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Radiofrequency Identification Track for Tray Optimization: An Instrument Utilization Pilot Study in Surgical Oncology☆

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ARTICLE INFO

Article history:
Received 26 October 2020
Revised 16 February 2021
Accepted 27 February 2021
Available online 12 April 2021

Keywords:
Surgical tray optimization
RFID
Sterile processing
Efficiency

ABSTRACT

Background: Surgical instrument tray reduction attempts to minimize intraoperative inefficiency and processing costs. Previous reduction methods relied on trained observers manually recording instrument use (i.e. human ethnography), and surgeon and/or staff recall, which are imprecise and inherently limited. We aimed to determine the feasibility of radiofrequency identification (RFID)-based intraoperative instrument tracking as an effective means of instrument reduction.

Methods: Instrument trays were tagged with unique RFID tags. A RFID reader tracked instruments passing near RFID antennas during 15 breast operations performed by a single surgeon; ethnography was performed concurrently. Instruments without recorded use were eliminated, and 10 additional cases were performed utilizing the reduced tray. Logistic regression was used to estimate odds of instrument use across cases. Cohen's Kappa estimated agreement between RFID and ethnography.

Results: Over 15 cases, 37 unique instruments were used (median 23 instruments/case). A mean 0.64 (median = 0, range = 0-3) new instruments were added per case; odds of instrument use did not change between cases (OR = 1.02, 95%CI 1.00-1.05). Over 15 cases, all instruments marked as used by ethnography were recorded by RFID tracking; 7 RFID-tracked instruments were never recorded by ethnography. Tray size was reduced 40%. None of the 25 eliminated instruments were required in 10 subsequent cases. Cohen's Kappa comparing

☆ Meeting Presentation: Presented as an Oral Presentation at the American College of Surgeons Scientific Forum in Chicago, IL, October 2020.

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0022-4804/© 2021 Published by Elsevier Inc.
https://doi.org/10.1016/j.jss.2021.02.049

RFID data and ethnography over all cases was 0.82 (95%CI 0.79-0.86), indicating near perfect agreement between methodologies.

Conclusions: Intraoperative RFID instrument tracking is a feasible, data-driven method for surgical tray reduction. Overall, RFID tracking represents a scalable, systematic, and efficient method of optimizing instrument supply across procedures.

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Introduction

While operating rooms (ORs) serve as the leading revenue source for health systems, they are also responsible for greater than 60% of hospital costs.[1,2] Successful completion of operations requires both complex coordination of team members as well as high material costs, and a large body of literature has emerged focusing on increasing efficiency and minimizing waste in the OR.[3-5] Effective management of surgical instrument supply has been identified as a hugely impactful target for optimizing OR workflow and material management.[5-8] However, hospitals currently lack any systematic means of collecting the surgical instrument utilization data necessary to manage this valuable resource. Historic refinement of instrument trays has therefore trended towards excess as new instruments are added without removal of infrequently used tools. Work by Stockert and Langerman have estimated that over 80% of surgical instruments go unused, resulting in unnecessarily high demands on central sterilization and processing (CSP), inflated maintenance and replacement costs, increased workload on surgical staff, and ultimately decreased efficiency in the OR.[9]

Traditionally, manual recording of instrument use by human ethnography has been performed to acquire real-time utility data and determine unnecessary supplies. Several recent studies have proposed more nuanced methods to track instrument utilization, most of which involve some variation of generating a standardized tray using either ethnography data[10] or after reaching a consensus amongst surgeons and other key stakeholders such as CSP personnel, scrub technicians, and nurses.[6,11,12] Despite some successes of these initiatives, the time investment necessary to implement these methods, either on behalf of surgeons or that of an observer to monitor operations, negate any efficiency gains. Furthermore, the inherent subjectivity and lack of quantitative data driving manual reduction methods critically constrain their scalability. Overall, these limitations highlight the need for an efficient, data driven method of quantifying intraoperative instrument utilization.

Radiofrequency identification (RFID) is a wireless technology that uses radio waves to transfer data from tagged objects through a reader to identify and track the object in real time.[13] RFID technology is already frequently used in ORs for ensuring that RFID-tagged surgical sponges and gauze are not retained in patients (i.e. using the “wand” over the surgical site at the end of an operation).[14] RFID tagging methods have previously been utilized for recording laparoscopic instrument use and workflow,[15] however the application of RFID technology to measure binary instrument use during open surgery with the goal of optimizing instrument supply is innovative and efficacious.

We have designed an RFID-based instrument tracking system that can integrate into the OR without impacting surgical workflow. In this feasibility study, we demonstrate the use of RFID technology as a data-driven method to track surgical instrument usage in real time as a safe, accurate, and scalable means of reducing surgical instrument tray size independent of human entry. Ultimately, intraoperative use of this technology has the potential to substantially reduce instrument oversupply and improve perioperative efficiency across hospital systems.

Methods

Small, autoclave-compatible RFID tags were attached to 124 surgical instruments from two breast trays (62 instruments and/or tray) using surgical tape (Fig. 1). Each unique RFID tag was associated with a unique identifier that was then recorded and linked to individual instruments in a separate decoder log. Tags were placed to avoid any interference with instrument use and the integrity of the tape was regularly reassessed, with no repairs required throughout the duration of the study. The tagged instruments were then processed conventionally via institutional core sterile processing. During operations, tagged instruments entered the field of view of reader antennas. Reads were limited to occur only when instruments were within the proximity of the surgical site. In this way, the RFID system, comprised of two RFID antennas and an RFID reader, allowed for intraoperative tracking of surgical instrument use. Any instrument detected by the antennas during the operative period was marked as “used.” A single ethnographer also logged the time at which an instrument entered the operative field (i.e. marked instrument as “used”); each time the instrument re-entered the field was marked as a new use.

Instrument use was tracked by both the RFID system and human ethnography during 15 initial cases with the original 62 instrument tray (Fig. 2). Instruments with no recorded use during the initial 15 tracked cases were removed from the instrument tray, and an additional 10 cases were performed utilizing the reduced instrument tray. Instruments removed from the tray were still available as individual peel packs upon the

Fig. 1 – RFID-Tagged Surgical Instruments: RFID tags were attached to 124 instruments from two breast trays (62 instruments/tray) using surgical tape, applied to avoid interference with instrument use.

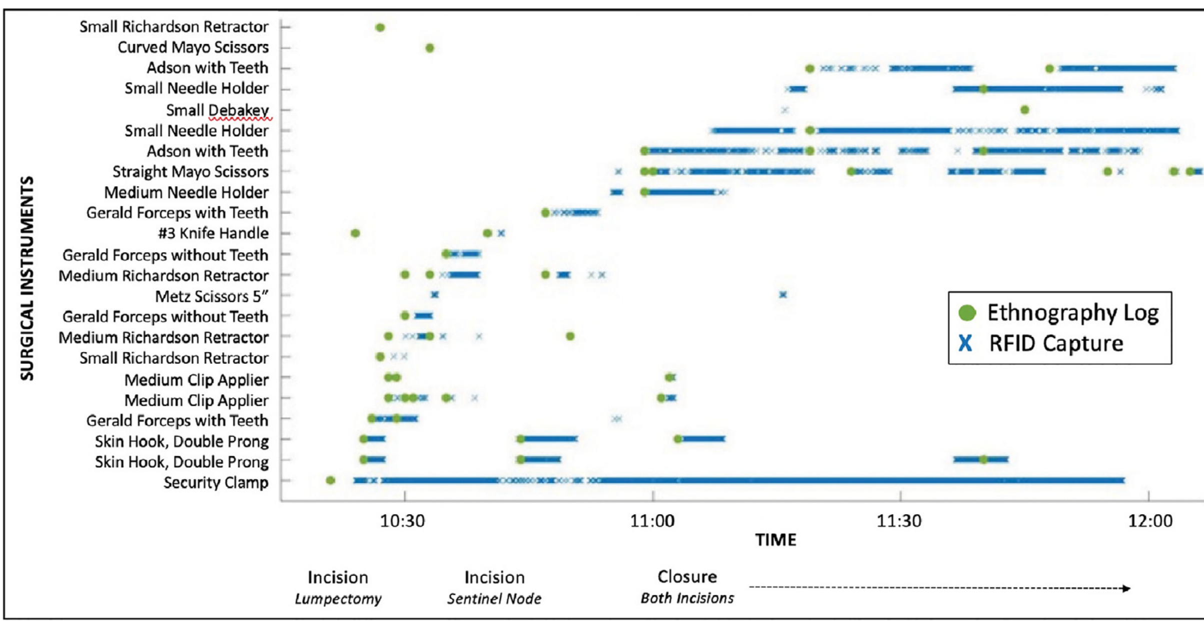

Fig. 2 – RFID capture and simultaneous ethnography log of lumpectomy with sentinel lymph node biopsy (Case #2): The ethnography log (indicated by the green dots) tracked the time of initiation of instrument use, while the RFID-antenna readings (indicated by the blue X's) continuously tracked the instrument while it remained within the surgical field. Stages of the operation can be linked to onset of use of specific instruments, such as use of the #3 Knife handle indicating separate incisions made for the lumpectomy and sentinel lymph node biopsy. Color version of figure is available online.

surgeon's request. Tracking by both RFID and ethnography was also performed during the subsequent 10 reduced-tray cases.

All surgical procedures were performed at an ambulatory surgical center by a single breast surgical oncologist. Procedures included lumpectomy and excisional breast biopsies, both with and without sentinel lymph node biopsy, or a combination of these two procedures.

Patient age, BMI, history of prior breast procedure, lymph node status, procedure laterality and pathologic tumor size were collected from the patient's electronic medical record. The study was approved and given exempt study status according to the Institutional Review Board. The Case Tracking Events log found in the patient electronic medical record was used to calculate tray setup time. Setup time was estimated as the time elapsed between the logged "Setup Start" and patient "In Room" times, as the "Setup Complete" time was less consistently logged.

Statistical analysis

Patient characteristics were summarized with N (%) for categorical variables and median (interquartile range, IQR) for continuous variables. Differences between the initial 15 cases and subsequent 10 cases were tested using the chi-square or Fisher's exact test for categorical variables, and the *t*-test or Wilcoxon rank sum test for continuous variables, as appropriate. Total instruments and new instruments used were summarized for each case and across all cases. Logistic regression was used to estimate both the unadjusted and adjusted association of instrument use with case number. Covariates included patient BMI, age, procedure laterality, prior breast operation, and ductal carcinoma in situ (DCIS) only disease. The data utilized for these models included one observation for each instrument for each case, and a binary variable was defined indicating if that instrument was used (1) or not (0) for each case. This binary variable was the outcome for all logistic models, and case number was included as a continuous predictor. Instrument type was not included as a covariate; instead, these models were built in the generalized estimating equations framework and included an exchangeable covariance structure to account for the repeated measures of individual instruments. Cohen's Kappa was used to estimate the agreement between RFID and ethnography. Stratified Cohen's Kappa was also used to estimate agreement after adjustment for select covariates. All statistical analyses were conducted using SAS version 9.4 (SAS Institute, Cary NC).

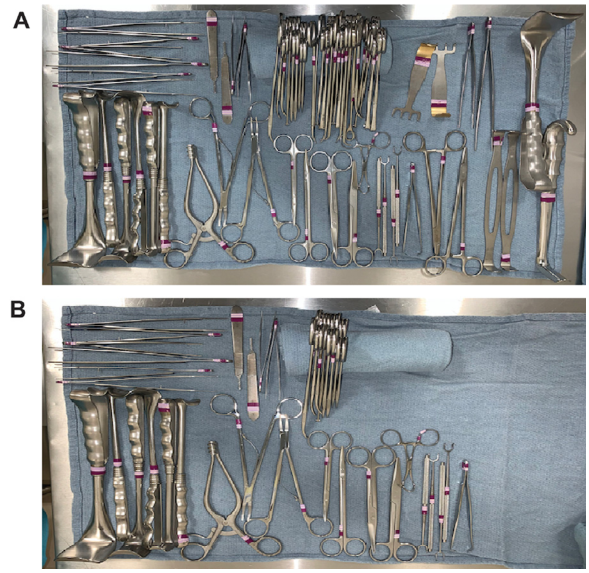

Fig. 3 – Instrument trays, full versus reduced: (A) All 62 instruments from the original tray, and (B) the 37 remaining instruments remaining after tray reduction. Color version of figure is available online.

Results

Patient and operative characteristics

Instrument use was tracked over a total of 25 operations performed between October 2019 and March 2020. Between one and four operations were observed on a single operative day with an average of 2.5 cases observed per operative day. There were a total of 10 observation days during the study period.

A total of 25 unique patients underwent surgery during the study period. There were no significant differences in patient age, BMI, prior history of breast surgery, or pathological tumor size among those who underwent surgery using the full or reduced tray (Table 1). Similarly, there were no clinically meaningful differences in operative characteristics, including procedure laterality and case type, among the initial 15 cases performed with the full tray and the final 10 cases performed with the reduced tray.

Baseline data collection

During the 15 initial operations tracked by ethnography and the RFID system, a median of 23 instruments from the 62 instrument tray were used per case. A total of 37 instruments were logged as having been used at least once by the RFID system over all cases, while 40.3% (N = 25) of the instruments were never used (Table 2). A total of 5 instruments had only a single recorded use throughout these initial 15 cases. A mean of 0.64 (median 0, range 0-3) new instruments were added per case. Regression modeling demonstrated the odds of instrument use was not associated with case number and did not change from case to case (odds ratio (OR) 1.02, 95% confidence interval (CI) 1.00-1.05, P = 0.06).

Reduced tray data collection

After the initial 15 cases, the 25 unused instruments were removed to produce a reduced instrument tray of 37 total instruments, which was a 40.3% reduction in tray size (Fig. 3).

Tracking then continued over 10 additional cases with the reduced instrument tray. There were no additional instruments added back to the reduced tray throughout these 10 tracked cases (Fig. 4). Even in non-tracked cases performed over the course of the study period, the surgeon did not require any of the eliminated instruments and continues to use the reduced trays by random assignment in this surgical center. During these cases, five instruments were never used, four of which had only a single use during the 15 initial cases, and one instrument was used only once (Table 2). Eliminating these five instruments without subsequent use in the 10 reduced tray cases suggests a final reduced tray of 32 instruments, which corresponds to a 51.6% utilization of the original tray. Regression modeling performed after 25 cases still demonstrated that the odds of instrument use was not associated with case number and did not change from case to case (OR 1.00, 95% CI 0.99-1.02, P = 0.70), and this was maintained even after adjustment for patient and procedure characteristics (OR 1.01, 95% CI 0.99-1.03, P = 0.40).

Agreement between RFID tracking and ethnography

During the initial 15 cases, all instruments marked as used by ethnography were recorded by RFID tracking, while 7 instruments tracked by RFID were never recorded by the human observer. Over 25 total tracked cases, Cohen's Kappa statistic measuring agreement between the RFID tracking data and human ethnography, the current gold-standard for intraoperative instrument tracking, was 0.824 (95% CI 0.790-0.857) (Table 3). This statistic indicates near perfect agreement between the two methodologies.[16] Even after adjustment for patient BMI, age, procedure laterality, and pathologic tumor size, the Kappa statistic remained $\geq$ 0.830 over all 25 cases.

Table 1 – Patient and operative characterstics.

	All cases	Cases 1-15 (Complete tray)	Cases 16-25 (Reduced tray)	*P*-Value
PATIENT CHARACTERISTICS				
Patient Age (Years) – Median (IQR)	56 (49 - 69)	62 (49 - 69)	51 (46 - 71)	0.80
Patient BMI – Median (IQR)	32.3 (25.9 - 34.6)	32.3 (28.1 - 35.9)	31.8 (25.0 - 34.4)	0.64
History of prior breast operation				1.00
No	18 (72%)	11 (73.3%)	7 (70%)	
Yes	7 (28%)	4 (26.7%)	3 (30%)	
DCIS only disease				0.27
No	21 (84%)	14 (93.3%)	7 (70%)	
Yes	4 (16%)	1 (6.7%)	3 (30%)	
LN Status*				1.00
Negative	12 (92.3%)	10 (90.9%)	2 (100%)	
Positive	1 (7.7%)	1 (9.1%)	0 (0%)	
Pathologic tumor size (mm) – Median (IQR)				
All Patients with available data	11.5 (6 - 18)	10 (5 - 16)	12.5 (11 - 18)	0.54
Patients with DCIS only disease	7.5 (3 - 18)	3 (3 - 3)	12 (3 - 24)	0.64
Patients without DCIS only disease	11.5 (8 - 18)	11 (6 - 18)	13 (11 - 18)	0.53
OPERATIVE CHARACTERISTICS				
Case type				0.01
Excisional biopsy	7 (28%)	2 (13.3%)	5 (50%)	
Lumpectomy	5 (20%)	2 (13.3%)	3 (30%)	
Lumpectomy + SLNB ± Excisional Biopsy	13 (52%)	11 (73.3%)	2 (20%)	
Procedure laterality				0.43
Bilateral	3 (12%)	3 (20%)	0 (0%)	
Left	15 (60%)	8 (53.3%)	7 (70%)	
Right	7 (28%)	4 (26.7%)	3 (30%)	
# of Trainees/Learners in the OR				0.16
0	5 (20%)	5 (33.3%)	0 (0%)	
1	8 (32%)	4 (26.7%)	4 (40%)	
2	12 (48%)	6 (40%)	6 (60%)	
Tray set-up time (minutes) – Median (IQR)	19.5 (14 - 30.5)	23 (14 - 35)	17 (14 - 21)	0.23

IQR = interquartile range; DCIS = ductal carcinoma in situ; LN = lymph node; SLNB = sentinel lymph node biopsy; OR = operating room.
*Out of patients who underwent LN Biopsy or Dissection only.

Effect of tray reduction on operating room efficiency

While not significant, median setup time decreased from an initial 23 min-17 min after implementation of the reduced tray ($P = 0.23$). Total instrument weights similarly were reduced over 30% from 2.7 kg including the full 62 instruments to 1.8 kg including the reduced 37 instruments. For this pilot study, the actual instrument tray, which houses the instruments themselves, was not downsized due to lack of availability, however, the tray itself accounts for a significant percentage of weight, and a reduction in the physical size of the tray itself may significantly reduce weight and storage space requirements.

Discussion

Surgical instrument tray reduction is a targeted and scalable means of improving intraoperative efficiency and ultimately cutting costs associated with perioperative care. Intraoperative RFID tracking of surgical instruments is a novel approach to reducing surgical tray size that eliminates the inherent bias and inefficiency of other previously reported methods. Using this RFID based instrument tracking, we were able to produce a final reduced tray of just 37 instruments, which accounted for a 40.3% instrument reduction. Importantly, our study proves this method is not only feasible, but highly accurate as compared to ethnography, the current gold standard. Furthermore, we have demonstrated that after tracking a limited number of cases, setup times and tray weights decreased, emphasizing the implications of tray reduction on perioperative staff workload and overall efficiency in the operative space.

Interestingly, the original instrument tray utilized by our breast surgeon was historically shared with Plastic Surgery and totaled 113 instruments as late as August 2019. However, scrub technicians and the surgical nursing team at our institution used their OR experience to reduce the tray nearly 55% to the 62 instrument tray used in our initial tracked cases. Within the last decade, we identified over a dozen quality im-

Table 2 – Instrument List – Full & Reduced Trays

Full Tray, *Cases 1-15*		Reduced Tray, *Cases 16-25*	
Instrument name	Number per tray	Instrument name	Number per tray
#3 Surgical knife	2	#3 Surgical knife	2
Adson with teeth	2	Adson with teeth	2
Allis clamp	4	Allis clamp	1
Appendecele retractor	2*	Appendecele retractor	1†
Army-Navy retractor	2	Curved Mayo scissors	1†
Curved Mayo scissors	1	Gerald forceps with teeth	2
Facelift retractor	2	Gerald forceps without teeth	2
Gerald forceps with teeth	2	Hemostat	2
Gerald forceps without teeth	2	Large Richardson retractor	1†
Hemostat	4	Martin forceps	1
Lahey clamp	4	Medium clip applier	2
Large Richardson retractor	2*	Medium Debakey	1
Long needle driver	2	Medium needle driver	2
Martin forceps	1	Medium Richardson retractor	2
Medium clip applier	2	Metz Scissors 5”	1
Medium Debakey	2	Metz Scissors 7”	1**
Medium needle driver	2	Security clamp	1
Medium Richardson retractor	2	Skin hook, double prong	4
Metz Scissors 5”	1	Small Debakey	1
Metz Scissors 7”	1*	Small needle driver	2
Right angle clamp	2	Small Richardson retractor	2
Security clamp	1	Straight Mayo scissors	1
Skin hook, double prong	4	Tonsil clamp	1†
Small Debakey	2	Weitlaner retractor	1†
Small needle driver	2	*Total: 37*	
Small Richardson Retractor	2		
Sponge stick clamp	1		
Straight Mayo Scissors	1		
Tonsil clamp	4*		
Weitlaner retractor	1*		
Total: 62			

* Single use, Cases 1-15; **Single use, Cases 1-10; †No use, Cases 1-10.

Table 3 – Cohen’s Kappa statistics estimating agreement between RFID tracking & ethnography over all cases.

Controlling for the following covariate:	Kappa statistic (95% CI)
None	0.824 (0.790-0.857)
Patient BMI	0.852 (0.822-0.882)
Patient age (Years)	0.843 (0.812-0.874)
Procedure Laterality	0.830 (0.798-0.863)
Pathologic Tumor Size (mm)	0.849 (0.814-0.885)

CI = confidence interval; BMI = body mass index.

provement initiatives across many health systems and service lines that documented similar efforts to identify and eliminate unused instrumentation with the goal of improving efficiency and cutting costs.[6-8,10,12,17-23] In the studies conducted by Farrelly et al.[6], Dyas et *al.*[7], and Malone et al.[12], approaches that similarly relied on experiential knowledge from OR staff as well as consultation of the attending surgeons were utilized to create reduced trays. Nast and Swords used intraoperative tracking of instruments by a human observer to determine instrument utilization percentage and produce a reduced instrument list later reviewed by a multidisciplinary team.[10] On average, these studies achieved a comparable 52% reduction in tray size, demonstrating the severity and universality of instrument oversupply in healthcare. However, after reduction, utilization rates of reduced trays in these studies still ranged from 48-71%, and 10% of cases required an extra instrument to be opened. In our feasibility study where 10 cases were performed with reduced trays generated from RFID-based instrument tracking, no extra instruments were required from separate peel packs, and our reduced tray utilization was 86%. Fur-

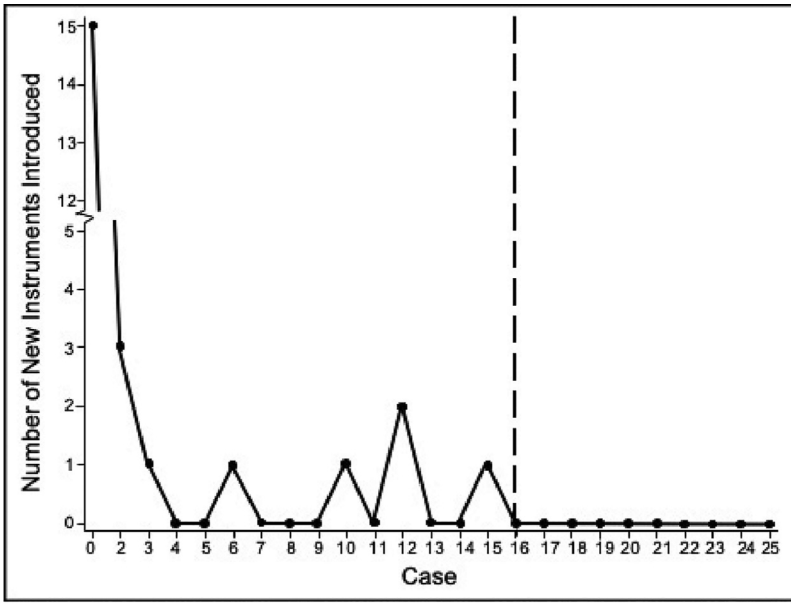

Fig. 4 – Number of new instruments introduced per case with both full and reduced tray: During the initial 15 tracked cases with the 62 instrument tray, a total of 37 instruments were logged as having been used at least once. A mean of 0.64 (median 0, range 0-3) new instruments were introduced per case. The vertical line in this graph at case 16 indicates introduction of the reduced instrument tray with only 37 instruments. After introducing this tray, no new (previously eliminated) instruments were introduced in the subsequent 10 cases. Color version of figure is available online.

thermore, this was achieved even after starting the study with a tray previously reduced by anecdotal methods. Indeed, we have shown that an RFID-based intraoperative tracking system is a data driven and ultimately more accurate and efficient means of surgical tray reduction that is not influenced by human error, inherent bias or the subjectivity of existing methods.

In addition to its accuracy, RFID based tracking is scalable and sustainable in a way that other tray reduction methods are not. Here, we have shown that tracking just a limited number of cases per surgeon can produce an accurately reduced tray with high utilization rate; we were able to produce a reduced tray with an 86% utilization rate after just 15 tracked cases with the original tray. Furthermore, our technology has minimal start-up costs, requires very little up-front work to coordinate (primarily instrument tagging), and can be easily implemented in a variety of operating room setups. RFID-based technology is also already widely utilized in ORs and itself poses minimal risk to patient care or safety.[24] Additionally, it takes just 3-5 min to set-up at the start of cases and therefore minimally interferes with intraoperative efficiency. Finally, and perhaps most critically, RFID-based instrument tracking does not rely on ethnography; once set up in the OR, the system collects data autonomously. Furthermore, the RFID system can longitudinally provide data as surgeon preferences evolve and supplies accumulate towards excess, allowing for continual improvement. It is therefore not difficult to predict that our technology, which requires neither significant manpower nor coordination outside the OR to implement, can easily be scaled and maintained across hospital systems in a way that observation-based tray reduction or meetings of key stakeholders within departments to produce reduced lists cannot.

Despite the advantages of this technology for accurate and scalable means of improving surgical instrument utilization and reducing inefficiency in the OR, there are a few limitations to use of this technology. First, the RFID system does require additional setup in the OR (approximately 3-5 min) once the patient is in the OR under anesthesia, but before they are prepped and draped, and therefore requires buy-in and commitment from both the attending surgeon and OR staff in order to implement it. However, this is only necessary during initial case tracking, and no longer required once a reduced tray has been implemented. There is also the up-front investment of time to tag instruments; in our study, it took 2 authors approximately 5 h to tag 124 instruments from both trays, though in the future, hospital systems may consider it worthwhile to purchase tagged instruments.

Furthermore, there is still some degree of inaccuracy in the RFID system and technology as we implemented it. There were several instruments known anecdotally to have never been used in previous cases (e.g. Large Richardson retractor, Weitlaner retractor) that were nonetheless tracked by the RFID system and therefore included in the reduced tray. While these instruments were not actively used in the operative field during any operations, it is likely that they were tracked and documented as "used" due to errors by the surgical team and trainees in the OR, such as an instance in which an appendecele retractor was offered by the surgical technologist in training instead of a medium Richardson retractor. Thus, the system is still susceptible to false positive reads that may ultimately decrease the magnitude of final tray reduction. However, these errors have no effect on future surgical workflow or operative outcomes in the way that false negative readings (i.e. used instruments are not tracked due to system error) may. Importantly, none of the instruments eliminated in the reduced tray were required in subsequent cases, indicating the system had an undetected false negative rate in our study. The power of the RFID technology's ability to accurately dictate supply management will also improve with increased case monitoring. Tracking instrument use over more cases would increase the number of false positive reads, but would also establish a more precise cutoff percentage to reduce truly unnecessary instruments (e.g. over 100 monitored surgeries, instruments used in less than 5% of cases are eliminated).

While this feasibility study was inherently limited by its observation of one surgeon in a single ambulatory surgical center, the scope is sufficient to demonstrate the utility of a system that can be broadly applied to other surgeons in a variety of operative settings. Additionally, human ethnography was used as the point of comparison for the RFID technology, but this is by no means a 100% accurate method itself. Ethnography is largely limited by human error due to distractions within the OR and observer fatigue both throughout a case and over the course of a single day of observation (e.g. recording up to 4 cases in one day). Thus, utilization rate of the reduced tray, and the number of instruments required from the peel packs are in fact more accurate measures of the accuracy of this technology. Finally, we used times recorded in the Case Tracking Events log found in the patient electronic medical record to calculate tray setup time. While the reduced tray did decrease setup time in our study, this log is an imprecise record of actual operative events, and thus only a surrogate for actual tray setup time. The authors recognize this as a limitation of the study, and both setup and final instrument counts should be timed explicitly by a human ethnographer over a variety of cases in future studies to determine the true impact of implementing a reduced tray on perioperative efficiency.

Future directions

To further test the scalability of this technology, we are currently proceeding with a confirmation study in which the reduced tray will be offered to a second breast surgical oncologist for use in the same or similar breast oncologic procedures (i.e. breast lumpectomy, excisional biopsy, sentinel lymph node biopsy, or combination thereof) to determine the rate of utilization and number of additional instruments required from separate peel pack. These studies will be help determine the utility of this technology when accounting for unique surgeon preferences.

Given the scalability and sustainability of this system, we envision application of this technology to other surgical divisions and institutions. Once implemented, this technology can be used to create highly accurate generalized trays within a given service line or for a specific procedure(s) performed by a group of surgeons (e.g. a lumpectomy or minor breast procedures tray versus a mastectomy tray). Instruments without any recorded use among all surgeons utilizing a tray can be eliminated; instruments with limited use by a single surgeon for select operative scenarios can be stored in separate surgeon-specific peel packs to keep tray size small, and eliminate the need to provide such instruments across a consolidated tray for the relevant service line or procedure. We anticipate that smaller trays without excess instrumentation will increase perioperative efficiency by reducing setup and instrument count times, decrease storage space once needed for larger, non-optimized trays, and improve sterilization quality due to decreased workload on CSP personnel. Ultimately, utilization of this technology to produce the data necessary to eliminate unused instrumentation and efficiently consolidate trays has the potential to improve the quality and efficiency of perioperative care on multiple levels.

Conclusions

Surgical instrument oversupply is a ubiquitous problem effecting the efficiency of perioperative workflow, however, there is a paucity of methods available that can provide the necessary data to address this issue. In this single center pilot study, we demonstrate the feasibility of using an intraoperative RFID-tracking system to reduce tray size. This novel, data driven method of monitoring surgical instrument utility has the potential to efficiently optimize supply chain management across health systems.

Author Contributions

L.A.O., I.T.H., L.H.R., and P.J.C. conceived and designed this study. Data acquisition was performed by L.A.O., I.T.H., and L.H.R. L.A.O., I.T.H., and S.M.T. performed data analysis. L.A.O drafted the original manuscript; L.A.O., I.T.H., S.M.T., P.J.C., and L.H.R. participated in critical revision.

Acknowledgment

We would like to thank the perioperative staff of the Davis Ambulatory Surgical Center (Durham, NC), particularly Sharilyn Gasparrelli, Melissa Gilliam, and Katherine Wrzesniewska, for assisting in the implementation of this study. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. S.M.T. reports a consulting relationship with Abbvie, Inc. that ended in January 2019 on work in bioequivalence that is unrelated to this work. This publication was made possible (in part) by Grant Number P30CA014236 from the National Cancer Institute a component of the National Institutes of Health (NIH). Its contents are solely the responsibility of the authors and do not necessarily represent the official view of NCI or NIH.

Disclosure

The authors reported no proprietary or commercial interest in any product mentioned or concept discussed in this article. Authors P.J.C. and I.T.H. are listed as inventors of the technology herein presented, though this technology is not currently licensed. P.J.C. and I.T.H. are employed by, and hold equity interest in a company with financial interest in that intellectual property.

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