

# Assessing the Magnitude and Costs of Intraoperative Inefficiencies Attributable to Surgical Instrument Trays

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- BACKGROUND:** Efficiency in the operating room has become a topic of great interest. This study aimed to quantify the percent use of instruments among common instrument trays across 4 busy surgical services: Otolaryngology, Plastic Surgery, Bariatric Surgery, and Neurosurgery. We further aimed to calculate the costs associated with tray and instrument sterilization, as well as the implications of missing or damaged instruments.
- STUDY DESIGN:** This was a single-site, observational study conducted on the surgical instrumentation at a large academic medical center in Chicago. Data were collected through direct observation by a trained investigator. Operating room instrument use and labor time required for cleaning and repacking instrument trays in central sterile processing (CSP) were analyzed using descriptive statistics and linear regression. Institutional data on volume and expenses were gathered from hospital leadership.
- RESULTS:** Forty-nine procedures and 237 individual trays were observed. Average instrument ( $\pm$ SD) use rates were 13.0% for Otolaryngology ( $\pm$ 4.2%), 15.5% for Plastic Surgery ( $\pm$ 2.9%), 18.2% for Bariatric Surgery ( $\pm$ 5.0%), and 21.9% for Neurosurgery ( $\pm$ 1.7%). An increasing number of instruments per tray was associated with decreased use and increased instrument error rate. Using recorded labor time, the cost of cleaning and repackaging an individual instrument was calculated to be \$0.10. Adding in CSP operating expenses and instrument depreciation per use, total processing cost per instrument increases to \$0.51 or more.
- CONCLUSIONS:** Our study demonstrates that the percent use of instruments across surgical specialties and multiple tray types is low. Attention to tray composition may result in immediate and significant cost savings. (J Am Coll Surg 2014;■:1–10. © 2014 by the American College of Surgeons)

Given the increasing scrutiny of health care expenditures, there is a growing body of literature assessing the efficiency of operating rooms and their impact on the delivery of patient care, physician satisfaction, and the hospital's bottom line. Surgeons can and should be proactive in this effort by focusing on costs that are directly controllable and vary with volume of usage.<sup>1</sup> The instrumentation used during a surgical procedure is one of the areas under surgeons' purview where cost-benefit metrics can be easily assessed. Several studies conducted in Europe

have calculated the comprehensive costs of sterilizing and packaging reusable instrumentation for each incremental use, with estimates ranging from €0.47 to €9.20 (roughly \$0.59 to \$11.52 US) per instrument, depending on instrument type.<sup>2-4</sup> Furthermore, Leslie Kroes<sup>5</sup> and colleagues, working in The Netherlands, found that reducing the volume of excess instrumentation sent through sterile supply processing could lead to savings between €55,000 and €65,000 (\$68,843 to \$81,360 US), and up to €125,000 (\$156,461 US) each year for a nonacademic hospital with 13 operating rooms.<sup>5</sup> Similarly, Farrokhi and associates,<sup>6</sup> at Virginia Mason Medical Center, used data from 2 neurosurgical procedures to estimate potential institutional savings up to \$2.8 million a year through a 70% reduction in instrument processing through sterile supply. Although these estimates are based on rough calculations, they lead us to believe that significant cost-cutting may be achieved by reducing the unnecessary

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**Table 1.** Operating Room Details by Specialty

Specialty	Procedures observed, n	Mean procedure length	Circulator retrievals per operative hour, n, mean (SD)	Percent of procedure operative time circulator spent outside of OR, mean (SD)	Percent of procedure operative time circulator spent outside of OR for instruments only, mean (SD)	Percent of procedure operative time surgeon spent waiting on instruments, mean (SD)
Otolaryngology	18	1 h, 23 min	5.0 ( $\pm$ 2.1)	9.4 ( $\pm$ 7.2)	2.5 ( $\pm$ 3.9)	1.8 ( $\pm$ 5.3)
Plastic surgery	12	2 h, 13 min	3.6 ( $\pm$ 3.1)	7.1 ( $\pm$ 7.1)	0.5 ( $\pm$ 1.3)	1.6 ( $\pm$ 3.5)
Bariatric surgery	13	2 h, 36 min	3.4 ( $\pm$ 1.6)	5.9 ( $\pm$ 4.4)	1.0 ( $\pm$ 1.7)	3.2 ( $\pm$ 7.4)
Neurosurgery	6	2 h, 13 min	6.1 ( $\pm$ 4.1)	15.5 ( $\pm$ 10.6)	0.5 ( $\pm$ 1.0)	5.9 ( $\pm$ 12.2)

Retrievals include any event in which the circulator left the operating room to obtain instruments or supplies needed for the case. Time surgeon spent waiting on instruments was defined by surgeon performing no other task during that time.

Total procedures = 49; total trays = 237.

OR, operating room.

sterilization, wear and tear, and processing of instruments that are opened and exposed in the operating room but not actually used during a procedure.

Moreover, Greenberg and coworkers<sup>7</sup> showed that a more streamlined instrument tray with fewer instruments can be both cost-effective and safe for the patient, and Farrokhi and colleagues<sup>6</sup> found that reducing the number of instruments in specific trays had no effect on surgical procedure times. In addition, Christian and colleagues<sup>8</sup> noted that excessive time spent counting instruments in the operating room can significantly compromise case progression and patient safety by drawing attention away from patient care activities. On the other hand, the inverse of excess instrumentation must be considered; an inadequate quality or quantity of instruments included in a tray can greatly disrupt operating room flow, causing the surgeon to stand idle, with the patient under anesthesia, and requiring the circulating nurse to leave the room to replace broken or missing instruments. Recent studies have linked operating room traffic flow and the number of door openings during a procedure to higher airborne bacterial counts and the potential for increased postoperative infection.<sup>9,10</sup> The ramifications of inadequate supply of instruments must be balanced against excess supply.

Based on stakeholder interviews, we have strong anecdotal evidence that a significant proportion of instruments included in certain surgical trays at our institution are consistently unused. The purpose of this study was to quantify the percent use of instruments among the most commonly used instrument trays in a sample of 4 busy surgical services at a university teaching hospital: Otolaryngology, Plastic Surgery, Bariatric Surgery, and Neurosurgery. We further aimed to calculate the costs associated with tray and instrument sterilization processing by using direct evaluation of the instrument processing workflow. Lastly, we aimed to quantify the time wasted by the surgeon and the circulating nurse when instruments are missing, broken, or unexpectedly needed during operative time.

Our hypothesis was that a substantial percentage of instruments in each surgical tray opened would go unused, and that these unused instruments would cost a nontrivial amount to be cleaned and repackaged in on-site central sterile processing (CSP). We further hypothesized that during each procedure, issues related to instruments and other supplies would result in unfavorable circulator absence from the operating room.

## METHODS

### Study design

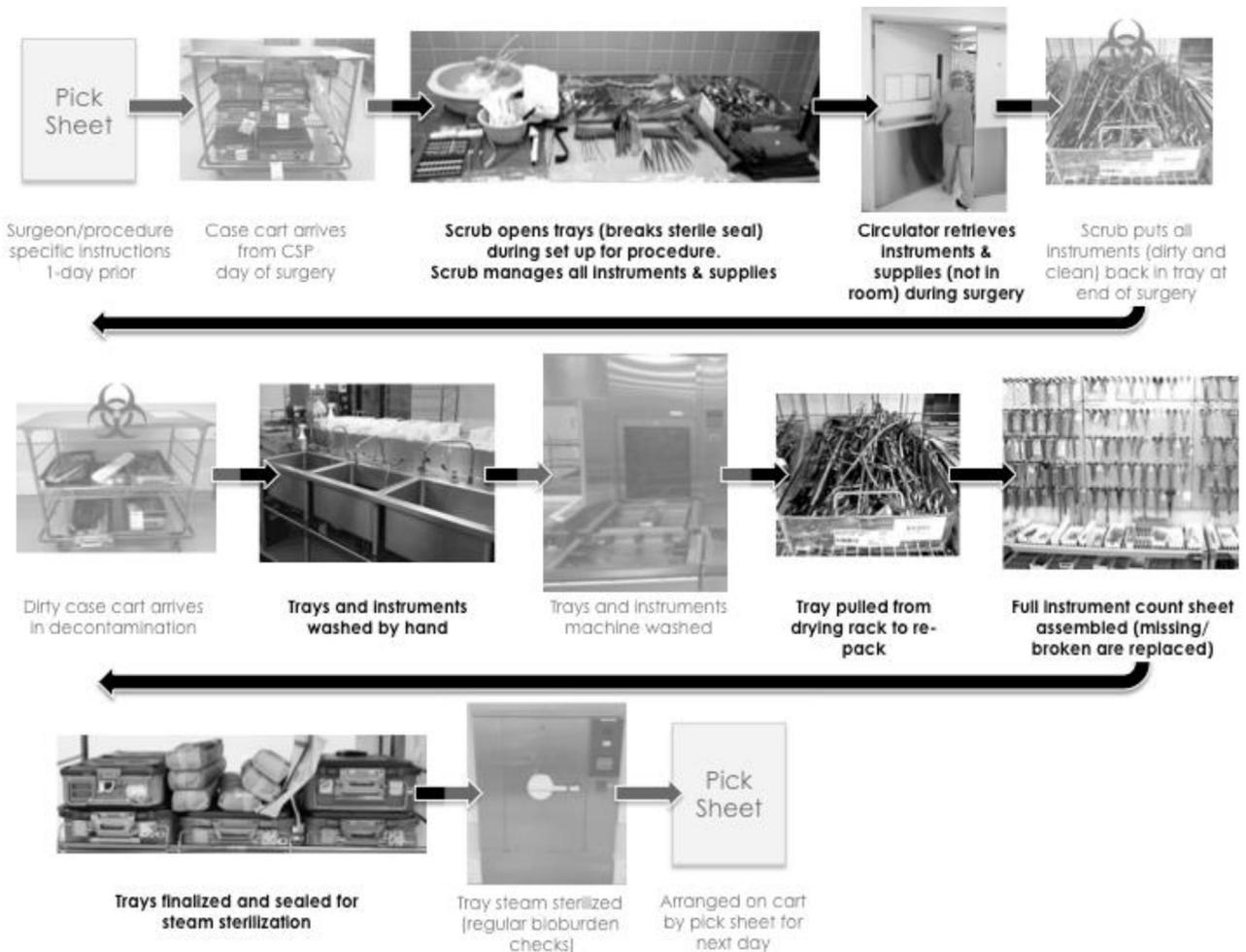
This was a single-site, observational study conducted on the surgical instrumentation used at a large academic medical center in Chicago. Surgical cases of Otolaryngology, Plastic Surgery, Bariatric Surgery, and Neurosurgery were identified through stakeholder interviews as the specialties most pertinent to the goals of this study: high volume instrument tray use, documented issues with instrumentation, a stated need for improvement, and a high weekly case load (Table 1). Based on historical usage data, the most frequently used surgical instrument trays in each of these 4 specialties were identified. The data on operating room instrument usage and operating room flow related to instruments and supplies, as well as the sterile processing labor time required to clean and repack an instrument tray were collected through in-person direct observation by a trained investigator using a calibrated stopwatch. Case cart assembly begins with a surgeon- and procedure-specific pick sheet 1 day before a scheduled procedure. The pick sheet details the instruments, trays, and supplies needed for the case. On the day of surgery, a case cart with sealed sterile instrument trays is sent to the operating room. Before the procedure, the scrub and circulator set up the operating room, breaking the sterile seal on all opened instrument trays. During the procedure, the circulator leaves the operating room to retrieve instruments and supplies not in available in the room. At the end of the procedure, the scrub places

all instruments (used and unused) back into their respective trays, and the dirty case cart is sent to central sterile processing. Once in central sterile processing, dirty trays of instruments are first washed and soaked by hand. Next, trays are passed through a machine washer. After drying, every instrument is removed from its tray, inspected, tested (replaced if needed), and repacked by hand. Newly packed instrument trays then undergo steam sterilization. Once steam sterilization is complete, instrument trays are ready to be placed on case carts (according to pick sheet), and the cycle repeats (Fig. 1).

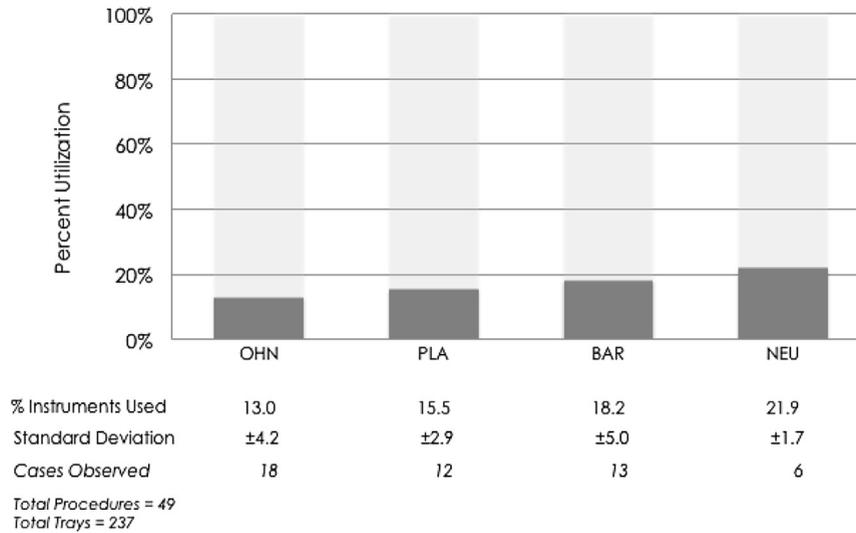
This research was approved by the University of Chicago Institutional Review Board (either expedited or nonhuman subjects determination depending on the portion of the study). All surgeons, nurses, operating room personnel, and central sterile processing staff involved in this study were educated on the data being collected and the purpose of the research.

### Data collection—operating room instrument use

Surgeons from the Otolaryngology, Plastic, Bariatric, and Neurological surgical services were contacted before this study for willingness to have an observer in their operating room. Data were collected from routine (weekday, non-emergent) surgical procedures over a period of 8 weeks in June through August 2012. A goal was set to collect data on 10 or more procedures in each of the target specialties. Data collection required that the investigator be present from anesthesia induction time until patient close/instruments down, recording the following: number and type of instruments used per tray opened; broken, missing, and unplanned instruments and trays; circulating nurse instrument and supplies retrieval events and times; time spent on pre- and postoperative instrument counts; surgeon nonoperative time due to instrument retrieval; and procedure duration. A “used” instrument was defined as having touched a surgeon’s hand. “Procedure length”



**Figure 1.** The instrument tray cycle: a long and complex process. Data collection was conducted on each of the areas in bold through in-person direct observation by a trained investigator using a calibrated stopwatch. CSP, central sterile processing.



**Figure 2.** Total instrument use for all opened trays. Instrument use (vertical axis) is presented by specialty (horizontal axis). OHN, otolaryngology; PLA, plastic surgery; BAR, bariatric surgery; NEU, neurosurgery.

was defined by first cut to patient close/instruments down. All data collected were recorded via pen and paper, and transferred to a database. Data entry was subjected to multiple data quality checks and validation.

#### Data collection—central sterile processing

Data on instrument trays processed through on-site CSP during peak volume times on weekdays only were collected over 2 weeks during the study period. Using a calibrated stopwatch, the investigator recorded the following: person time needed to hand wash instrument trays in the decontamination area; person time needed to repack instrument trays before sterilization; and tray name. Total instrument counts per tray were provided by perioperative administration. Sterile processing technician hourly wage, along with CSP operational costs, were gathered from hospital leadership.

#### Data analysis

The data were analyzed and summarized using descriptive statistics and linear regression. To test our hypothesis that a substantial percentage of each surgical tray opened goes unused, we applied the equation:

$$\text{Current Tray A Utilization} = \text{ICount}_{\text{UsedA}} / \text{ICount}_{\text{TotalA}}$$

where the number of instruments included in tray A =  $\text{ICount}_{\text{TotalA}}$  and the number of instruments from tray A that were used in the procedure =  $\text{ICount}_{\text{UsedA}}$ . We plotted both the time to hand wash a tray and the time to pack a tray against the number of instruments per tray, and used

linear regression to calculate the time required to decontaminate each incremental instrument, and the time required to pack each incremental instrument before steam sterilization. To test our hypothesis that the unused instruments cost a nontrivial amount to be cleaned and repacked in CSP, we used the equation:

$$\text{Cost of Cleaning and Re-packing Instrument} \\ I = E_w \times (I_{ct} + I_{pr})$$

where the average time in seconds to clean 1 instrument =  $I_{ct}$ , the average time in seconds to pack 1 instrument =  $I_{pr}$ , and the average CSP employee wage per second =  $E_w$ . The average CSP employee wage at the time of the study was \$19.84 per hour, which translates to:

$$\begin{aligned} \$19.84 \text{ per hour} &\div 60 \text{ minutes per hour} \\ &\div 60 \text{ seconds per minute} \\ &= \$.006 \text{ per second} \end{aligned}$$

We also collected institutional data on CSP monthly volume, expenditures on individual instruments, and items such as detergents, biologic and quality checks, and maintenance and repair contracts to fully estimate instrument processing costs.

## RESULTS

### Instrument trays in the operating room

Forty-nine procedures were observed in Otolaryngology ( $n = 18$ ), Plastic Surgery ( $n = 12$ ), Bariatric Surgery ( $n = 13$ ), and Neurosurgery ( $n = 6$ ). A total of 237 individual trays were observed across these specialties. The average

( $\pm$ SD) specialty-specific instrument use was 13.0% for Otolaryngology ( $\pm$ 4.2%), 15.5% for Plastic Surgery ( $\pm$ 2.9%), 18.2% for Bariatric Surgery ( $\pm$ 5.0%), and 21.9% for Neurosurgery ( $\pm$ 1.7%; Fig. 2). At the level of the individual instrument tray, we noted an inverse relationship between instrument use and number of instruments per tray (Fig. 3, Box A). Of the 237 trays opened, 40 (17%) of these trays had 1 or 0 instruments used after opening (Fig. 3, Box B). This happened most frequently with Otolaryngology trays (16 of 73 trays, 22%), and slightly less frequently with Plastic Surgery trays (10 of 58 trays, 17%), Bariatric Surgery trays (10 of 76 trays, 13%), and Neurosurgery trays (4 of 30 trays, 13%) (Table 2).

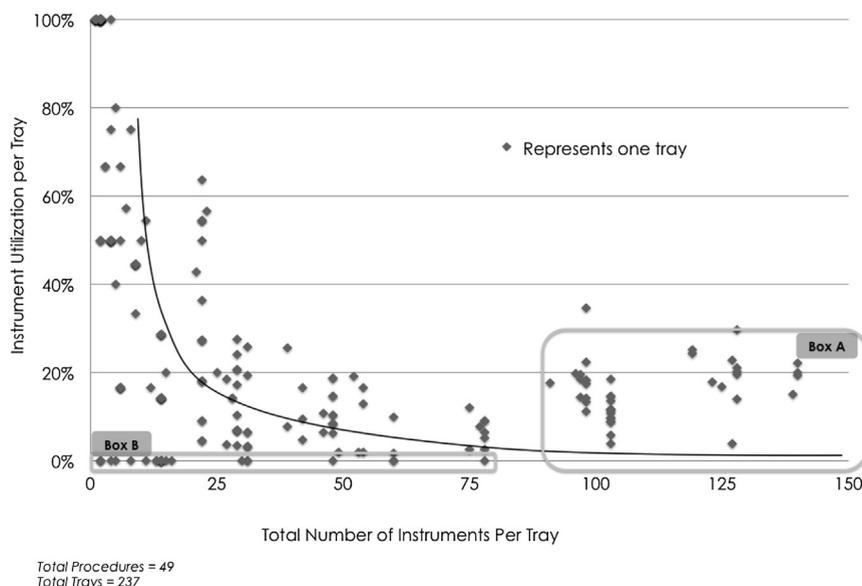
When comparing usage of specific instrument types across specialties, we found that among 3 similar trays in Otolaryngology, Plastic Surgery, and Neurosurgery, the average number of forceps, scissors, and suctions used per tray was consistent, regardless of number available (Fig. 4). We also identified where excess instrumentation of a certain type may exist. For example, less than 20% of all clamps provided in each of these trays are used.

Lastly, of the 237 trays observed, 25 trays (10.5%) were delivered to the operating room with instruments missing and recorded as missing, 1 tray (0.4%) was delivered to the operating room with instruments missing and not recorded as missing, and 14 trays (5.9%) were delivered to the operating room with broken instruments. Instrumentation issues were observed to dramatically increase by tray size, with an error rate of 49% for trays with greater than 40 instruments, contrasted against an error

rate of 13% for trays with 40 instruments or less. During the 49 cases observed, a total of 18 trays were requested by the surgeon to be sent up from central sterile processing during active operating time. This occurred for various reasons such as the need for an unplanned instrument or to replace a broken or missing instrument. The average time from surgeon request to circulator phone call to CSP was 42 seconds ( $\pm$ 1 minute, 42 seconds), and the average time from phone call to CSP to tray arrival was 6 minutes, 30 seconds ( $\pm$ 6 minutes, 35 seconds).

### Operating room flow

The circulating nurse left the operating room, on average, between 3.4 times per hour (Bariatrics) and 6.1 times per hour (Neurosurgery) during the procedures observed (Table 1). As a percentage of procedure time, this translates to the circulating nurse being outside of the operating room from an average of 5.9% of operative time (Bariatrics), up to 15.5% of operative time (Neurosurgery). The majority of these retrievals were for essential disposable items not stored inside the operating room. The subset of time the circulator spent outside of the operating room devoted specifically to instrument retrieval ranged from an average of 0.5% of operative time (Plastic Surgery and Neurosurgery) to 2.5% of operative time (Otolaryngology). Out of the 49 observed procedures, the surgeon was idle in nonoperative time attributable to instrumentation in 14 (29%) of the cases. During these 14 procedures (Otolaryngology, 2; Plastic Surgery, 3; Bariatric Surgery, 6; Neurosurgery, 3), the



**Figure 3.** Instrument use by tray size. Instrument use (vertical axis) is presented by number of instruments included in the tray (horizontal axis).

**Table 2.** Frequency of Minimal Use of Instruments after Opening a Tray

Specialty	Trays with 0 instruments used (frequency), n (%)	Trays with only 1 instrument used (frequency), n (%)	Trays observed, n	Total frequency of minimal use, %
Otolaryngology	15 (21)	1 (1)	73	22
Plastic surgery	6 (10)	4 (7)	58	17
Bariatric surgery	1 (1)	9 (12)	76	13
Neurosurgery	2 (7)	2 (7)	30	13
Total	24 (10)	16 (7)	237	17

Minimal use was defined as only 1 or 0 instruments used in a tray that was open, exposed, and made unsterile—excluding trays with 5 or fewer instruments. Frequency indicates the percentage of total trays opened that are categorized as “minimal use.” Total procedures = 49; total trays = 237. OR, operating room.

average surgeon idle waiting time was 8 minutes, 57 seconds, or 9.1% of total operative time (range 1 minute, 19 seconds to 39 minutes; 0.4% to 30.6% total operative time). None of the procedures observed met the criteria for pre- and postoperative instrument counts at the time of this study (no large open cavities, no blind cavities, and no risk for retained foreign body as defined by the department or unit).

**Instrument trays in central sterile processing**

Sixty-one trays were observed being decontaminated, and 35 trays were observed being packed before steam sterilization in the on-site central sterile processing unit. A significant linear relationship was noted both for time to decontaminate vs number of instruments per tray, as well as time to pack vs number of instruments per tray (Fig. 5). Using linear regression analysis, it was determined that an incremental instrument takes 4.02 seconds to decontaminate ( $R^2 = 0.68$ ), and 12.51 seconds to pack before sterilization ( $R^2 = 0.83$ ).

**Cost calculations**

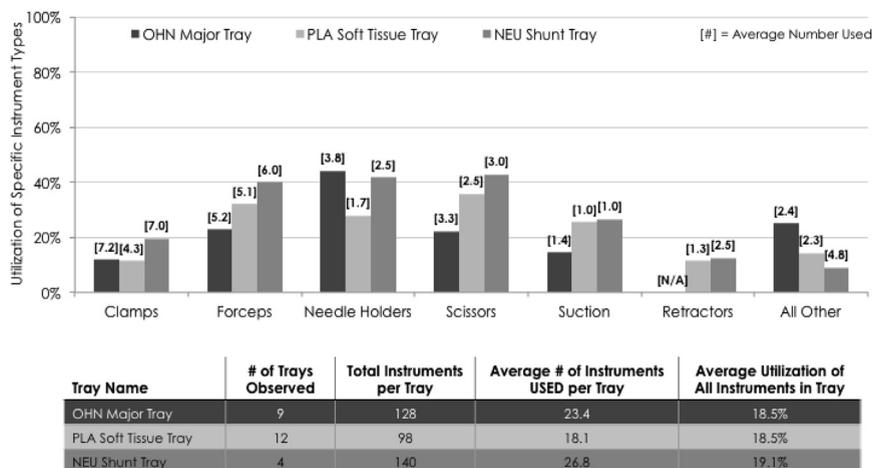
At the time of this study, the average sterile processing employee wage was \$0.006 per second. Based on this, we calculated the labor cost of cleaning and repackaging an unused instrument to be \$0.10 per instrument:

$$\text{Cost of Cleaning and Repacking Instrument I} = E_w \times (I_{ct} + I_{pt})$$

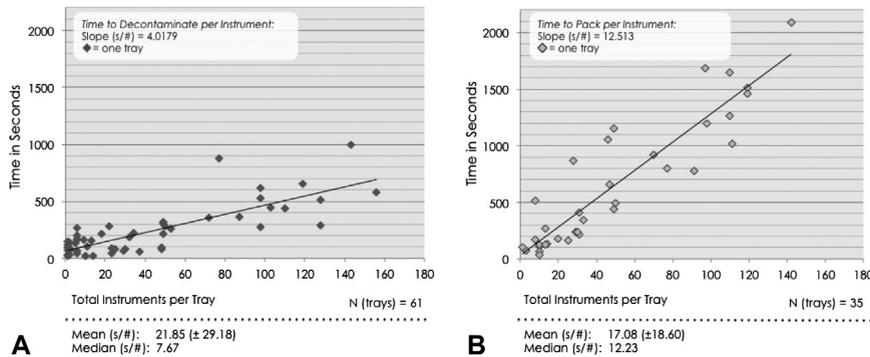
$$E_w = \$0.006 \text{ per s, } I_{ct} = 4.02 \text{ s, } I_{pt} = 12.51 \text{ s}$$

$$\$0.10 \text{ per instrument} = \$0.006 \text{ per second} \times 16.53 \text{ seconds}$$

To gain a more complete understanding of the processing costs per instrument beyond employee wages, we considered the utilities, maintenance, and repair costs of operating CSP. Our institution processes an average 222,500 instruments per month for the main operating rooms. If we assume CSP operates at 80% capacity, total



**Figure 4.** Use of specific instrument types included in 3 specialty trays. Use of instruments included in similar specialty trays (vertical axis) is presented by instrument type (horizontal axis). OHN, otolaryngology; PLA, plastic surgery; BAR, bariatric surgery; NEU, neurosurgery.



**Figure 5.** (A) Decontamination and (B) tray packing time by tray size. Time to decontaminate instruments and time to pack instruments (vertical axis) is presented by the total number of instruments included in each tray (horizontal axis).

capacity would be 278,125 instruments per month. Utilities expenses for detergents, biologic checks, and quality checks amount to \$25,000 per month. Water and electricity are rolled up into central operating costs and are not included in this amount. Annual repair expenses for the previous year totaled \$195,000, and maintenance contracts amounted to \$267,058. Combined repair and maintenance average \$38,505 per month. The per-instrument CSP operating costs of detergent, biologic and quality checks, maintenance, and repair calculates as:

$$\begin{aligned}
 &(\$25,000 + \$38,505) \text{ per month} \\
 &\div 278,125 \text{ total capacity instruments per month} \\
 &= (\$0.09 + \$0.14) = \$0.23 \text{ per instrument}
 \end{aligned}$$

This is a conservative estimate of the true expense of processing 1 instrument because we were unable to include depreciation of CSP washers and sterilizers, depreciation of the instrument tray container, and expense of maintaining CSP square footage and instrument storage space. To estimate the per use depreciation costs of \$0.02 to \$0.18 for an individual instrument, we identified 5 of the most commonly used instruments and obtained purchase price and estimated lifespan data from our institution's primary vendor (Table 3). Instrument per use depreciation cost is calculated by dividing the purchase price by the estimated lifespan. Exposures in the setting of lifespan estimates are independent of how the instrument was handled in the operating room (used or unused) during the procedure. One "exposure" means the instrument was exposed in the operating room, sent back down to CSP for cleaning and sterilization, and repackaged—a process known to subject the instruments to high heat and chemicals, and to cause baseline wear and tear, loss of integrity, and breakdown of instrumentation. It was also noted by both perioperative leadership and our instrument supply

representatives that many instruments are actually "lost" before they wear out—loss of instruments may be a consequence of excess instrumentation and results in a shorter lifespan than our estimates (Table 3).

If we include the instrument depreciation per use, CSP operating costs of detergent, biologic and quality checks, and equipment maintenance and repair, we find the total expense of cleaning and repacking an unused instrument increases to \$0.12 to \$0.28 in direct costs, and up to \$0.51 or more per instrument when considering the full expense of processing through CSP (Table 4).

### Qualitative observations

There were other observed factors that we believe contributed to the inefficiencies and costs of surgical instrument processing. Some delays in decontamination were caused by dried bio-burden that had to be scrubbed off (which can be mitigated by brief washing and spraying enzymatic detergent in the operating room before sending trays for decontamination). Delays in tray packing were derived from instruments being placed in the wrong tray in the operating room at the end of a procedure, requiring a

**Table 3.** Per Use Depreciation Costs for 5 Commonly Used Instruments

Instrument	Purchase price, \$	Estimated lifespan in exposures, n	Per use cost, \$
Clamps	13.00	675	0.02
Retractor	20.00	900	0.02
Forceps	12.00	300	0.04
Scissors	28.00	450	0.06
Needle driver	115.00	640	0.18
Average			0.06

The needle driver used in this example has a purchase price of \$55, and a \$20 replacement carbide insert is required every 160 uses, with a total estimated life span of 640 uses (total price: \$55 + \$20 + \$20 + \$20 = \$115). Other instruments are replaced in their entirety.

**Table 4.** Detailed Breakdown of Total Processing Cost per Individual Instrument

		Total processing cost, \$
Direct (driven by excess instruments in trays)		
Labor	Time to clean (requires CSP employee to directly handle each instrument; cleaning time affected by type of instrument) Time to pack (requires CSP employee to identify and handle each instrument) [Figure 5]	\$0.10
Depreciation	Varies by instrument type (delicate and precise instruments have shorter lifespans than bulkier, blunt instruments) [Table 3]	\$0.02 to \$0.18
Indirect (driven by excess volume through CSP)		
Utilities	Detergents Biologic checks Quality checks (ensuring that machines are functioning properly and adequate sterilization occurs)	\$0.09
Repair	Maintenance contracts for sterilization equipment Additional repair of equipment needed for categorizing, tracking, and packing instruments	\$0.14
Additional (unaccounted for during this study)		
Quantifiable	Water and electricity (rolled up into institutional central operating costs) Depreciation of durable equipment (washers, steam sterilizers, tray containers) CSP floor space and storage space Labor costs from time spent during OR procedure setting up complex trays, searching for instruments on disorganized back table, and pre-/post-operative instrument counting Replacement costs for instruments lost or damaged in heavy disorganized trays	
Unquantifiable	Burden to employees lifting heavy trays Organizational coordination for a larger volume of instrument inventory Disruption of operating room flow and surgeon and staff focus	

Direct costs are determined to be those driven by excess instrumentation included in each tray. Indirect costs are those driven by excess volume of instrumentation through central sterile processing.  
CSP, central sterile processing; OR, operating room.

sterile processing employee to track down the right pieces for each tray. Also adding time to tray packing were instruments such as suction tubes, which require more hands-on quality checks, and trays with many clamps that all had to be individually opened before the decontamination wash cycle.

## DISCUSSION

To our knowledge, this is the first study to examine surgical instrument tray use across multiple specialties. The results validate our hypothesis that a substantial percentage of each surgical tray opened goes unused. The numbers we found are notably lower than expected, with the highest observed use rate at 21.9% ( $\pm 1.7\%$ ) for Neurosurgery. The issue of low use is pervasive across

all 4 specialties observed, and we speculate that this is likely similar for the majority of surgical procedures in the study hospital's operating rooms. Predictably, we found that an inverse relationship exists between the number of instruments included in each tray, and the overall instrument use for that tray. Additionally, the number of errors per tray (missing or broken instruments) increases with the size of the tray. It is worthwhile to consider the root cause of excess instrumentation: is it a consequence of ineffectively predicting what will be needed (either poor planning or holdover "legacy" trays that have not been updated), or is there inherently such a significant amount of variability between individual cases that the excess is warranted? We suspect it is the former, and further research is imperative to better characterize this issue.

We found that cleaning and repackaging an instrument that went unused in the operating room costs on average \$0.10 per instrument by the most conservative estimates, and up to \$0.51 or more per instrument using more comprehensive cost metrics. This is compatible with findings of Farrokhi and colleagues,<sup>6</sup> who roughly calculated an estimated processing cost per instrument of \$0.77 at Virginia Mason. We had intended to look at time spent by the scrub and circulator in pre- and postoperative instrument counting; however, the subset of cases we observed was exempt from this practice at the time of this study. We imagine that instrument counting would likewise reflect a linear time cost for excessive instruments and we intend to study this in future investigations. Additionally, each tray full of instruments must be set up before the start of every procedure, and one can imagine that excess instrumentation lengthens this process as well.

The savings in labor time spent cleaning and repacking excess instrumentation could be realized immediately by removing individual instruments from trays, and reductions in costs of operating CSP can be achieved over time by decreasing the total volume of unnecessary processing. To put this in perspective, eliminating 80 unused instruments from 1 tray type that is opened 10 times a week for 50 weeks could result in savings of:

$$\begin{aligned} &80 \times [\$0.10 \text{ to } \$0.51] \times 10 \times 50 \\ &= \$4,000 \text{ to } \$20,400 \text{ per year} \end{aligned}$$

on just 1 tray type. This amount is indeed nontrivial, especially considering that our institution processes approximately 100,000 trays and over 2.6 million instruments per year.

We also validated our hypothesis that during each procedure, the circulator spends a considerable amount of total operating time outside of the operating room retrieving instruments and other supplies. This is particularly a problem when the circulator is out of the room and scrubbed staff or anesthesiology staff are required help with a nonsterile task. Our study numbers show that the circulator spends on average anywhere from 5.9% to 15.5% of operative time outside of the operating room. However, circulator retrievals due to instrumentation were only 1 component of the out-of-room time, comprising an average of 2.5% (Otolaryngology) or less of total operative time. Rather, the primary reason for circulator exit was for disposable supplies. Detailed assessment of the disposables needed and reasons behind a mismatch between items needed and items available in the operating room is the subject of ongoing investigation.

Despite delayed availability of needed instruments, surgeon nonoperative idle time was low. We presume the lack of idle time was due to the ability of the surgeon

to work on another task while waiting for certain instruments; it is unclear whether the need to change tasks while waiting on instruments results in a measurable detriment to the flow or timing of the procedure and this is worth further investigation.

Ensuring that the right instrumentation arrives at the right time for the right procedure is a complex process with many moving parts. The safety of the patient is of utmost importance during any procedure, and we surmise that the low use rates are in part driven by the critical need to be prepared for multiple scenarios—a plethora of excess instruments may be a factor in the low relative incidence of circulator instrument retrieval and surgeon waiting found in our study. This is the key balance against reducing instruments in trays—ensuring that the needed instruments are still readily available. We did find that certain disposable items (such as suture) were not readily available, resulting in a considerable amount of out-of-room time in retrieval of these items. Moving these items into the operating room may decrease the retrieval times, but may not always been an option when dealing with confined space. The impact of door openings on air quality and infection risk to the patient was not captured in this study and merits future consideration.

The cost-savings that can be realized by eliminating excess instrumentation and creating more tailored and streamlined trays warrants the attention of surgeons, staff, and hospital administrators alike. Further research and collaboration with surgeons and operating room staff is needed to better understand which instruments should be eliminated from trays, and if smaller, more tailored trays could be used for a specific procedure rather than a large catchall tray. Certain instrument types (such as clamps and suction tubes) that are costly to clean and in great excess offer low-hanging fruit in the steps toward addressing the problem. Any investigation to improve tray use must be balanced against the risk of increasing surgeon waiting or idle time and potential disruptions to workflow in the operating room and central sterile processing, while maintaining patient safety as the top priority.

### Future implications

With health care expenditures continuing to be a topic of both national and individual importance, it is critical that hospitals streamline care to provide equivalent or superior outcomes at a lower cost. Additionally, payors will drive this pressure through capitated payments and bundled care offerings. In taking steps toward controlling costs, there first needs to be proper identification of the problem, followed by spreading awareness, then coming to agreement on the issue at hand, as well as potential remedies. Surgeons are perfectly positioned to play a central

role in reducing expenditures in the operating room without compromising quality and patient safety. Operating room nurses and staff likewise have critical insight into the barriers that hinder ideal workflow. It is imperative that those who are on the front lines of delivering care are active and empowered in the discussion of creating a more efficient and lower cost health care system.

### Limitations

Data collection was performed at a single institution, by a single observer, over a short period of time, thereby limiting the generalizability of the findings. Moreover, the nature of the in-person data collection may have caused staff to unconsciously change their behavior and the way they interacted with the instrumentation (Hawthorne effect). For feasibility reasons, only broad instrument type was captured for the used instruments; however, a more detailed record of the specific instrument brand, size, and style would provide better data for decision making. Future work should focus on understanding the array of costs surrounding equipment and instrument depreciation, as well as how cleaning costs might increase or decrease based on instrument type. Furthermore, batching for instrument sterilization suggests that some cost factors (eg, detergents and sterilization equipment) will not have a linear relationship. Therefore inflection points for certain levels of instrument reduction should be investigated.

Despite these limitations, this study is the most comprehensive assessment of the impact of excess surgical instruments on operating room costs and workflow. We have identified several areas of inefficiency that are directly affected by excess instrumentation and by mismatch between disposable items needed and items available in the operating room, supporting the importance of critical evaluation of instrument trays and provision of disposables.

### CONCLUSIONS

Overall, our study demonstrates that across 4 surgical specialties and multiple tray types, the percent use of instruments in surgical trays is low, and use rapidly declines with an increasing number of instruments per tray. Attention to tray composition may result in immediate and significant cost savings in the form of reduced central sterile processing labor. We also found that the circulator spends a significant amount of time outside of the operating room during a procedure, due primarily to obtaining additional disposable items. As the primary decision-makers regarding tray composition, instrumentation and

disposable use, surgeons have a critical role in helping to address these inefficiencies.

### Author Contributions

Study conception and design: Stockert, Langerman

Acquisition of data: Stockert

Analysis and interpretation of data: Stockert, Langerman

Drafting of manuscript: Stockert, Langerman

Critical revision: Langerman

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### REFERENCES

1. Traverso LW. The laparoscopic surgical value package and how surgeons can influence costs. *Surg Clin North Am* 1996;76:631–639.
2. Adler S, Scherrer M, Ruckauer KD, Daschner FD. Comparison of economic and environmental impacts between disposable and reusable instruments used for laparoscopic cholecystectomy. *Surg Endosc* 2005;19:268–272.
3. Demoulin L, Kesteloot K, Penninckx F. A cost comparison of disposable vs reusable instruments in laparoscopic cholecystectomy. *Surg Endosc* 1996;10:520–525.
4. Prat F, Spieler JF, Paci S, et al. Reliability, cost-effectiveness, and safety of reuse of ancillary devices for ERCP. *Gastrointest Endosc* 2004;60:246–252.
5. Kroes L. Creating more efficiency and patient safety by changing processes and contents of instrument trays. Master thesis Health Science. School of Management and Governance. Department of Science, Technology, Health and Policy studies (STeHPS). University of Twente, Enschede, The Netherlands. February 2009.
6. Farrokhi FR, Gunther M, Williams B, Blackmore CC. Application of lean methodology for improved quality and efficiency in operating room instrument availability. *J Healthc Qual* 2013 Sep 24. [Epub ahead of print]
7. Greenberg JA, Wylie B, Robinson JN. A pilot study to assess the adequacy of the Brigham 20 kit for cesarean delivery. *Int J Gynaecol Obstet* 2012;117:157–159.
8. Christian CK, Gustafson ML, Roth EM, et al. A prospective study of patient safety in the operating room. *Surgery* 2006;139:159–173.
9. Panahi P, Stroh M, Casper DS, et al. Operating room traffic is a major concern during total joint arthroplasty. *Clin Orthopaed Rel Res* 2012;470:2690–2694.
10. Andersson AE, Bergh I, Karlsson J, et al. Traffic flow in the operating room: An explorative and descriptive study on air quality during orthopedic trauma implant surgery. *Amer J Infect Control* 2012;40:750–755.