Comparing surgical trays with redundant instruments with trays with reduced instruments: a cost analysis

A. John-Baptiste PhD, L.J. Sowerby MD MHM, C.J. Chin MD, J. Martin PharmD MSc, B.W. Rotenberg MD MPH

Abstract

Background: When prearranged standard surgical trays contain instruments that are repeatedly unused, the redundancy can result in unnecessary health care costs. Our objective was to estimate potential savings by performing an economic evaluation comparing the cost of surgical trays with redundant instruments with surgical trays with reduced instruments ("reduced trays").

Methods: We performed a cost-analysis from the hospital perspective over a 1-year period. Using a mathematical model, we compared the direct costs of trays containing redundant instruments to reduced trays for 5 otolaryngology procedures. We incorporated data from several sources including local hospital data on surgical volume, the number of instruments on redundant and reduced trays, wages of personnel and time required to pack instruments. From the literature, we incorporated instrument depreciation costs and the time required to decontaminate an instrument. We performed 1-way sensitivity analyses on all variables, including surgical volume. Costs were estimated in 2013 Canadian dollars.

Results: The cost of redundant trays was $21 806 and the cost of reduced trays was $8803, for a 1-year cost saving of $13 003. In sensitivity analyses, cost savings ranged from $3262 to $21 395, based on the surgical volume at the institution. Variation in surgical volume resulted in a wider range of estimates, with a minimum of $3253 for low-volume to a maximum of $52 012 for high-volume institutions.

Interpretation: Our study suggests moderate savings may be achieved by reducing surgical tray redundancy and, if applied to other surgical specialties, may result in savings to Canadian health care systems.

In 2015, total health care expenditures in Canada were estimated at $219 billion.[1] Although hospitals represented the largest category of expenditures at 29.5%, this proportion has been steadily decreasing over the last 2 decades. The decline is due in part to provincial and territorial policies to promote cost cutting in hospitals. In Ontario, activity-based funding in the form of Health-Based Allocation Models has been implemented to promote quality care and incentivize increased efficiency.[2,3] Similar funding initiatives have previously been implemented in British Columbia and Alberta.[4] As a result, hospitals are keen to identify areas of potential cost savings.

Surgical tray redundancy is recognized as a difficulty in surgical units.[5–8] At one hospital, a review of 49 procedures and 247 trays within 4 surgical specialties (otolaryngology, plastic surgery, bariatric surgery and neurosurgery) showed that rates of instrument use varied from 13.0% to 21.9%.[7] After surgery, sterile processing personnel decontaminate instruments through manual cleaning. Personnel assemble standardized trays by packing instruments onto trays, which are then washed and sterilized in a washer–disinfector machine for the next surgical procedure. Since all instruments in an opened tray require sterile processing, unused instruments incur potentially avoidable costs. In a previous study, we conducted a review of instruments on surgical trays in the otolaryngology departments of St. Joseph's Health Care London and the London Health Sciences Centre, London, Ont.[9] We found that the average tray use ranged from 20.1% to 51.7%, suggesting substantial redundancy. We have proposed streamlined trays — "reduced trays" — that would reduce the number of instruments by more than 50%. In this study, our objective was to perform an economic evaluation of streamlined trays to quantify the potential cost savings that may result from implementing the reduced trays.

Methods

We conducted a model-based economic evaluation comparing redundant trays to reduced trays. We performed a cost-analysis for 5 common otolaryngology surgical procedures (septoplasty, septorhinoplasty, skin cancer excision, endoscopic sinus surgery and tonsillectomy). The analysis was performed from the hospital perspective and incorporates the costs incurred by the hospital in sterile processing of surgical trays. The model estimated costs as a function of the number of instruments on the tray, the number of surgical procedures, the per instrument decontamination and packing times, personnel time costs and the per instrument depreciation cost.

$$\text{Cost}_{tray} = (n_{procedures} \times n_{instruments}) \times [\text{cost}_{time} (\text{time}_{decontaminate} + \text{time}_{pack}) + \text{cost}_{depreciation})$$

Costs were estimated in 2013 Canadian dollars.

Data sources

We incorporated data from several sources into the model. We used local hospital data from 2 tertiary care academic hospitals, the London Health Sciences Centre and St. Joseph's Health Care, in London, Ont. For the 5 otolaryngology procedures, we obtained 2013 hospital data on surgical volumes. We incorporated data on the number and composition of extant trays and proposed reduced trays comprising fewer, more frequently used instruments, based on findings from our earlier review of tray use.[9] The details of extant and reduced tray composition are provided in Appendix 1 (available at www.cmajopen.ca/content/4/3/E404/suppl/DC1).

To estimate the time to pack instruments during tray assembly, we obtained routinely collected data from the hospital central processing unit at the London Health Sciences Centre on the time to assemble otolaryngology trays between Jan. 1, 2013, and Dec. 31, 2013. The data set represented 173 trays, with a total of 9445 assemblies, and provided the mean packing time per tray across all surgical procedures. To obtain a sample representative of the 5 tray categories of interest, we selected tray categories with a minimum of 10 instruments, and a minimum of 10 repeated assemblies. For each tray, we divided the total number of instruments per tray by the average tray assembly time to calculate a mean per instrument packing time and incorporated the 2.5 and 97.5 percentiles of the per instrument packing time as the extreme ends of the range for sensitivity analysis. From the human resources department, we obtained the mean wage rates of central processing personnel, along with the minimum and maximum wage rates. We calculated a per second wage rate by dividing hourly rates by 3600.

Because routinely collected data on decontamination times and per instrument depreciation costs were not available from the local hospitals, we conducted a review of the literature to identify studies with relevant information. We incorporated a minimum and maximum decontamination time for trays with more than 10 instruments from the University of Chicago Medicine Hospitals study using data from 61 trays.[7] From the

literature, we incorporated a mean per instrument depreciation cost of US$0.06 (minimum US$0.02, maximum US$0.18), which had been calculated by dividing instrument purchase prices by their estimated lifespans.[7] We used the purchasing power parity for health of 1.0206 to convert US dollars to Canadian dollars.[10] The purchasing power parity for health is an exchange rate estimated by comparing the price of a standard package of health-related goods and services, including hospital services, between 2 countries.

Statistical analyses

To compare our estimates with others from the literature, we estimated a per instrument labour cost by adding the per instrument decontamination and packing times and multiplying by the per second labour cost.[7] All analyses were performed using R for Statistical Computing (R Foundation for Statistical Computing, Vienna, Austria; https://www.R-project.org/).

Sensitivity analyses

We performed a series of one-way sensitivity analyses. We varied each parameter across its plausible range, with the other parameters set to their base case values. In this way, we characterized minimum and maximum cost savings for the range of each input parameter. We varied the reduction in tray size from 25% to 110%, corresponding to less reduction in tray size and greater reduction, respectively. We also, varied the surgical volume between 25% and 400%, corresponding to a low and high surgical volume, respectively. The surgical volume at our institution does not vary to a great extent. Sensitivity analysis on surgical volume is, however, pertinent to the external generalizability of our estimates to other institutions.

Scenario analysis

In the study conducted at the University of Chicago Medicine Hospitals, investigators estimated indirect cost savings from reduced trays for 49 procedures, spanning 4 surgical services (otolaryngology, plastic surgery, bariatric surgery and neurology). Indirect cost savings were estimated by allocating the operating costs of the sterile processing unit to each instrument to account for decreases in utilities, reagents, quality checks and equipment maintenance.[7] We incorporated these additional cost savings into a scenario analysis, rather than the base case analysis, owing to concerns that reductions in indirect cost are sensitive to scale. In our hospital, reagents for the washer–disinfector are used in standard aliquots irrespective of the number of surgical trays or the number of instruments in the machine. Reducing trays for 5 surgical procedures would not likely result in fewer cycles of operation for the washer–disinfector, and thus substantial savings from utilities, reagents and equipment repair and maintenance would not likely be realized.

Results

In the base case analysis, the estimated annual cost of redundant trays at London Health Science Centre and St. Joseph's

Health Care for the 5 procedures was $21 806 and the annual cost of reduced trays was expected to be $8803. Our analysis suggests that if we had implemented the proposed tray reduction at our institution, based on the number of procedures performed in 2013, we may have saved $13 003 in that year. Our base case per instrument labour cost was $0.13.

Study parameters

The 2013 hospital data on surgical volumes are shown in Table 1. Of a total of 173 trays, 39 met our inclusion criteria, representing 4541 assemblies. We calculated a mean per instrument packing time of 17.5 s and a per second cost of personnel time of $0.006 (Table 2). We incorporated a

decontamination time of 4.02 s per instrument. Minimum and maximum decontamination times were 1.07 s (15 s, 14 instruments) and 13.64 s (22 s, 300 instruments) per instrument, respectively. In the scenario analysis, we incorporated a per instrument indirect cost of US$0.23 by converting to Canadian dollars using the purchasing power parity (Table 2).[7,10]

Sensitivity analysis

Based on the surgical volume at our own institution, the extent of tray reduction was an important factor in the cost-saving estimates. One-way sensitivity analysis suggested that removing fewer instruments from the tray at 25% of the base case reduction would result in a cost saving of $3262, whereas

Table 1: Annual surgical volumes at London Health Sciences Centre and St. Joseph's Health Care

Procedure	No. of procedures each year	No. of instruments on extant trays	No. of instruments on proposed trays	Difference	Percent reduction
Septoplasty	197	84	33	51	61
Tonsillectomy	336	34	13	21	62
Skin cancer excision	220	43	27	16	37
Endoscopic sinus surgery	505	100	36	64	64
Septorhinoplasty	190	142	60	82	58

Table 2: Model input parameters

Variables	Base case value	Range	Source
Per instrument decontamination time, s	4.02	1.07–13.64	Stockert and colleagues[7]
Per instrument packing time, s	17.5	7.6–31.6	Analysis of local hospital data on tray packing times
Per second cost of personnel time, $	0.006	0.0058–0.0061	Derived from hospital human resources data by dividing hourly wages by 3600
Per instrument cost of depreciation, $	0.06	0.02–0.18	Derived from Stockert and colleagues;[7] purchasing power parities for health[9]
Per instrument indirect cost, $	0.23	NA	Derived from Stockert and colleagues;[7] purchasing power parities for health[9]

Table 3: Results of 1-way sensitivity analysis

Variable	Minimum value	Maximum value	Minimum cost saving, $	Maximum cost saving, $
Per instrument decontamination time, s	1.07	13.64	11 796	16 940
Per instrument packing time, s	7.6	31.6	8 951	18 773
Per second cost of personnel time, $	0.0058	0.0061	12 798	13 208
Per instrument cost of depreciation, $	0.02	0.18	10 205	21 395
Tray reduction	Smaller tray reduction (25% of base case)	Larger tray reduction (110% of base case)	3 262	14 300
Surgical volume	Lower surgical volume (25% of base case)	Higher surgical volume (400% of base case)	3 253	52 012

Note: The base case cost saving estimate is $13 003.

removing 10% more than the base case would result in a cost saving of $14 300 (Table 3). The per instrument packing time was also an important factor. In one-way sensitivity analysis, the estimated cost savings ranged from $8951 to $18 773 over the plausible range of per instrument packing times (Table 3).

Variation in surgical volume was associated with the largest variation in cost savings estimates. With all other parameters remaining the same, an institution performing 1/4 of the volume would save $3253 (Table 3). An institution performing 4 times the surgical volume would save $52 012 per year (Table 3).

Scenario analysis

In a scenario analysis that incorporated indirect cost savings, the cost of redundant trays was $48 781, the cost of reduced trays $19 692 and the estimated cost savings was $29 088 per year.

Interpretation

Our analysis suggests cost savings can be achieved by reducing surgical trays for 5 otolaryngology procedures. Although these savings are modest when considered in the context of the entire hospital budget, the effect could be greater if redundancy were addressed for a broader range of surgical procedures across specialties.

Our per instrument labour cost of $0.13 is comparable with the US$0.10 per instrument estimated by Stockert and colleagues.[7] Our institution did have a higher per instrument packing time of 17.6 seconds indicated by our local hospital data, compared with 12.51 seconds in the previous study.[7] Our per instrument cost is lower than that obtained by Morris and colleagues, with a per instrument processing cost of US$0.70, and lower that of than Florijn, with an estimate of €1 per instrument.[5,11] The input data for these cost estimates are not provided and thus the reasons for the higher costs when compared with our study are unclear. Our per instrument processing cost was also lower than that of Farrokhi and colleagues, with a per instrument processing cost of US$0.77.[12] Their estimate incorporated indirect costs, which accounts for some of the discrepancy when compared with our per instrument cost.

Several studies reported overall cost-saving estimates. In the Netherlands, cost savings were estimated to range between €55 000 and €81 360 each year.[5] Farrokhi and colleagues estimated potential savings of up to $2.8 million a year, with a 70% reduction in instrument processing for all surgical procedures at Virginia Mason Medical Center, a 300-bed hospital with 24 operating rooms.[12] The higher cost saving estimates when compared with our base case estimate are due in large part to the inclusion of a broader range of surgical procedures,[5,12] and inclusion of overhead costs.[12] Wannemuehler and colleagues estimated annual savings of $850 in sterile processing costs and a further $1468.99 savings in instrument purchasing costs associated with reducing an adenotonsillectomy tray.[8]

Indirect cost savings have been incorporated into other surgical instrument cost analyses.[7,12,13] Our base case estimate of savings conservatively excluded overhead costs. Our cost estimate would be an underestimate of the overall savings if the reduction in 5 otolaryngology trays were applied within a strategy spanning multiple procedures and surgical services. Our scenario analysis, incorporating the indirect costs of reagents, utilities, quality checks and equipment maintenance, suggested higher potential cost savings of $29 088.

Limitations

Our study is model based and, therefore, we incorporated data from a study conducted in the US. Uncertainty about variables can affect the results and lead to over or underestimation of the savings. We mitigated this effect by incorporating local data when possible, converting from US dollars to Canadian dollars using purchasing power parities and performing extensive sensitivity analysis.

Our study did not account for effects on operating room processes. Tray reduction may result in faster operating room set up, easier retrieval of instruments during operations and faster operating room clean-up. The evidence suggests that tray reduction speeds up operating room set up. This has recently been shown in the otolaryngology literature, with a significant 1-minute reduction in operating room turnover before and after reducing the number of instruments on the adenotonsillectomy tray.[8] Farrokhi and colleagues compared processes before and after tray optimization and found that a 70% reduction in the number of instruments for minimally invasive spine surgery (197 to 58), decreased set up time by 37% (from 13.1 to 8.2 min, $p = 0.0015$).[12]

Tray reduction may also result in adverse consequences such as the need, albeit infrequently, to retrieve instruments that are not on the surgical trays during procedures. Making a tray readily accessible in the operating room to be opened when extra instruments are required is a precautionary measure that can ensure clinical outcomes are not adversely affected. After implementing reduction in the adenotonsillectomy tray, Wannemuehler and colleagues found that the extra tray was accessed 3.6% of the time and that 93.75% of surgeons and other personnel were satisfied with the reductions.[8] An extra tray would attenuate tray reduction cost savings slightly, owing to the need for sterile processing of the extra tray.

The cost savings we estimated may not represent real savings to the hospital, particularly if there are no adjustments to the number of hours worked by central processing personnel. However, we are confident in our assumption of a linear relationship between time savings and cost savings. At our institutions, central processing personnel are paid by the hour, and managers have recently reduced hours to address budgetary challenges. In 2015, the reduction in employee hours at London Health Sciences Centre was equivalent to 97 full-time positions and was equivalent to 24 full-time positions at St. Joseph's Health Care.[14] This suggests that time savings from reduced trays have the potential to translate into cost savings.

The cost savings are based on a sampling of retrospective data, and ideally would be validated through prospective implementation of tray optimization.

Conclusion

Eliminating tray redundancy for 5 otolaryngology procedures is associated with a potential cost saving of $13 003. Owing to the promise for cost savings, the extent and generalizability of the savings, in addition to the impact on operating room processes, should be explored further in prospective studies. If tray redundancy is as common as literature-based estimates suggest, the broader implications for health care systems in Canada would be substantial when projected over a number of surgical procedures. For hospitals and departments interested in tray reduction, our suggestion would be to engage all invested parties, including nurses, physicians and operating room personnel, to identify frequently opened trays and to measure instrument utilization rates. Commercial products exist that can help facilitate instrument reduction and supply chain optimization. Our findings indicate that eliminating tray redundancy may be a simple and feasible opportunity for hospitals seeking to reduce costs.

References

1. National health expenditure trends, 1975 to 2015. Ottawa: Canadian Institute for Health Information; 2015. Available: https://secure.cihi.ca/free_products/nhex_trends_narrative_report_2015_en.pdf (accessed 2016 Mar. 5).
2. Health System Funding Reform (HSFR). Toronto: Ontario Ministry of Health and Long-Term Care; 2015. Available: www.health.gov.on.ca/en/pro/programs/ecfa/funding/hs_funding.aspx (accessed 2015 July 20).
3. Sutherland JM. *Hospital payment mechanisms: an overview and options for Canada.* Ottawa: Canadian Health Services Research Foundation; 2011. Available: www.cfhi-fcass.ca/Libraries/Hospital_Funding_docs/CHSRF-Sutherland-HospitalFundingENG.sflb.ashx (accessed 2015 July 4).
4. Surgical volume trends, 2008: within and beyond wait time priority areas. Ottawa: Canadian Institute for Health Information; 2008.
5. Kroes L. *Creating more efficiency and patient safety by changing processes and contents of instrument trays.* M.Sc. thesis, Health Science School of Management and Governance, Department of Science, Technology, Health and Policy studies (STeHPS) University of Twente, Enschede, The Netherlands; 2009.
6. Morris LF, Romero Arenas MA, Cerny J, et al. Streamlining variability in hospital charges for standard thyroidectomy: Developing a strategy to decrease waste. *Surgery* 2014;156:1441-9, discussion 1449.
7. Stockert EW, Langerman A. Assessing the magnitude and costs of intraoperative inefficiencies attributable to surgical instrument trays. *J Am Coll Surg* 2014;219:646-55.
8. Wannemuehler TJ, Elghouche AN, Kokoska MS, et al. Impact of Lean on surgical instrument reduction: Less is more. *Laryngoscope* 2015;125:2810-5.
9. Chin CJ, Sowerby LJ, John-Baptiste A, et al. Reducing otolaryngology surgical inefficiency via assessment of tray redundancy. *J Otolaryngol Head Neck Surg* 2014;43:46.
10. Choosing interventions that are cost effective (WHO-CHOICE): Purchasing Power Parity 2005. Geneva: World Health Organization: 2005. Available: www.who.int/choice/costs/ppp/en/ (accessed 2015 July 20).
11. Florijn EP. *Optimisation of the distribution of surgical instruments over trays. Cost effectiveness and quality improvement of an operating theatre.* M.Sc. thesis, Industrial Engineering and Management, Logistical Processes in Healthcare, University of Twente, Enschede, The Netherlands; 2008.
12. Farrokhi FR, Gunther M, Williams B, et al. Application of lean methodology for improved quality and efficiency in operating room instrument availability. *J Healthc Qual* 2015;37:277-86.
13. Prat F, Spieler JF, Paci S, et al. Reliability, cost-effectiveness, and safety of reuse of ancillary devices for ERCP. *Gastrointest Endosc* 2004;60:246-52.
14. London hospitals forced to cut millions from budgets, St. Joseph's dips into reserves. London (Ont.): AM980; 2015. Available: www.am980.ca/2015/03/31/42341/ (accessed 2015 July 20).

Affiliations: Department of Anesthesia and Perioperative Medicine (John-Baptiste, Martin); Department of Epidemiology and Biostatistics (John-Baptiste, Martin); Department of Otolaryngology–Head and Neck Surgery (Sowerby, Rotenberg), Interfaculty Program in Public Health (JOhn-Baptiste), Schulich School of Medicine and Dentistry, Western University; and Center for Medical Evidence, Decision Integrity, Clinical Impact (John-Baptiste, Martin), University of Toronto (Chin), Mount Sinai Hospital, Toronto, Ont.