boards, footboards) to OR table 5. Obtain medications to be used during operation from automated dispensing medication system **6. Walk to obtain supplies from surgical supply room during case when needed** **7. Walk to preoperative holding to interview patient** **8. Move OR equipment to correct position (eg, laparoscopic screens, towers)** **9. Open and review surgical instrument trays** **10. Move OR table back to original position after case concludes** **11. Dress OR table with clean linen** **12. Interview patient in preoperative holding before case** **13. Escort patient from preoperative holding into OR**	8	6. Removed; all supplies are now picked the day before cases and placed in case cart near OR 7. Removed 8. Now in parallel with PST 9. Now in parallel with PST 10. Now in parallel with housekeeping 11. Now in parallel with housekeeping 12. Now in parallel with nurse facilitator 13. Now in parallel with nurse facilitator
CST			
6	1. Gather surgical instrument trays for procedure from sterile core 2. Bring surgical instrument trays into OR 3. Set up sterile OR tables for surgical instruments 4. Open/review surgical instrument trays 5. Count surgical instruments **6. Remove dirty instruments from OR and walk to sterile core**	1	6. Now in parallel with PST

(*Continued*)

Table 2. Continued

Historic Tasks, n	Details of Historic Tasks	Tasks Removed, Streamlined, or Paralleled, n	Details of Tasks Removed, Streamlined, or Paralleled
Housekeeping			
5	**1. Wipe down OR table, instrument tables, and other equipment** **2. Sweep and mop floor** **3. Remove trash from OR** 4. Move OR table back to original position after case concludes 5. Dress OR table with clean linen	3	1. Now in parallel with second housekeeper 2. Now in parallel with second housekeeper 3. Now in parallel with second housekeeper
Patient transport			
7	1. Receive patient bed request 1 day before operation 2. Arrange needed wheelchairs for patient transport to OR 1 day before operation 3. Wait in holding area the morning before first case to escort patient to OR 4. Deliver patient from holding to OR **5. Wait with patient outside of OR doors for circulating nurse** **6. Wait for next transport request** **7. Walk to holding area to pick up next patient when transport request is received**	3	5. Removed 6. Removed 7. Now streamlined during previous case, no longer waiting for request
Patient support technician			
4	**1. Walk to obtain supplies from surgical supply room during case when needed** **2. Escort patient from preoperative area into OR** 3. Move OR equipment to correct position (eg, laparoscopic screens, towers) 4. Open and review surgical instrument trays	2	1. Removed 2. Now in parallel with circulating nurse

The boldface tasks correspond to the tasks that were removed, streamlined, or paralleled.

CRNA = certified registered nurse anesthetist; CST = certified surgical technologist; OR = operating room; PACU = postanesthesia care unit; PIT = Performance Improvement Team; PST = patient support technician.

members) were identical in the two groups. The historic and PIT Crew operation outcomes are shown in Table 3 and Figures 1 and 2, respectively. Median operating room turnover time was reduced from 37 minutes (range, 26 to 167 minutes) in the historic group to 14 minutes (range, 10 to 45 minutes) in the PIT crew group ($p < 0.0001$).

Comment

Prolonged operating room turnover time remains an area of frustration for surgeons, anesthesiologists, members of the perioperative staff, and administrators. In addition, long operating room wait times erode patient satisfaction [11]. Perhaps the greatest reason for this universal hospital problem is the lack of alignment between operating room stakeholders. Surgeons are incentivized by volume and quality, whereas often times nurses and anesthesiologists are commonly paid hourly [12–14]. Most all stakeholders in health care work collaboratively to ensure the highest quality and safety for patients. However, surgeons cannot go home until all of their case volume is complete. Labor unions, hospital dogma, and institutional policies are common cultural barriers to change. There are many costs to prolonged operating room turnover time, including the inability to perform more electively scheduled operations, the added cost of overtime, the erosion of work–life balance, and the opportunity loss of performing an operation on urgent patients in the emergency department or hospital consults.

The most challenging obstacle was the workflow of the anesthesiologist. If an anesthesiologist is the sole practitioner during an operation, he or she is not able to leave the operating room to prepare the next patient until the operation has concluded. One of our first steps was to ensure that all operations during the PIT Crew trial included a CRNA with the anesthesiologist. This allows the anesthesiologist to leave the operating room before the preceding case has concluded to meet the next patient in preoperative holding, start the patient's intravenous line, and obtain consent for anesthesia. In addition, we

Table 3. Historic Versus PIT Crew Outcomes

Outcome	Historic Operations	PIT Crew Operations	*p* Value
Number of operations	86	42	
Number of operating room turnovers	69	35	
Operating room turnover time, minutes			
Minimum	26	10	
Maximum	167	45	
Median	37	14	<0.0001

A Mann-Whitney U test indicated that the median operating room turnover time was significantly less for the PIT Crew operations (n = 42, median was 14 minutes) than for historic operations (n = 86, median was 37 minutes), $U = 95$, $p < 0.0001$, two-tailed.

PIT = Performance Improvement Team.

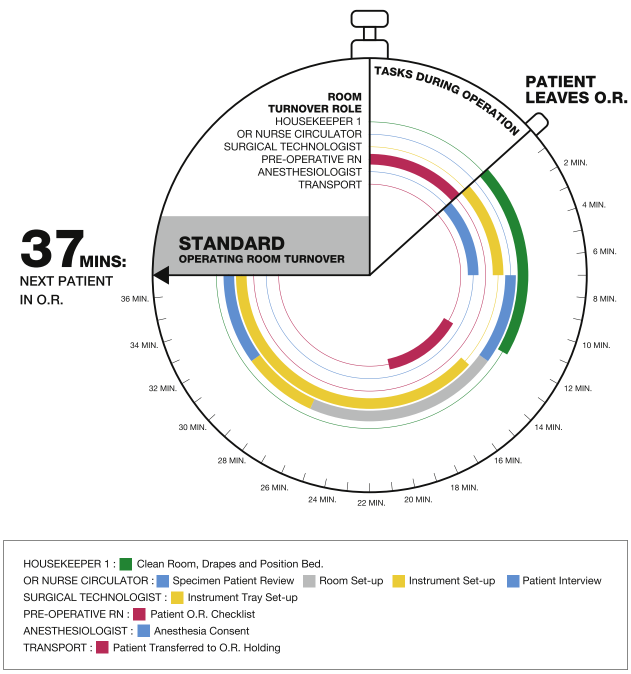

Fig 1. Selected team member tasks during the standard (ie, historic) operating room (OR) turnovers. Note the median turnover time is 37 minutes. (MN = minute; RN = registered nurse.)

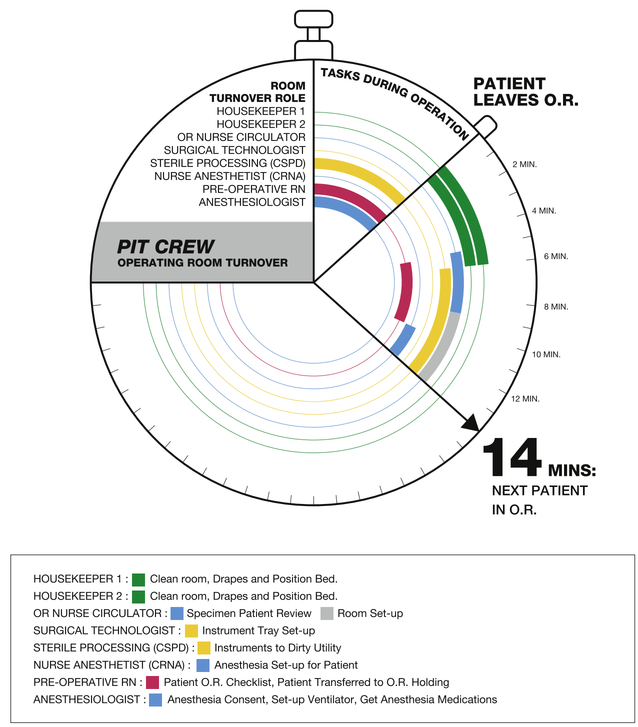

Fig 2. Selected Performance Improvement Team (PIT) Crew team member tasks during PIT Crew trial operating room (OR) turnovers. Note the median turnover time has decreased to 14 minutes ($p < 0.0001$). (CRNA = certified registered nurse anesthetist; CSPD = central sterile processing department; MN = minute; RN = registered nurse.)

eliminated anesthesia travel time to the pharmacy for medications used that day. We received regulatory permission to draw up all of the patient's anesthesia medications and set up the patient's intravenous equipment and deliver them the night before.

Another change we made was to the circulating nurse task list. It was observed that many of the tasks performed by the circulating nurse during turnover time required travel to other areas of the operating room, such as walking to surgical supply room to retrieve supplies or walking to preoperative holding to interview the patient. In the PIT Crew operations, all anticipated surgical supplies were stocked in a case cart the night before and a checklist was implemented. This eliminated two tasks for the circulating nurse as noted in Table 2. Simultaneously, we also assigned several tasks to be streamlined and performed in parallel to increase efficiency and reduce redundancy, as shown in Table 2.

These improvements to the PIT Crew team had cost; the overnight pharmacist was $373.04 per day and the dedicated anesthesia technician was $428.70 per day. A housekeeper was added for the PIT Crew trial, bringing the cost of dedicated housekeeping staff to $248.56 per day. In our subsequent iterations of the PIT Crew, we have eliminated the cost of the second housekeeper and better used additional housekeepers. If a minimum of five cases were performed each PIT Crew trial day, an estimated 70 minutes per day of nonvalued time was eliminated and thus the opportunity gain of performing another operation in that room without the cost of overtime staff.

Gottschalk and colleagues [15] examined operating room turnover times in hand surgery at a specialized orthopedic hospital and an ambulatory surgical center, also located in New York City. Their data suggest that surgeon presence in the operating room and earlier case times (among others) were factors that contributed to decreased turnover time. Although not specifically studied in the PIT Crew team, we have found that surgeon's presence around the operating room during turnover over time and their direct presence in the operating room as soon as the patient enters does predict shorter total operative times.

One concern of this study was not only patient safety but also the safety of the PIT Crew members. We were concerned that pressure for a decreased turnover time could potentially lead to employees slipping or falling on wet, recently cleaned operating room floors. There were no injuries to the PIT Crew team members or to patients during this study. There were no reports of decreased efficiencies in other operating rooms or other safety issues identified.

Perhaps one of the most important findings of this study is that we were able to engage different team members from multiple disciplines and to foster their ability to work together as a team to solve a shared problem. It is important to note that the true return on investment depends on the surgeon, his or her direct and indirect cost, the payer mix, the profit margin of the operations selected, the type of workforce used (overtime versus non-overtime staff), and improved throughput. As improvement is made and culture changes, an interesting finding is the "halo effect" that may lead to improved operating room turnover time in non-pilot situations (ie, non-PIT Crew).

During the PIT Crew study, a third general surgeon operating in a nearby room expressed interest in reducing his own turnover time without the PIT Crew during the time frame of this study. This data were obtained to ensure that we did not increase the turnover times of other operating rooms, and, although not a primary end point of this study nor reported in our results section, it is an important finding that deserves comment. He piloted his own improved turnover time with no added cost and no formal PIT Crew. Over the length of the study, his median turnover time decreased from 36 to 32 minutes. More impressively, for the first time in his 30-year career at our institution, he was able to achieve six operating room turnover times less than 20 minutes. These improvements all occurred during the time of our study and may result from a halo effect and culture change.

Strengths of this study include the prospective nature of the design, the review of all team members' processes, the prospective data collection and strict entry criteria of operating surgeons, the use of same team members (not including the CRNA and extra housekeeper), and the use of the same operations performed in the same manner.

There are limitations to this study. First, teams get better over time, and one would expect that turnover time would get better with team experience (although we do not have data to suggest that is true). Second, we realize that the PIT Crew team members may perform more efficiently knowing that the operating room turnover time was the primary end point of this study. The optimal methodology would be a prospective, randomized blinding trial. Third, these are highly selected surgeons and operations, and the scalability of the PIT Crew team remains unknown and is under current study at our institution. Finally, the true return of investment on better turnover time remains unproved. Many believe that unless an extra operation is performed, it is of no benefit. The return on investment of improved work–life balance and reducing overtime should not be lost.

The sustainability and scalability of decreased turnover time is a challenge, especially in New York City. If staff members are unionized, the ability to incentivize them with bonuses, lunches, preferential parking, or scheduling choices present other challenges. In addition, hospitals in New York City present other obstacles, including prolonged transit time for patients and materials secondary to the need for frequent elevator usage and navigating old infrastructure. Finally, the cost of basic utilities and operations for hospitals in New York City is higher than in other parts of the United States [16], and financial limitations of not-for-profit medical centers may be an important impediment to institutional change.

More importantly, stakeholders must sustain these changes after the initial enthusiasm has waned. In previous studies [17, 18], lean and value stream mapping was successful in providing high-quality, efficient patient care for high-risk procedures. The lessons learned from these previous projects were instrumental in designing this new study for a New York City health care system and culture. In conclusion, lean and value stream mapping can be used to successfully decrease operating room turnover times in a New York City academic hospital. This process requires extensive and dedicated buy-in from all stakeholders, including surgeons, anesthesiologists, operating room staff, and administration.

The authors wish to thank Evan Light for his original figure artwork and Dr Chandra Goparaju for his assistance with data analysis.

References

1. Macario A, Dexter F, Traub RD. Hospital profitability per hour of operating room time can vary among surgeons. Anesth Analg 2001;93:669–75.
2. Guan J, Karsy M, Brock AA, Couldwell WT, Schmidt RH. Overlapping surgery: a review of the controversy, the evidence, and future directions. Neurosurgery 2017;64(CN_suppl_1):110–3.
3. Saha P, Pinjani A, Al-Shabibi N, Madari S, Ruston J, Magos A. Why we are wasting time in the operating theatre? Int J Health Plann Manage 2009;24:225–32.
4. Delaney CL, Davis N, Tamblyn P. Audit of the utilization of time in an orthopaedic trauma theatre. ANZ J Surg 2010;80: 217–22.
5. Sultan J, Charalambous CP. Theatre time utilisation in elective orthopaedic surgery. J Perioper Pract 2012;22:262–5.
6. Cerfolio RJ, Steenwyk BL, Watson C, et al. Decreasing the preincision time for pulmonary lobectomy: the process of lean and value stream mapping. Ann Thorac Surg 2016;101:1110–5.
7. Cerfolio RJ, Smood B, Ghanim A, Townsley MM, Downing M. Decreasing time to place and teach double-lumen endotracheal intubation: engaging anesthesia in lean. Ann Thorac Surg 2018;108:1212–8.
8. Tagge EP, Thirumoorthi AS, Lenart J, Garberoglio C, Mitchell KW. Improving operating room efficiency in academic children's hospital using Lean Six Sigma methodology. J Pediatr Surg 2017;52:1040–4.
9. Collar RM, Shuman AG, Feiner S, et al. Lean management in academic surgery. J Am Coll Surg 2012;214:928–36.
10. Joosten T, Bongers I, Janssen R. Application of lean thinking to health care: issues and observations. Int J Qual Health Care 2009;21:341–7.
11. Harnett MJ, Correll DJ, Hurwitz S, Bader AM, Hepner DL. Improving efficiency and patient satisfaction in a tertiary teaching hospital preoperative clinic. Anesthesiology 2010;112:66–72.
12. Cerfolio R. Solving the American Healthcare Crisis. Brookline, MA: BusinessGhost, Inc; 2018.
13. Sun EC, Dutton RP, Jena AB. Comparison of anesthesia times and billing patterns by anesthesia practitioners. JAMA Netw Open 2018;1:e184288.
14. Patterson P. Tying anesthesia salaries to on-time starts, turnovers. OR Manager 2012;28:14.
15. Gottschalk MB, Hinds RM, Muppavarapu RC, et al. Factors affecting hand surgeon operating room turnover time. Hand (N Y) 2016;11:489–94.
16. U.S. Bureau of Labor Statistics. New York–New Jersey Information Office. Average Energy Prices, New York-Newark-Jersey City – November 2018. Available at https://www.bls.gov/regions/new-york-new-jersey/news-release/averageenergyprices_newyorkarea.htm. Accessed February 14, 2019.
17. Cichos KH, Linsky PL, Wei B, Minnich DJ, Cerfolio RJ. Cost savings of standardization of thoracic surgical instruments: the process of lean. Ann Thorac Surg 2017;104:1889–95.
18. Cerfolio RJ, Minnich DJ, Wei B, Watson C, DeCamp MM. Achieving a 3-star Society of Thoracic Surgery Lobectomy Ranking by using continuing process improvement, lean methodology, and root cause analysis. Semin Thorac Cardiovasc Surg 2017;29:550–7.