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Improving operating room and surgical instrumentation efficiency, safety, and communication via the implementation of emergency laparoscopic cholecystectomy and appendectomy conversion case carts

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A B S T R A C T

In the perioperative environment, communication, safety, and efficiency are paramount to ensure the effective delivery of patient care. Often overlooked, however, is the role that surgical instrumentation plays in these aspects of perioperative care. Through an analysis of the sterile processing environment at Massachusetts General Hospital (MGH), we identified a large amount of instrumentation being cycled unnecessarily throughout the system. This pattern was particularly notable for laparotomic equipment that is sent to almost all laparoscopic cases so that it is available in the event of conversion to laparotomy. Prompted by this analysis along with the high case volume and low conversion rate of laparoscopic cholecystectomies and appendectomies, we redesigned the laparotomic instrument supply chain for these procedures by placing all laparotomic conversion instruments on dedicated emergency case carts. In one month following implementation we avoided cycling nearly 15,000 pounds of unused instrumentation through the perioperative environment and have increased staff safety and communication among perioperative leadership.

Objective: to reduce the amount of unnecessary surgical instrumentation that is cycled through the perioperative environment.

1. Introduction

Massachusetts General Hospital has 58 active operating rooms (ORs) and performs over 37,000 surgical procedures each year.[1] The Central Sterile Processing and Supplies department (CSPS) needs to marshal thousands of surgical instruments and supplies expeditiously in order to ensure the smooth functioning of the operating theater. As within any other large academic medical center, MGH CSPS faces significant challenges across all phases of the surgical instruments supply chain, including inventory management, kit assembly and procurement, and instrument decontamination. One of the most salient challenges at our institution has been that, despite increased inventory levels, numerous complaints regarding the lack of instrument availability are presented to the administration on a daily basis. In this work, we describe a multi-disciplinary, data-driven effort to increase instrument availability by reducing the volume of instruments that are processed by CSPS without compromising service levels and patient safety.

At MGH, surgical instrumentation is kept in a primary storage location in the basement of one of the main campus buildings. From there, instrumentation is picked based on each case's needs (recorded on preference cards), arranged into instrument kits/trays, and placed onto case carts to be sent to the ORs for individual cases. Case carts for elective cases are assembled the day before the scheduled case; for emergent cases, CSPS has strategically placed different types of "emergency carts" close to ORs to promptly provide instrumentation if needed. From the ORs, instruments follow two paths: any used instrument kits are sent to decontamination (located at the primary storage location); all unused kits are placed on racks designated for unused instrumentation and are eventually returned to their appropriate storage location (Fig. 1).

Because inventory is spread across numerous physical locations (e.g., adjacent rooms to the ORs, case carts and emergency carts), there is often a perception that instrumentation is unavailable when it is needed, even if the absolute total inventory levels are appropriate.

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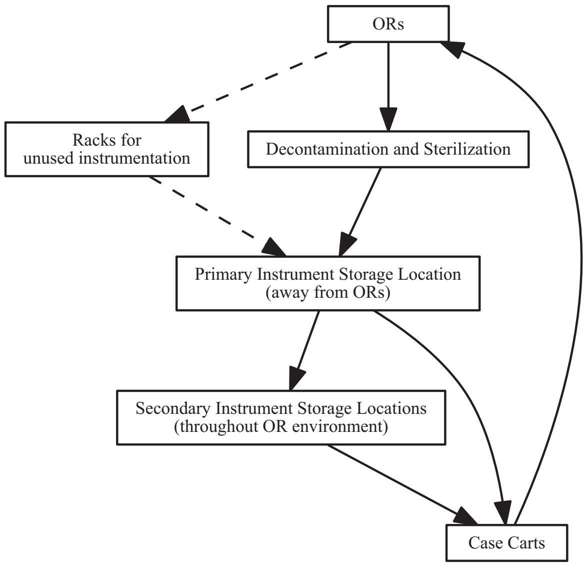

Fig. 1. Stylized process flow map showing the movement of instrumentation through the perioperative environment. The process flow indicated by dashed lines is the primary focus of this work.

Thus, staff have an incentive to ask for many instrument kits to be sent to cases just in case the instrumentation might be required. Consequently, many kits can go unused and must be returned to central storage, which itself is a very time-consuming process. Unfortunately, this unnecessary cycling of instrumentation reinforces the perception of a lack of availability as the kits become tied up in even more locations. This problem is exacerbated by the mistrust and blaming culture that is common between personnel in the OR and the sterile processing departments.[2]

To our knowledge, we are the first to report on the implementation of a quality improvement initiative that aims to reduce unnecessary instrument processing, quantified primarily by the mass of instruments not moved around the perioperative environment. A key feature of our work is an emphasis on developing communication and trust between all teams that run the OR. Of particular importance in this project was the use of data to strategically guide the creation of a process supported by leadership across perioperative services, nursing, and CSPS—and one that maintained excellent patient care as its primary priority. Some related work in the systems-based process improvement literature includes Farrokhi et al.'s study of the application of lean methodology in the perioperative environment that resulted in the reduction of $60,000 in wasted processing of surgical instruments over one year.[3] Regarding communication, Overdyk et al.'s OR efficiency awareness education initiative resulted in the decrease of case turnover time by 16 min after just two weeks.[4] By addressing critical behavioral aspects of the surgical instrumentation supply chain, our work serves to address Blackmore et al.'s observation that "despite the central role of instruments in surgical procedures, relatively little has been published in the medical literature on improving the quality of instrument delivery to the OR".[5]

2. Materials and methods

This project was undertaken as a Quality Improvement (QI) Initiative at MGH, and as such was not formally supervised by the Institutional Review Board per their policies.

To begin, our team created a process map of instrumentation flow throughout the perioperative environment (Fig. 1); this, in combination with data from CSPS's instrument tracking system (Sterile Processing Microsystem, Mequon, WI), helped to identify key data collection process points (small stock areas on the OR floors to which instruments are scanned) and to quantify the volume of unused trays that were returned from each case. All scans of instruments at process points throughout the perioperative environment were manually collected over a one-week period; during this period, there were over 40,000 scans of more than 7000 distinct kits.

Overall, 16% of instrument kits sent to cases were unused and returned to the central storage location. However, this rate was substantially higher for specific kits—in particular, two items immediately stood out: the general retractor and the Bookwalter retractor, which had return rates of 36% and 28%, respectively (Fig. 2). Coincidentally, these items also had the two highest absolute numbers of returns during the course of a week for any single set type.

These data helped us identify general surgery laparoscopic procedures as a substantial driver of returned instrumentation. More specifically, our team decided to focus on laparoscopic cholecystectomies and appendectomies; these two case types are ones for which laparotomic equipment such as retractors was put in *all* case carts, whether elective or non-elective. The reasoning behind this was patient safety: if unforeseen circumstances or complications prohibit the removal of the organ via laparoscopic cannula, the surgeon may be required to

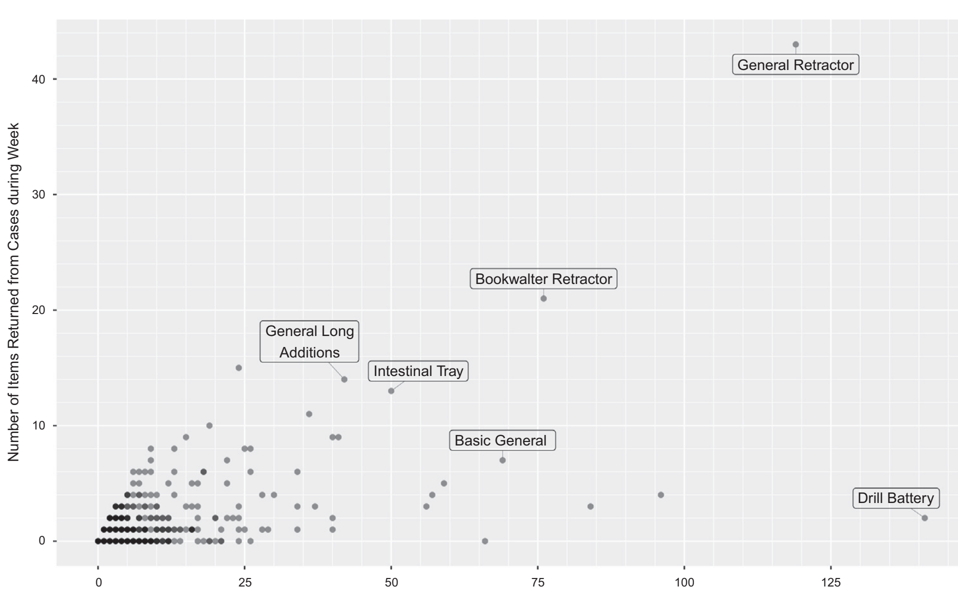

Fig. 2. Volume of instrumentation sent to and returned from cases during week, shown for each instrument set. This is based on one week of instrument movement data analyzed in the exploratory (pre-implementation) phase of research. Several items of interest are labeled. In particular, the general retractor and Bookwalter retractor, both of which are relatively high-volume items, are the two items with the highest number of returns during the week. In contrast, the drill battery (orthopaedics, cardiac) is a high-volume item which experiences very few returns.

"convert" the procedure into an "open" one. This requires the surgeon to make one or more large incisions around the gallbladder or appendix to remove the affected organ, for which the retractors are needed.[6]

Further analysis of our data supported the initial belief that these procedures (laparoscopic cholecystectomy & appendectomy) would be good candidates for this study:

2.1. High volume

Cholecystectomies and appendectomies represent the 3rd and 9th most common surgical procedures at MGH, respectively. Given the advances in laparoscopic surgical technology over the past 20 years, almost all are scheduled as laparoscopic cases; even urgent/emergent cholecystectomies and appendectomies are frequently performed laparoscopically.[7]

2.2. Low intra-operative conversion rates

Conversion rates for cholecystectomies and appendectomies at MGH are quite low: in calendar years 2014–2015, laparoscopic cholecystectomies had only a 7% conversion rate to an open procedure, and laparoscopic appendectomies, 4% (based on over 1300 and 700 cases, respectively). This is compared to 7.5% and 8.6% nationally in 2010 and 2012, respectively.[7,8]

2.3. Opportunity for standardization

Appendectomies and cholecystectomies are routinely performed in specific operating rooms by many different surgeons across multiple surgical services. Further, instrument preferences (as detailed on preference cards) are highly variable across individual surgeons, especially with regard to which laparotomic instrumentation should be brought for laparoscopic cases. Hence, this project provided an ideal opportunity for standardization.

Given the low conversion rates of laparoscopic cholecystectomies and appendectomies, our team felt confident in removing all open conversion instrumentation from preference cards. To account for emergencies, additional open instrumentation (Table 1) was placed throughout the OR environment in strategic OR locations as informed by historical procedural case data. We used two years of case booking and billing data detailing in which ORs laparoscopic-to-open conversions have occurred in the past. The analysis revealed that our emergency carts needed to be placed in two distinct physical locations around the ORs: one setup in a clean core adjacent to several high-volume general surgery ORs, and two setups in a single case cart adjacent to ORs designated for emergency general surgery patients. In this way, the team worked together to design a new process that would not compromise patient safety.

The two case carts, labeled as "emergency conversion carts," were secured with plastic locks to ensure they remained closed when not needed. This locking system helped provide a visual aid for OR Resource Specialists (ORSs) to easily verify whether any of the instrumentation had been taken and thus needed to be replaced. A backup storage cart containing two additional six-kit open instrumentation setups was also stored in CSPS to ensure that the instrumentation could be refilled quickly; if a surgeon decides to intraoperatively convert to an open procedure, the circulating nurse will take the appropriate open instrumentation from the nearest emergency conversion cart. An ORS is then notified to ensure that the instrumentation can be replaced promptly.

Table 1
Conversion sets and weights. These six types of open instrumentation are used for a variety of open procedures as well as for conversions from a laparoscopic approach. Each emergency conversion cart comprises all six instrument kits. Weights are based on the actual sets used at MGH. It is important to note that, prior to our work, these six sets were not taken to every laparoscopic appendectomy or cholecystectomy case; instead, depending on a surgeon's specific preference card, some subset of these six sets was taken in addition to their desired laparoscopic equipment. For example, all surgeons listed the Bookwalter retractor on their laparoscopic cholecystectomy preference cards, while only some surgeons requested an intestinal tray.

Set name:	Weight (lbs.)
Basic General	23.75
General Long Adds	13
Bookwalter Retractor	28
Bookwalter Extension Bar	6
Intestinal Tray	15
General Retractor Set	13.5
Total	99.25 lbs

3. Results

To quantify the success of our initiative, we analyzed data from our electronic sterilization database to track instrument returns, assessed the initiative's impact on staff safety, and evaluated the efficacy of the location of emergency carts. To tackle concerns during the first month of implementation and to ensure the long-term viability of the initiative, the team conducted daily morning huddles with OR Nursing Team Leaders, ORSs, CSPS leadership, and Perioperative Services Leadership & Researchers. Additionally, our findings have been communicated to the rest of the MGH OR staff via electronic public announcements.

3.1. Instrument returns

Table 2 illustrates the weekly changes in laparotomic instrument return volume after our initiative was implemented. The median weekly instrument returns (those instruments returned to CSPS without being used during the case) decreased by 45 kits. This resulted in a monthly reduction of nearly 15,000 pounds (6800 kg) of moved metal, annualized to an estimated 178,776 pounds (81,000 kg) of metal not moved.

One distinctive feature of the data as shown in Table 2 is the large variability in the reduction in weekly returns across the different instrument kits; for example, fourteen fewer Bookwalter retractors were being returned weekly, while only four fewer intestinal trays were being returned. In part, we believe that this is reflective of the lack of standardization across surgeons prior to our work, in which slightly different emergency laparotomic instrumentation was brought for each laparoscopic case, depending on the surgeon's preferences. Through the creation of an emergency case cart which holds the instrumentation necessary for *any* surgeon to convert a laparoscopic cholecystectomy or appendectomy, we have indirectly eliminated a large degree of heterogeneity from surgeons' preference cards.

It is also important to contextualize the return volume as it relates to overall case volume (Table 3). The case volume appears to have remained stable before and after implementation. Further, observe that approximately 25 laparoscopic cholecystectomy and appendectomy cases occur per week, while the return volume of Bookwalter retractors has only decreased by 14 per week in the period following implementation (see Table 2). We believe that this discrepancy is related to the fact that Fig. 1 is an idealized representation of the instrumentation supply chain. Indeed, laparotomic instrumentation that is unused during laparoscopic cases does not travel always through the entire return process (for example, it may be pulled from the case cart and moved directly to another case cart); as such, the return volume reflected in the data is a conservative estimate of actual volume of unused instrumentation.

Table 2
Changes in weekly volume of unused instrumentation across all surgical cases. "Pre-implementation" is based on weekly data for seven months prior to the implementation of the process change for laparoscopic cholecystectomies and appendectomies, while "Post-implementation" is based on weekly data for six weeks after implementation (July 25, 2016, through September 1, 2016). The estimate of median reduction shown is the Hodge-Lehmann (pseudo)median estimator. The distribution of weekly volume of returns for instruments is statistically different (at the 0.05 level) for all items other than the Bookwalter retractor extension bar via the Wilcoxon rank-sum test (*p* values, from top to bottom, are 0.002, 0.001, 0.301, 0.001, 0.010, and 0.021). Annualized reduction in weight moved is based on weight of the kits, the median estimator, and the observation that any returned kit is moved at least four distinct times: from storage shelf to case cart, case cart to top of case cart when not used at case, top of the case cart to a returns shelf, and returns shelf back onto the original storage shelf.

Instrument Kit	**Average Number of Returns per Week**		**Estimate of Median Reduction in Weekly Returns**	**Weight per Kit (lbs)**	**Annualized Reduction in Weight Moved (lbs)**
	Pre-implementation	***Post-implementation***			
Basic general	13.48	6.67	6	23.75	29,640
General long additions	22.79	16.00	8	13	18,928
Bookwalter retractor	30.28	16.33	14	28	81,536
Bookwalter extension bar	15.24	12.83	2	6	2,496
Intestinal tray	4.38	0.50	4	15	12,480
General retractor set	55.79	43.50	12	13.5	33,696
Total	141.97	95.83	45		178,776

Table 3
MGH Operating Room case volume (overall and laparoscopic appendectomy/cholecystectomy) pre- and post-implementation. "Pre-implementation" is based on weekly data for seven months prior to the implementation of the process change for laparoscopic cholecystectomies and appendectomies, while "Post-implementation" is based on weekly data for six weeks after implementation (July 25, 2016, through September 1, 2016). There is no statistically observable difference in means (per a standard *t*-test). The *p*-values are as follows: total volume ($p = 0.53$); laparoscopic cholecystectomy and appendectomy volume ($p = 0.14$).

Total OR Case Volume (Per week)		**OR Case Volume (Laparoscopic Cholecystectomy & Appendectomy only, per week)**	
Pre-implementation	***Post-implementation***	***Pre-implementation***	***Post-implementation***
646.88	707.00	23.53	27.67

3.2. Staff safety

The Association of periOperative Registered Nurses (AORN) recommends that "instrument sets and trays prepared for sterilization not exceed 25 pounds" so as to decrease the "risk of ergonomic injury to personnel handling the sets".[9] Given that the Bookwalter retractor violates this safe limit (see Table 1) and that the laparotomic conversion set as a whole weighs nearly 100 pounds, the elimination of open sets from laparoscopic case carts have also increased staff safety. By eliminating the need to transport nearly 100 pounds of instrumentation for each cholecystectomy and appendectomy performed at the hospital, we have reduced the potential risk of physical harm to CSPS and OR staff members, as well as better adhered to the universally-accepted guidelines for healthcare workplace safety.

3.3. Location of conversion carts

The placement of conversion carts throughout the OR environment is especially important at a large institution where there are 58 active ORs spread across multiple buildings. Our data-driven approach dictated that two conversion cart setups be outside of the ORs specifically designated for general surgery urgent/emergent waitlist patients. In the initial six weeks after the roll-out of the process change, the only conversion cart used was the one placed outside of the general surgery waitlist case room. An added benefit of a targeted, strategic approach for designing the location of the emergency carts is that they are in areas where they are unlikely to be used; as a result, staff is less likely to use the instrumentation on the emergency carts for unintended purposes.

3.4. Huddle communication & problem solving

The daily huddles of this process redesign still occur (on a less frequent basis) and prove to be an extremely effective way of communicating any issues, concerns, or praise of the new process to the leadership of all parties involved. For example, the basic general instrument kits were initially taken from the open conversion cart for other procedures. After discussing this during a huddle, we labeled the open conversion carts as "emergency only" and placed plastic emergency locks on them to discourage staff from retrieving instrument sets unnecessarily.

3.5. Communication to staff

To best prepare the entire perioperative staff for the process improvement, we implemented a number of advertisements displayed on the OR lounge televisions the weeks before, during, and after the system implementation. These were received positively; the staff were proud to see their achievements announced and excited about the process improvement initiative.

4. Discussion

Two critical pieces made the initiative successful. First and foremost, data served a critical role in designing the strategy and in driving the conversation with stakeholders. And secondly, communication channels were established in order to raise feedback and guarantee long-term sustainability.

4.1. Role of data

Data played a central role in all stages of this work. Data analysis first guided the team to identify the instruments with highest volume of returns (general and Bookwalter retractors) and the laparoscopic surgical procedures with which they were most commonly associated. Later, the calculation of the "laparoscopic-to-open" procedure conversion rates and where they occurred were crucial to effect change; unplanned conversions were proven to be infrequent enough to allow us to safely remove all laparotomic instrumentation from the standard laparoscopic case carts. Further, our analysis allowed us to determine the most logical emergency instrumentation placement and quantities. The corresponding data also was critical in addressing misconceptions that had previously been sources of distrust between the different staff roles across the OR environment.

4.2. Role of communication

Establishing robust communication channels between OR nursing and CSPS staff was a crucial element of the initiative. The absence of instrumentation during a procedure can easily become a matter of patient safety as it requires a timely response from both OR nursing and CSPS personnel should the instruments be needed unexpectedly, which can in turn also increase procedure turnaround time. When instrumentation is missing or there are delays in finding any for a given procedure, mistrust builds between those involved in the case.

To that end, our team ran daily huddles for over four weeks after the rollout date. These provided quick, effective, and cooperative communication between the leaders of all different roles involved in the new system. As a result, problems identified by the staff early on were either eliminated with ease or brought to leadership's attention for further review. At the same time, potential misinformation came to light and was addressed before it propagated throughout the system. Furthermore, we found the daily huddles to be useful in enabling and expanding communication about other issues related to perioperative efficiency that were outside the scope of the initial process redesign. This has led to the positive reconnection of critical teams in the OR environment.

4.3. Conclusions and future work

In this work, we describe the implementation of a quality improvement initiative aimed at streamlining the surgical instrument supply chain by reducing the volume of unused returned instruments throughout the MGH perioperative environment. Prompted in part by a low conversion-to-open rate for laparoscopic cholecystectomies and appendectomies, we implemented a new system that removed all laparotomic conversion instrumentation for these two procedures and placed them on emergency carts near ORs that most often have converted cases. Our results suggest that between the open conversion case cart implementation on July 25, 2016, and September 1, 2016, we avoided cycling 15,000 pounds of surgical instrumentation through CSPS. Given this 35-day estimate, we anticipate the reduction of nearly 180,000 pounds of moved instrumentation by July 25, 2017, more than twice the weight of a Boeing 737-400 airplane.[10]

We plan to expand our initiative to more laparoscopic procedures throughout MGH in an effort to continue to increase OR and CSPS efficiency. Based on our initial successes, our team has already implemented a similar process for laparoscopic sleeve (partial vertical) gastrectomy and Roux-en-Y gastric bypass procedures and has plans to expand to other surgical services as well.

OR efficiency at MGH and at other large medical centers is of paramount importance to reduce costs, relieve staff tension, and provide optimal care for patients. We believe that this project serves as an example of how seemingly small process changes in the OR environment can have a significant impact on the perioperative workflow. Given the high case volume in many large medical centers, reducing unnecessary instrumentation cycling throughout the hospital on the scale of all laparoscopic surgeries can provide substantial cost and labor reductions while improving communication, trust, and safety across the perioperative environment.

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