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Effects of a Surgical Receipt Program on the Supply Costs of Five General Surgery Procedures

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Background: Surgical supplies occupy a large portion of health care expenditures but is often under the surgeon's control. We sought to assess whether an automated, surgeon-directed, cost feedback system can decrease supply expenditures for five common general surgery procedures.

Materials and methods: An automated "surgical receipt" detailing intraoperative supply costs was generated and emailed to surgeons after each case. We compared the median cost per case for 18 mo before and after implementation of the surgical receipt. We controlled for price fluctuations by applying common per-unit prices in both periods. We also compared the incision time, case length booking accuracy, length of stay, and postoperative occurrences.

Results: Median costs decreased significantly for open inguinal hernia ($433.45 to $385.49, $P < 0.001$), laparoscopic cholecystectomy ($886.77 to $816.13, $P = 0.002$), and thyroidectomy ($861.21 to $825.90, $P = 0.034$). Median costs were unchanged for laparoscopic appendectomy and increased significantly for lumpectomy ($325.67 to $420.53, $P < 0.001$). There was an increase in incision-to-closure minutes for open inguinal hernia (71 to 75 min, $P < 0.001$) and laparoscopic cholecystectomy (75 to 96 min, $P < 0.001$), but a decrease in thyroidectomy (79 to 73 min, $P < 0.001$). There was an increase in booking accuracy for laparoscopic appendectomy (38.6% to 55.0%, $P = 0.001$) and thyroidectomy (32.5% to 48.1%, $P = 0.001$). There were no differences in postoperative occurrence rates and length of stay duration.

Conclusions: An automated surgeon-directed surgical receipt may be a useful tool to decrease supply costs for certain procedures. However, curtailing surgical supply costs with surgeon-directed cost feedback alone is challenging and a multimodal approach may be necessary.

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Introduction

Surgical procedures represent a significant expenditure in the American health care system. In 2011, inpatient hospitalizations following operating room (OR) procedures comprised 28.9% of total hospitalizations but made up 47.9% of the aggregate cost of inpatient admissions.[1] This equates to approximately $160 billion annually.[2] Previous literature has demonstrated that disposable surgical supplies, both implantable and nonimplantable, represent a significant portion of surgery-associated costs.[3,4] Although surgeons are often not involved in the negotiation of supply costs with suppliers, they play an integral role in providing feedback to administrators on which surgical supplies should be purchased for the OR and have direct control on which specific disposable supply to use in a given case. However, disposable supply costs can vary widely among providers—even for the same procedure at a single institution.[5] While in the past, efforts to decrease supply costs have relied on altruism, surgeons are increasingly employed by, or are intimately associated with, large integrated health systems that bear an ever-growing share in the financial risks of health care expenditures associated with their patients. With a need to become more cost-competitive to maintain viability, these health systems, and hence their providers, must develop strategies to reduce expenditures in the costly surgical environment.

Despite their role in driving procedural expenses, surgeons are notoriously unreliable at estimating the costs associated with their operative equipment.[6,7] To combat this problem, multiple studies have examined a strategy of physician education to contain costs. One method has been to provide cost feedback to surgeons. Results have been mixed, with one study featuring cost audits and regular lectures showing no effect,[8] but other studies showing that surgeons are responsive to cost feedback and can produce significant reductions in OR expenses.[9-13] However, most studies were limited to a single procedure[9,12,14] and centered around educating surgeons on the specific procedure with targeted cost-saving measures. This presents a scalability issue, as it is very resource-intensive and difficult to operationalize on a departmental or hospitalwide level. A less resource-intensive, albeit more passive, way to educate surgeons regarding OR supply costs is the use of a surgical receipt or scorecard. These receipts can show surgeons the cost of the disposable items they used during a given case. Several studies have demonstrated that surgeons can be responsive to this type of feedback.[15,16] However, these studies have also focused on a single procedure. Recently, one promising study compared the use of a surgeon-directed cost scorecard across multiple specialties at a single institution, showing that it can reduce costs on a departmental level.[11] However, there are concerns regarding the sustainability of this program as a departmental incentive was provided and the scorecard was generated manually each month for the duration of the study period.

Most of the previous studies have been in the context of a limited study period. To our knowledge, no study has yet looked at the effects of an automated and operationalized surgeon-directed cost feedback system's effects on surgical expenditures. Such a system was established at our institution in October 2015. We performed a retrospective study of the effects of such a system on the surgical expenditures for five common surgical procedures.

Materials and methods

This is a single-institution, multi-hospital retrospective study comparing trends in per-case supply costs for five commonly performed general surgery procedures before and after the implementation of an institutionwide surgical receipt program. The five procedures analyzed were laparoscopic cholecystectomy, laparoscopic appendectomy, open inguinal hernia, lumpectomy, and thyroidectomy. Before data analysis, we obtained approval by our institutional review board.

Our primary outcome of interest is a comparison of the per-case costs of these five operations before and after implementation of the surgical receipt. We analyzed changes in case costs over an 18-mo period before and after the surgical receipt was introduced, separated by an unmeasured 1-mo transition period (October 2015), in which the receipt was rolled-out to the health system. The research timeline is shown in Figure 1.

Beginning in October 2015, surgical receipts were provided to the primary surgeon of record for each surgical procedure performed at our institution. The principal intent of the receipts was to establish and nurture a culture of attention to variable costs in the OR by surgical faculty. Receipts were delivered by email within 3 d after a procedure in pdf format. Information presented on these receipts included total case cost, a list of supplies and implants used during the case, associated per-unit cost and per-case sums for each supply item, and a comparison of the primary surgeon's case cost with an average of all other providers for the same procedure at our institution. The surgical receipt does not include any information regarding supply or hospital charges, which are distinct from supply costs.[17] The surgical receipt also includes other ancillary information, such as the surgical and nursing team, the accuracy of the booked case length, and whether the case started on time. An example of a surgical receipt can be seen in Figure 2. Surgical receipts are created, distributed, and maintained by the Surgery, Anesthesiology, Musculoskeletal, Neurology, and Imaging Services (SAMNIS) department at our institution. SAMNIS perform monthly audits through direct observation in the OR and through the use of "audit bags" to collect the packaging of used supplies. In addition, surgeons who review the receipts also act as auditors for the accuracy of the receipts "charged" to each case. As this was an institutionwide initiative, all primary surgeons received receipts regardless of department or surgical subspecialty. The surgical receipt was provided for both inpatient and outpatient procedures, and at all hospitals within the health system. No financial or personal incentives were provided within the department for surgeons to decrease his or her supply costs. However, controlling supply costs was a departmental directive and the surgical receipt was provided as a tool to help surgeons achieve that directive.

Using data from SAMNIS, we selected our procedures of interest from a listing of the twenty most commonly

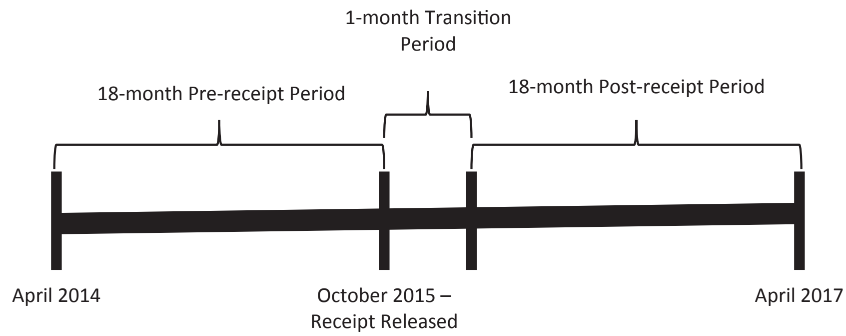

Fig. 1 – Study protocol. The surgical receipt was implemented in October 2015. We allowed for a 1-mo transition period and compared an 18-mo period before and after implementation of the surgical receipt.

performed procedures at our institution, as identified by frequency of Common Procedure Terminology (CPT) codes. After excluding minor procedures (i.e., incision and drainage, colonoscopy), we selected five representative general surgery operations. The procedures were selected to represent the most commonly performed procedures, across multiple general surgical subspecialties, and surgical approaches. Procedures were identified by the primary CPT code associated with the OR encounter. From the selected procedure list, we extracted the total case cost—a function of disposable supply cost plus implantable supply cost—as well as total disposable supply cost, total implant cost, and itemized tallies of cost and usage for all supply items for each individual OR case.

We excluded combined cases in which multiple service lines were involved within the same OR case. However, if multiple procedures were performed by the same service line, and the primary CPT code was one of interest, then these cases were included. For example, if a parathyroidectomy was performed in addition to the thyroidectomy, and the primary CPT code was a thyroidectomy, then this case was included. In addition, we excluded cases in which an implant was placed during a laparoscopic cholecystectomy (2 cases in the before period, 1 case in the after period), laparoscopic appendectomy, and thyroidectomy (1 case in the before period). We also excluded cases in which a breast implant or tissue expander was placed in lumpectomy procedures (5 cases in the before period, 8 cases in the after period). One thyroidectomy case in the after period was excluded due to an error in the database in which no supplies were attributed to that case. Finally, 17 open inguinal hernia cases (8 in the before period, 9 in the after period) were excluded because an open inguinal hernia was ultimately performed after a conversion to open from an initial laparoscopic approach or an open inguinal hernia was performed as part of a larger procedure (i.e., kidney donation, pancreatectomy). The above cases were excluded because these do not represent the standard of care for these procedures.

Recognizing concerns that attention to cost on the part of treating surgeons may have an effect on patient outcomes, we examined four secondary outcomes for each of our procedures of interest: incision-to-closure time, booking accuracy, lengths of stay, and number of postoperative morbidity or mortality occurrences. For this last variable, we obtained our institution's outcomes data set. This data set follows the strict reporting guidelines set by the American College of Surgeons National Surgical Quality Improvement Program. The data set takes a limited sample of cases for each procedure. The capture rate of each procedure can be seen in Table 3. To classify booking accuracy, OR minutes were analyzed for each procedure. At our institution, an accurately booked case length was defined as being within 15% of the scheduled length. Incision-to-closure time (skin minutes) was recorded by the intraoperative nursing staff, who notes the time when the skin incision is made and when the skin is completely closed or when the surgical drapes are removed (if the skin incision is not closed by the surgeon). Finally, length of stay is defined as the duration of hospitalization. Skin minutes, booking accuracy, and length of stay data were obtained from the SAMNIS database. We extracted the secondary outcomes data for each case in the preintervention and postintervention time frames.

Master price list

A change in overall supply costs may be due to either decreased utilization of supplies or changes in the cost of individual supplies. To control for changing market prices between the before and after period, we calculated a master price list for each item. During the before period, prices of each specific item were averaged to arrive at the master price. We then applied the master prices to calculate an adjusted supply cost for each case in the before and after period. If an item was used only during the after period, we calculated an averaged after price for the item. This price adjustment ensured that changes in supply costs can be attributed to patterns of use, not differences in pricing.

Statistical analysis

We compared the median per-case supply cost before and after surgical receipts using the Mann–Whitney U test (MWU) for each procedure of interest. This analysis was performed with both unadjusted and price-adjusted data, so as to interrogate if any changes in the crude analysis that remained significant after price was held constant.

For procedures of interest which featured implants in addition to disposable supplies, we performed subanalyses of median per-case costs with and without implants using MWU test.

UC San Diego MEDICAL CENTER

Surgical Receipt v.3

Service line	Sv - Colorectal
Log ID	271130
Surgery Date	10/17/2017
Room	[redacted]
Scheduled In Room	17:45
In Room	16:27
First Case?	N
On Time?	Y
Minutes Delayed	-
Proc Level	P) Elective
Scheduled Procedure	COLOSTOMY, LAPAROSCOPIC
Procedure Description	LAPAROSCOPIC LOOP SIGMOID COLOSTOMY
Skin Minutes	112
Scheduled Room Minutes	90
Room Minutes	139
Anesthesia Minutes	133
Room Booked Within +/- 15%?	N
Total Case Cost	$ [redacted]
Implant Cost	$ [redacted]
Supply Cost	$ [redacted]
Charges Triggered By	[redacted]

Category	Name
Anesthesiologist - Anesthesia Provider	[redacted]
Circulator	[redacted]
Primary - Physician	[redacted]

Average case cost last 6 months	[redacted]	All Providers
COLOSTOMY, LAPAROSCOPIC	(9) $ [redacted]	(16) $ [redacted]

For questions please reference Log ID [redacted]

Supply Type	Product Name	Manufacturer	One Time Supply	Used	Waste	Unit Cost	Case Cost
SUPPLY	LAPAROSCOPIC SYSTEM GELPOINT AD...	APPLIED MEDICAL RESOU...	N	1	0	[redacted]	[redacted]
	SURGICAL PACK LAPAROSCOPIC	PHS (CUSTOM PACKS)	N	1	0	[redacted]	[redacted]
	CLEARIFY SYSTEM VISUALIZATION SCO...	COVIDIEN	N	1	0	[redacted]	[redacted]
	ELECTRODE FLAT L-HOOK LAPAROSCOP...	COVIDIEN	N	1	0	[redacted]	[redacted]
	SUTURE VICRYL PLUS 3-0 18" SH POPS	ETHICON INC	N	3	0	[redacted]	[redacted]
	GOWN MICRO COOL LG BLUE, AAMI LVL 4	KIMBERLY-CLARK CORP	N	4	0	[redacted]	[redacted]
	SLEEVE SCD KNEE MEDIUM	COVIDIEN	N	1	0	[redacted]	[redacted]
	SET TUBE PNEUMOCLEAR HIGH FLOW ...	STRYKER MEDICAL	N	1	0	[redacted]	[redacted]
	SUTURE VICRYL PLUS 3-0 27" SH VCP316	ETHICON INC	N	4	0	[redacted]	[redacted]
	KIT NATURA ILEOSTOMY 70MM FLANGE	CONVATEC	N	2	0	[redacted]	[redacted]
	GOWN SURGICAL ULTRA SM BLUE, AAMI...	KIMBERLY-CLARK CORP	N	2	0	[redacted]	[redacted]
	GLOVE SURGICAL BIOGEL SIZE 6.5	MOLNLYCKE HEALTH CARE...	N	4	0	[redacted]	[redacted]
	JMC ONLY- O.R. CAMERA COVER LIGHT,...	CARDINAL HEALTH INC	N	1	0	[redacted]	[redacted]
	GLOVE BIOGEL PI ULTRATOUCH SIZE 6	MOLNLYCKE HEALTHCARE	N	2	0	[redacted]	[redacted]
	SPONGE LAP RF DETECT 18" X 18" XRAY...	RF SURGICAL	N	3	0	[redacted]	[redacted]
	SOLUTION IRR POUR BTL 0.9% NS 100...	BAXTER HEALTHCARE CO...	N	1	0	[redacted]	[redacted]
	GLOVE BIOGEL INDICATOR UNDERGLO...	MOLNLYCKE HEALTH CARE...	N	3	0	[redacted]	[redacted]
	GLOVE BIOGEL SUPER-SENSITIVE SIZE ...	MOLNLYCKE HEALTH CARE...	N	3	0	[redacted]	[redacted]
	SOLUTION IRR POUR BTL H20 1000ML	BAXTER HEALTHCARE CO...	N	1	0	[redacted]	[redacted]
	PROTECTOR ULNAR NERVE	DEROYAL INDUSTRIES INC	N	1	0	[redacted]	[redacted]
	GLOVE BIOGEL INDICATOR UNDERGLO...	MOLNLYCKE HEALTH CARE...	N	2	0	[redacted]	[redacted]
	GLOVE BIOGEL PI INDICATOR SIZE 6	MOLNLYCKE HEALTHCARE	N	1	0	[redacted]	[redacted]
	GLOVE BIOGEL PI INDICATOR SIZE 6.5	MOLNLYCKE HEALTHCARE	N	1	0	[redacted]	[redacted]
	TOWELS OR BLUE 4-PACK STERILE, DI...	MEDLINE INDUSTRIES INC	N	1	0	[redacted]	[redacted]
	CATHETER ROBINSON 16FR	BARD	N	1	0	[redacted]	[redacted]
	SPONGES PEANUT IN HOLDER 5/PACK-...	BIOSEAL MEDICAL PACKA...	N	1	0	[redacted]	[redacted]
	SURGILUBE JELLY 2OZ- STERILE	APPLICARE	N	1	0	[redacted]	[redacted]
	CLIPPER BLADE ASSY FOR 9670 CLIPPER	CAREFUSION	N	0	0	[redacted]	[redacted]
	DRESSING SPONGE CURITY 4X4 16 PLY	COVIDIEN	N	0	0	[redacted]	[redacted]
	DRESSING TEGADERM HP 4" X 8"	3M HEALTH CARE	N	0	0	[redacted]	[redacted]
	DRESSING TELFA STRL 3" X 8"	COVIDIEN	N	0	0	[redacted]	[redacted]
	PNEUMONEEDLE INSUFFLATION 14GA X...	ETHICON INC	N	0	0	[redacted]	[redacted]
	RELOAD ENDOPATH ECHELON FLEX 60...	ETHICON INC	N	0	0	[redacted]	[redacted]
	RETRACTOR ALEXIS WOUND PROTECT...	APPLIED MEDICAL RESOU...	N	0	0	[redacted]	[redacted]
	RETRACTOR ALEXIS WOUND PROTECT...	APPLIED MEDICAL RESOU...	N	0	0	[redacted]	[redacted]
	SPONGE KITTNER ROLL GAUZE	CAREFREE	N	0	0	[redacted]	[redacted]
	STAPLE RELOAD ECHELON ENDOPATH ...	ETHICON INC	N	0	0	[redacted]	[redacted]
	STAPLER ECHELON FLEX 60 POWERED ...	ETHICON INC	N	0	0	[redacted]	[redacted]
	SUCTION IRRIGATOR STRYKEFLOW2- S...	STRYKER MEDICAL	N	0	0	[redacted]	[redacted]
	SUTURE VICRYL PLUS 3-0 27" SH VCP784	ETHICON INC	N	0	0	[redacted]	[redacted]
	TISSUE SEALER- ENSEAL G2 LAP, 35CM,...	ETHICON INC	N	0	0	[redacted]	[redacted]
	TRAY FOLEY SURESTEP LUBRI-SIL I.C.1...	BARD	N	0	0	[redacted]	[redacted]
	TROCAR ENDOPATH XCEL BLADELESS ...	ETHICON INC	N	0	0	[redacted]	[redacted]
	TROCAR ENDOPATH XCEL BLADELESS ...	ETHICON INC	N	0	0	[redacted]	[redacted]
	TROCAR ENDOPATH XCEL STABILITY S...	ETHICON INC	N	0	0	[redacted]	[redacted]
	Total			**48**	**0**	-	**$** [redacted]

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Fig. 2 – Example of a surgical receipt. The surgical receipt was compiled and delivered to the primary surgeon for each case within 3 d of the operation. The surgical receipt included, among other things, the cost of each item, the total supply cost for the case, a comparison of supply costs between the surgeon and his/her peers, and case length booking accuracy. (Color version of figure is available online.)

Table 1 – Median unadjusted and adjusted case costs.

Procedure	Number of cases		Unadjusted analysis			Adjusted analysis		
	Before	After	Before	After	P-value	Before	After	P-value
Laparoscopic cholecystectomy	245	259	$886.77	$816.13	0.002	$888.15	$816.60	<0.001
Thyroidectomy	205	243	$861.21	$825.90	0.034	$858.16	$812.90	0.003
Open inguinal hernia	158	184	$429.45	$372.49	<0.001	$434.97	$410.73	<0.001
Laparoscopic appendectomy	228	211	$1321.50	$1351.20	0.101	$1303.96	$1342.30	0.166
Lumpectomy	385	426	$325.67	$420.53	<0.001	$327.51	$403.88	<0.001

In comparing before *versus* after implementation of the surgical receipt, there was a significant decrease in median supply costs for laparoscopic cholecystectomy, thyroidectomy, and open inguinal hernia. There was no significant difference in laparoscopic appendectomy, but there was a significant increase in lumpectomy. This finding was consistent after adjusting for price changes during the study period.

MWU test was performed to compare median incision-to-closure durations and length of stays between the pre-intervention and postintervention groups. A χ^2 test was used to analyze booking accuracy and American College of Surgeons National Surgical Quality Improvement Program postoperative occurrence rates during the two periods.

For all calculations, two-tailed significance thresholds were set at $P < 0.05$. Statistical analysis was performed using SPSS (IBM Corp, Version 25, Armonk, NY) and R Studio (Version 3.3.2).

Results

Our five procedures of interest from April 2014 to May 2017 were lumpectomy ($n = 811$), laparoscopic cholecystectomy ($n = 504$), laparoscopic appendectomy ($n = 439$), thyroidectomy ($n = 448$), and open inguinal hernia repair ($n = 342$).

Median per-case costs

Median case cost analysis is reported in Table 1. Three of the five procedures demonstrated significant reduction in median case cost after implementation of the surgical receipt program. Median cost for laparoscopic cholecystectomy decreased from $886.77 per case to $816.13 ($P = 0.002$), for thyroidectomy from $861.21 to $ 825.90 ($P = 0.034$), and for open inguinal hernia repair from $429.45 to $372.49 ($P < 0.001$). For all three procedures, postintervention median case costs remained significantly reduced after price adjustment, for laparoscopic cholecystectomy from $888.15 to $816.60 ($P < 0.001$), for thyroidectomy from $858.16 to $812.90 ($P = 0.003$), and for open inguinal hernia repair from $434.97 to $410.73 ($P < 0.001$).

By contrast, laparoscopic appendectomy cost did not change significantly from $1321.50 to $1351.20 ($P = 0.101$) unadjusted and from $1303.96 to $1342.30 ($P = 0.166$) price-

Table 2 – Secondary outcome measures.

Procedure	Outcome	Before	After	P-value
Laparoscopic cholecystectomy	Median skin minutes	75	96	<0.001
	Percent of accurately booked cases	36.3%	39.6%	0.464
	Median length of stay (d)	1	1	0.821
Thyroidectomy	Median skin minutes	79	73	<0.001
	Percent of accurately booked cases	32.5%	48.1%	0.001
	Median length of stay (d)	1	1	0.093
Open inguinal hernia	Median skin minutes	70	74.5	0.125
	Percent of accurately booked cases	38.0%	34.2%	0.500
	Median length of stay (d)	0	0	0.441
Laparoscopic appendectomy	Median skin minutes	57.5	61	0.131
	Percent of accurately booked cases	38.6%	55.0%	0.001
	Median length of stay (d)	1	1	0.671
Lumpectomy	Median skin minutes	55	54	0.251
	Percent of accurately booked cases	50.6%	54.4%	0.360
	Median length of stay (d)	0	0	0.083

When comparing the before *versus* after implementation of the surgical receipt, there was a significant increase in the median skin minutes for laparoscopic cholecystectomy. However, there was a significant decrease in skin minutes for thyroidectomy. There was an increase in the proportion of accurately booked cases for thyroidectomy and laparoscopic appendectomy. There were no differences in median length of stay for any of the procedures.

Table 3 – NSQIP outcomes.

Procedure	Number of captured cases		Number of postop occurrences		P-value
	Before	After	Before	After	
Laparoscopic cholecystectomy	123 (50.2%)	64 (24.7%)	7	1	0.268
Thyroidectomy	31 (15.1%)	28 (11.5%)	0	0	-
Open inguinal hernia	85 (53.8%)	51 (27.7%)	4	5	0.302
Laparoscopic appendectomy	161 (70.6%)	85 (40.3%)	3	1	1.00
Lumpectomy	140 (36.4%)	129 (30.3%)	2	5	0.264

There were no differences in the postoperative outcomes before and after implementation of the surgical receipt.

adjusted. Median lumpectomy cost increased from $325.67 to $420.53 ($P < 0.001$) unadjusted and from $327.51 to $403.88 price-adjusted ($P < 0.001$).

Exclusion of implant costs

Open inguinal hernia repair and lumpectomies were the two procedures in our analysis in which implantable supplies are standard of care. Implanted meshes were often used in inguinal hernia repairs, and radiographic targets markers were sometimes used in lumpectomies. In the before period, all 158 open inguinal hernias had an implanted mesh, whereas 182 of the 184 open inguinal hernias had an implanted mesh in the after period. In lumpectomies, only 30 of 385 had radiographic marker in the before period, but 85 of 385 had one in the after period.

When excluding implanted inguinal meshes, the median per-case disposable supply costs for inguinal hernia repair remained significantly decreased when price adjustment was applied from $143.00 before intervention to $134.51 ($P = 0.004$).

When excluding radiographic target markers from analysis and adjusting for price, median per-case supply costs for lumpectomy continued to be significantly increased, from $287.38 to $355.30 ($P = 0.024$).

Secondary outcomes

Secondary outcome measures are shown in Table 2. Median incision-to-closure times were not significantly different between preintervention and postintervention time frames for laparoscopic appendectomy ($P = 0.131$), lumpectomy ($P = 0.251$), and open inguinal hernia ($P = 0.125$). Laparoscopic cholecystectomy (median 75 min to 96 min, $P < 0.001$) saw an increase in the median incision time. Thyroidectomy saw a significant decrease in incision-to-closure time (median 79 min to 73 min, $P < 0.001$).

There was a significant increase in booking accuracy for laparoscopic appendectomy ($P = 0.001$) and thyroidectomy ($P = 0.001$) during the study period. Although the proportions of accurate booking increased for laparoscopic cholecystectomy and lumpectomy, neither reached a level of significance ($P = 0.464$ and $P = 0.360$, respectively). Conversely, the proportion of accurately booked open inguinal hernia cases decreased in the postintervention period, but this was also not significant ($P = 0.499$).

Length of stays was not significantly different for any of the five procedures during the course of the study (Table 2). We also analyzed patients' clinical outcomes of these five procedures during our study periods (Table 3), where there were no significant differences in the number of postoperative occurrences for any of the procedures.

Discussion

In our primary analysis of five representative general surgery procedures, we saw a significant reduction in median OR case costs for three of five commonly performed general surgery procedures at our institution. This finding was consistently observed after controlling for fluctuations in supply pricing, suggesting changing patterns of surgeon use—reducing supply waste and choosing less expensive alternatives—as the primary driver of decreased supply costs. However, we saw no significant difference in one procedure and a significant increase in supply costs for another procedure. Our secondary analysis showed that there was no difference in the length of stay or postoperative complications for any of the procedures between the two study periods. We saw an increase in the booked case length accuracy in laparoscopic appendectomy and thyroidectomy. However, laparoscopic cholecystectomy saw an increase in the skin minutes, whereas thyroidectomy saw a decrease in the skin minutes.

This study demonstrated that a fully operationalized surgeon-directed cost feedback system has the potential to decrease OR disposable supply costs for select procedures. One of the biggest barriers to implement such a system is making it operationally feasible. One advantage of our system is automation. Supplies are recorded under a case once the OR nurse scans the item into the computer and receipts are automatically generated and delivered to the surgeon. This level of automation is required to make such a system operationally feasible. In addition, after the initial startup costs of setting up the database, the cost of maintaining this system is low.

The fact that only three of the five procedures saw a decrease in supply costs suggests that surgeon-directed feedback can be effective in reducing supply costs but only in certain circumstances. A systematic review on the topic found that as study size increased, the cost savings decreased.[18] This may reflect challenges with scaling such a feedback system or publication bias in which only impressive small studies are published. It may also be that as a surgeon-directed cost feedback system is only effective for certain procedures and must be a targeted intervention. When applied to multiple procedures and groups of surgeons, as in our study, it may be that some surgeons (or divisions) were more flexible in their practice patterns and were open to feedback regarding costs, whereas others were not. In addition, it may be that certain procedures are already highly standardized, and therefore, there is little room to change practice patterns. For example, most surgeons at our institution perform laparoscopic appendectomies similarly and use the same items. Studies have shown that standardization of preference cards can lead to decreased costs across multiple procedures and specialties,[19-21] so perhaps cost utilization in such procedures are already maximized. Another consideration in the analysis of our data is the effect of time. We attempted to perform a time trend analysis, but the high variability in the median supply costs of each procedure prevented accurate models to be built. We have included a visual representation of the median supply costs per month compared with the overall median supply cost for the before period for each procedure (Appendix).

Interpretation of cost data can be highly complex. A decrease in the supply cost can be attributed to changes in item utilization (either substituting for a cheaper alternative item or omitting items) or changes in the price of the item itself. The goal of the surgical receipt is to influence supply utilization through either substitution to more cost-effective and clinically comparable alternatives or through reduction in unnecessary utilization. To control for changes in the price of the items, we used a novel price adjustment technique. While previous studies have used the consumer price index (CPI) as a surrogate for changes in price,[11] we directly controlled for the changes in price of the item by establishing a master price list for each item. We believe that this method is superior because the master price list makes all items the same price across the study period, thereby removing the change in the price of the item as a possible cause for changes in overall supply costs. Conversely, the CPI is based on the average change in prices on a macrolevel and adjusting for supply costs using the CPI is subject to assuming an "average" change in prices has occurred at our institution over the study period.

It is extremely difficult to pinpoint which specific supplies led to changes in the median supply costs for each procedure. However, we can compare the change in median cost per case for different supply types in the before and after period, and identify the supply types that had the largest increase or decrease during the two periods (Table 4). For supplies that are used in every case (e.g., laparoscopic instrument packs for laparoscopic cases), a change in median case cost would signify a change in the cost of the supply itself. But for supplies that are not required for every case, it is difficult to attribute a change in median case cost to changes in the cost of the individual supply *versus* changes in utilization due to cost feedback or shifts in practice patterns. We attempted to control for changes in per-item price over the course of the study period with our novel price adjustment method, but accounting for changes in practice patterns is challenging. For example, the increase in the use of BioZorb (Focal Therapeutics, Aliso Viejo, CA) radiographic markers for lumpectomy cases in the after period may be indicative of a shift in the standard of care, whereas the decreased use of energy dissectors in laparoscopic cholecystectomy may be due to the cost feedback received by surgeons. As surgeons incorporate more technology in the hope of improving patient care, the cost of OR expenses also increases on a yearly basis.[11] This fact makes it even more important to address controllable product costs in an effort to implement new technology in a cost-sensitive manner.

The results of our secondary analysis, mainly the unchanged length of stay and postoperative morbidity rate, suggest that overall clinical outcomes were likely unaffected by the implementation of the receipt. Historically, all procedures included in this study have low morbidity rates, so it's possible that the numbers of patients included are too small to identify modest differences for these low morbidity procedures. Likewise, this study is likely not adequately powered to detect differences in length of stay due to the fact that it is rare for patients to stay greater than 1 d in the hospital for these procedures. One concern of reducing the utilization of preferred products is increased inefficiency and consequently prolongation of the procedure. The incision-to-closure time increased significantly for laparoscopic cholecystectomy by 21 min and modestly for open inguinal hernia while decreasing for thyroidectomy. This result is hard to interpret,

Table 4 – Possible drivers of changes in total supply costs per case.

Procedures	Change in median supply costs	Possible drivers of changes in supply costs
Laparoscopic cholecystectomy	Significantly lower	Decreased use of energy dissectors, decreased use of hemostatic dressings
Thyroidectomy	Significantly lower	Increased use of cheaper surgical clips
Open inguinal hernia	Significantly lower	Decreased cost of surgical meshes
Laparoscopic appendectomy	Nonsignificantly higher	Increased use of more expensive staplers, decreased cost of laparoscopic instrument packs
Lumpectomy	Significantly higher	Increased use of radiographic markers, increased use of energy dissectors

The change in the supply costs for each procedure can be attributed to either changes in the cost of the supply or changes in the utilization of the supply.

as many factors can affect how long a surgeon takes to complete a case. While it can be argued that the change in skin minutes may be related to the fact that the surgeon is now using a different item due to the cost feedback he or she received, this is also very difficult to prove. A deeper analysis of this finding shows that for laparoscopic cholecystectomies at our institution, 40.7% of surgeons in the after period did not perform any in the before period. In other words, these tended to be younger, newer, and less-experienced surgeons. For these surgeons, the median skin minutes was 106 min, which may have contributed to the increase in the median skin minutes of all surgeons in the after period. This suggests that the increase in skin minutes for laparoscopic cholecystectomy may be unrelated to the effects of the surgical receipt. However, any change in case duration can have a profound impact on the cost to the hospital system, as multiple studies have shown that OR is a cost-dense environment.[17] Therefore, this finding, even if unrelated to the surgical receipt, is important to note. Booking accuracy increased for four of the five cases (although, only two were statistically significant). This is a potential benefit of the receipt, as it includes feedback to the surgeon on the accuracy of their scheduled case duration. More accurate booking of cases has the potential to increase OR efficiency and generate more revenue and decrease overall costs to the hospital.[22,23]

Limitations

The operational nature of the surgical receipt is a source of limitations in our study. The operational database was not built for research purposes. For example, it did not contain any patient demographic or comorbidity data. This study is also retrospective in nature, so a control group was not possible. Our database also did not include the cost of medications. Although this was not the main outcome measure for this study, medications have the potential to encompass a significant portion of the total cost of a surgical procedure. The surgical procedures were selected after querying for the most common major procedures performed by general surgery at our institution, which may be a source of selection bias. Procedures were identified by the primary CPT associated with the case. This has the potential to capture cases in which multiple procedures were performed, but the primary CPT associated with the case was one of interest. However, this possibility is not likely to be related to implementation of the intervention, so it should have equal effect on both periods. In addition, we grouped procedures by the primary CPT code but did not have intraoperative details to analyze. For example, not all laparoscopic cholecystectomies are the same and differences in each case may lead to different supplies to be used. This lack of intraoperative details represents a potential new area of research in future studies. Finally, surgical receipts during the study period were delivered to surgeons by email, so that there is no way to assess whether they had been viewed by their recipients—a measure that would represent adherence to the intervention. However, review of the surgical receipt was a departmental directive, so it is not unreasonable to think that most surgeons reviewed their receipts. The ability to track readership of the cost feedback system is a priority for future iterations of the receipt. However, it is not possible with the current software platform but merits further development in future studies. Along with refinements in the receipt, our next steps forward will be in defining active interventions and exploring alternative methods to curtail surgical supply costs.

Conclusions

Our study shows that controlling surgical supply costs remains challenging, but an automated and operationalized surgeon-directed cost feedback system may be a useful tool to control surgical expenditures for health care systems. Despite a hands-off approach without financial incentives, there was a significant decrease in median case costs for three commonly performed surgical procedures. More studies will be needed to elucidate specific reasons for increasing or decreasing supply costs after implementation of such a receipt, and how surgeon-directed cost feedback can impact other procedures and specialties. In addition, surgeon-directed cost feedback alone may not be sufficient to decrease supply costs and a multimodal approach to change surgeon behavior may be necessary.

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Disclosure

The authors report no proprietary or commercial interest in any product mentioned or concept discussed in this article.

Supplementary data

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