



# Staplers vs. loop-ligature: a cost analysis from the hospital payer perspective

Richard Hilsden<sup>1,4</sup> · Nadia Khan<sup>2</sup> · Kelly Vogt<sup>1,3</sup> · Christopher M. Schlachta<sup>1</sup>

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## Abstract

**Background** Presently, there is equipoise regarding the surgical technique used to manage the appendiceal stump during laparoscopic appendectomy. The purpose of this research was to determine whether the routine use of loop ligature, compared to stapling, is cost effective from a hospital payer perspective.

**Methods** A retrospective cohort study was conducted amongst patients undergoing emergency laparoscopic surgery for acute appendicitis at two major academic hospitals. In order to eliminate possible systematic bias arising from one technique being preferentially employed with more complex presentations, patients were divided into study groups based on the technique routinely employed by their surgeon, loop ligature (LLA) versus stapler (LSA). Pediatric patients and open appendectomies were excluded. Costs were determined using a previously published model derived from publicly available data from the Ontario Case Costing Initiative, in conjunction with local cost data for disposable procurement. Secondary outcomes included operating room time, length of stay, and complication rates.

**Results** Between Jan 1, 2014 and Dec 31, 2015, 567 adult patients had an emergency laparoscopic appendectomy for acute appendicitis. In comparing surgeons who routinely employed LLA to LSA, there was a significant decrease in total mean hospital cost with LLA (\$1988 ± \$143 vs. \$2253 ± \$99,  $p=0.002$ ). In addition, mean disposable cost was reduced for surgeons using LLA (\$310 ± \$27 vs. \$668 ± \$26,  $p<0.001$ ). This reduction in cost was not associated with a difference in length of stay (1.5 vs. 1.4 days,  $p=0.28$ ) or complication rates (8% vs. 10%,  $p=0.43$ ).

**Conclusions** These findings suggest that surgeons who routinely use loop ligature to secure the appendiceal base during emergency laparoscopic appendectomy offer more cost-effective care compared to stapler users, saving their institution more than \$200 per case with no clear disadvantages. A shift from routine use of staplers to loop ligature should result in significant overall cost savings to the hospital.

**Keywords** Appendicitis · Laparoscopic appendectomy · Cost-analysis · Endoscopic stapler · Loop ligature

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✉ Richard Hilsden  
richard.hilsden@londonhospitals.ca

<sup>1</sup> Department of Surgery, Schulich School of Medicine & Dentistry, Western University, London, ON, Canada

<sup>2</sup> Department of Surgery, Faculty of Medicine, University of Ottawa, Ottawa, ON, Canada

<sup>3</sup> Department of Epidemiology and Biostatistics, Schulich School of Medicine & Dentistry, Western University, London, ON, Canada

<sup>4</sup> Department of Surgery, London Health Sciences Centre, University of Western Ontario, University Hospital, 339 Windermere Road, P.O. Box 5339, London, ON N6A 5A5, Canada

Acute appendicitis remains one of the most common diseases managed by acute care general surgeons [1]. Surgical management is the standard of care, [2, 3] and laparoscopic appendectomy (LA) has been advocated as the technique of choice by many authors, over open appendectomy [4–10]. LA is the most common management strategy for appendicitis; however, new controversy has arisen regarding the technique for closure of the appendicular stump. Options include loop ligature, clips, staplers, bipolar devices, and suturing, as well as other less prevalent options. Despite the myriad of approaches, no single method has emerged as superior in terms of patient outcomes, such as leak or surgical site infection (SSI) [11].

When deciding between procedures that have comparable patient outcomes, as is the case with the available

appendiceal stump management techniques, the focus of the provider and surgical leaders should shift toward optimizing value [12]. In the context of health care, value is best defined by the health outcomes achieved per dollar spent [13]. By this standard, when comparing two methods that provide similar patient outcomes, the treatment strategy with the lowest cost should be considered the superior technique.

In the case of LA, this logic can be applied to the two most commonly reported techniques in the literature (endoscopic stapler and loop ligature) [14–16]. Most studies, comparing disposable instrument costs, report a 4x increase in cost associated with staplers as compared to loop ligatures [11]. However, it should be recognized that the disposable instruments used in an operation represent only a fraction of the costs associated with a patient's total hospital stay. Operating room time and length of stay on the ward contribute considerably to the total cost from the health care payer perspective [17]. To that end, it is argued that the potential savings in OR time or length of stay among patients who have a stapled appendectomy could outweigh the additional direct cost associated with stapler use [18]. To date, no study has directly compared laparoscopic stapling to loop ligature using total cost from a hospital payer perspective as the primary outcome. We undertook this study to determine what the cost impact would be for surgeons using a routine stapler strategy compared to surgeons using a routine loop ligature strategy for management of the appendiceal stump.

## Methods

The primary outcome was the cost difference among the two surgical techniques from the perspective of the hospital payer. When determining the appropriate study methodology, the authors recognized that individual surgeons may use a variety of methods to control the appendiceal stump across their practice, and that the condition of the appendiceal base may influence the decision to use one technique over another. For example, necrosis of the appendix to the base may prompt surgeons to use a stapler and consequently a direct comparison between cases of stapling versus loop ligature may risk bias against staplers due to more complicated pathology. To mitigate this bias, patients were grouped based on the surgeons' general preference to use loop ligatures compared to laparoscopic staplers, rather than by the actual stump closure technique performed in each case.

To identify the surgeon's preference and subsequent patient grouping, a pilot research project was performed in which a random sample of appendectomies, for all surgeons at the two participating academic hospitals, were selected. The operative report of each of these cases was reviewed and the appendiceal stump management procedure of choice was identified. Surgeons were then classified as stapler surgeons

or endoloop surgeons based on the proportion of cases where they chose to manage the appendiceal stump using laparoscopic staplers versus loop ligatures. Surgeons who stapled less than 50% of the cases of appendicitis were categorized as non-stapler surgeons and surgeons who stapled greater than 50% were categorized as stapler surgeons. Nineteen surgeons performed laparoscopic appendectomies at our institution during the study period. Eight surgeons were categorized as routine endolooping surgeons and eleven were categorized as routine users of staplers. Endolooping surgeons used a stapler in 25% of cases, whereas stapling surgeons used staplers in 91% of cases ( $p < 0.001$ ). Surgeons in our institution who typically stapled used the ECHELON FLEX 45® stapler (Ethicon US) with one bowel load (blue), for the appendix, and one vascular load (white) for the mesoappendix. Surgeons who routinely used loop ligatures typically used two ENDOLOOPS® (Ethicon US) on the appendiceal stump and one more distally (for a total of three ENDOLOOPS®) prior to dividing the appendix with laparoscopic scissors. This analysis was completed a priori.

A retrospective cohort study design was used, and institutional ethics review board approval was obtained prior to data collection (Western Ethics Research Board# 107683). A 2-year convenience sample of all appendectomies performed from January 1st, 2014 to December 31st, 2015 was obtained. Data were abstracted retrospectively from the electronic medical record, and, if required, obtained from paper charts. Data abstraction was performed with the chart reviewers blinded to the categorization of the cases as belonging to a stapling surgeon or an endolooping surgeon. The inclusion criteria were all adult patients with a diagnosis of acute appendicitis who ultimately proceeded to operative management of their condition. Exclusion criteria included patients who underwent open appendectomy, or a right colectomy as the primary procedure, as were patients who had surgery (eg. diagnostic laparoscopy) but did not have an appendectomy, pediatric patients, and all patients managed non-operatively. Pathologic records were also evaluated to confirm the diagnosis of appendicitis and to determine perforation rate. OR time, length of stay, technique for stump closure, complications, age, weight, gender, pathologic diagnosis, and pre-operative imaging were obtained from the medical record.

An operating room cost model was developed using data from the Ontario Case Costing Initiative (OCCI), local institutional procurement costs for disposables, local contract rates for staff, and from the Ontario Physician Services Schedule of Benefits as sources of data (Table 1). The Ontario Case Costing Initiative is a publicly accessible dataset where hospitals contribute their estimate of costs for hospital encounters based on clinical diagnosis and procedures performed [19]. Estimates of cost attributable to length of stay, preoperative imaging, and post-operative care

**Table 1** Cost model components

Model item	Cost	Source
Disposables		
Stapler	\$390.00	Local contract
Load	\$186.00	Local contract
Endoloop®	\$19.58	Local contract
Endotrachial tube	\$5.35	Local contract
Drug costs		
Desflourane	\$0.65/ml	Local contract
Sevoflourane	\$0.59/ml	Local contract
Propofol	\$0.07/ml	
Staff		
RN/h	\$49.37	Local contract
RPN/h	\$35.72	Local contract
OR aid/h	\$26.35	Local contract
Investigations		
CT	\$491	OCCI
Ultrasound	\$356	OCCI
Visit costs		
Admission per day	\$776.23	OCCI
ER visit	\$286	OCCI
Physician billing		
Surgeon-nonperforated	336.60	OHIP 2014
Surgeon-perforated	451.50	OHIP 2014
Anesthesia-base	105.07	OHIP 2014
Anesthesia per 15 min	15.01	OHIP 2014
Surgeon-consult	90.30	OHIP 2014
Surgeon-follow up	41.20	OHIP 2014

was estimated from data available in this database. Variable OR time costs were incorporated throughout the model using data from previously published research from our institution [20]. Anesthesia and surgeon provider costs were determined using data from the Ontario Schedule of Benefits, and costs for disposable instrumentation were determined using the local procurement cost data.

Statistical analysis was performed using SPSS (ver. 24 Chicago, Illinois). Student's *t*-test was performed for

normally distributed continuous variable data. For non-normally distributed data, medians were reported, and significance calculated using the Mann–Whitney U test, and the chi-squared test was performed for categorical data.

## Results

A total of 1078 patient of all ages were identified in the electronic medical record as having a diagnosis of acute appendicitis. After exclusions, 567 patients who underwent laparoscopic appendectomy during their index admission formed the study cohort.

A total of 243 appendectomies were performed by surgeons identified as being endoloop surgeons and 324 appendectomies were performed by the stapler surgeons.

Analysis from the Ontario Case Costing Initiative revealed that, for patients undergoing appendectomy, a day of hospital admission had an average cost of \$776. The cost of a CT scan was \$491, and the cost of an ultrasound was \$356. During the study period, each ENDOLOOP® cost the local institution \$19.58. A single firing of a laparoscopic stapler cost \$576, with each additional stapler firing costing \$186 (Table 1).

For the primary outcome of mean cost borne by the hospital payer, cases performed by non-stapler surgeons were \$1988.50 ( $\pm$  \$143) compared to \$2253.48 ( $\pm$  \$99) for cases performed by stapler surgeons ( $p = 0.002$ , Table 2). Disposable costs were significantly lower among non-stapler surgeons ( $\$310 \pm \$26.51$  vs.  $\$668 \pm \$26.10$ ,  $p < 0.001$ ). From the provincial payer perspective, which includes direct physician billing to the provincial insurer, there was also statistically significant difference in cost between surgical groups ( $\$2795.69 \pm \$151$  vs.  $\$3031.51 \pm \$105$ ,  $p = 0.004$ ). A secondary cost analysis was performed based on actual technique used, regardless of the surgeon's typical practice. Cases that were performed with loop ligature demonstrated a significant mean cost savings compared to staplers, from the hospital payer perspective ( $\$1635.48 \pm \$80$  vs.  $\$2435.99 \pm \$115$ ,

**Table 2** Outcomes

	Endoloop® surgeons	Stapler surgeons	p value
N	243	324	
Mean cost hospital perspective	\$1988.50 ( $\pm$ \$143.22)	\$2253.48 ( $\pm$ \$99.47)	$p = 0.002$
Mean cost provincial perspective	\$2795.69 ( $\pm$ \$151.70)	\$3031.51 ( $\pm$ 105.49)	$p = 0.004$
OR time min (median)	69 (IQR 52–90)	66 (IQR 46–80)	$p = 0.003$
Disposable cost	\$309.94 ( $\pm$ \$26.52)	\$667.85 ( $\pm$ \$26.10)	$p < 0.001$
Length of stay (days)	1.5	1.4	$p = 0.284$
Stapler use (% of cases)	25%	91%	$p < 0.001$
Complications	8%	10%	$p = 0.43$
Perforated	19%	21%	$p = 0.49$

$p < 0.001$ ). These savings were again demonstrated from the view of the provincial payer ( $\$2376.42 \pm \$69$  vs.  $\$3165.49 \pm \$121$ ,  $p < 0.001$ ). Finally, we analyzed the data based on the surgeons usual practice excluding cases where an endolooping surgeon stapled and a stapling surgeon used a loop ligature. This left a total of 476 cases. Loop ligature cases on this analysis again were cheaper than stapled cases from the hospital payer perspective ( $\$1648.93 \pm \$187$  vs.  $\$2324.02 \pm \$104$ ,  $p < 0.001$ ).

OR time was non-normally distributed, and analysis revealed a small increase in median OR time among surgeons routinely using the loop ligature (69 min IQR 52–90 vs. 66 min IQR 46–80,  $p = 0.003$ ). There was no significant difference between mean length of stay between the non-stapler and the stapler surgeon groups (1.5 days vs. 1.4 days  $p = 0.28$ ). There was no significant difference in the perforation rate between the two groups (24% vs 21%,  $p = 0.106$ ).

Among perforated cases alone, the endolooping surgeons increased their use of staplers from 25 to 42%, and the routine stapling surgeons use of staplers was unchanged (90% vs 91%). Evaluating hospital costs, there was no difference between mean costs borne by endolooping surgeons vs. stapling surgeons ( $\$2758.10 \pm \$414$  vs.  $\$2755.39 \pm \$321$ ,  $p = 0.595$ ).

Evaluating all complications, there was no difference between the endolooping surgeons and the stapling surgeons (8% vs 10%  $p = 0.43$ , Table 3). The majority of the complications were classified as infections ( $n = 34$ ), with wound infections and intra-abdominal abscess being the dominant post-operative complications. In addition, the stapler surgeon group had three bleeding complications while the loop ligature group had one such event. As well 2 post-op hernias were identified among the surgeons who stapled while the surgeons that did not routinely use a stapler had a single postoperative hernia identified during the study period.

**Table 3** Complications

Complication	Endoloop® surgeons	Stapling surgeons	
Diarrhea/C. Diff	1	1	
Infections	11	23	
Bleeding	1	3	
Hernia	1	2	
Other	6	4	
	20	33	
Total (% of cases)	8%	10%	$P = 0.43$

## Discussion

Laparoscopic appendectomy lends itself to a number of technical options for the surgeon. The factors that may influence a surgeon's choice of technique include training, experience, perceived time efficiency, perceived impact on outcomes, and potentially cost. At our institution, most surgeons were categorized as being stapler surgeons with most patients receiving a stapled appendectomy. This is important, as the financial pressures on payers have resulted in efforts to contain costs through reduction in reimbursement, which, in some cases, has caused the cost of operating room consumables to exceed the reimbursements provided to the hospital [21].

Our findings demonstrate that, from a hospital payer perspective, surgeons who routinely use loop ligatures to secure the appendiceal base during emergency laparoscopic appendectomy offer more cost-efficient care than routine stapler users, saving their institution more than \$200 per case. Had the stapling surgeons at our institution routinely endolooped their cases our institution would have experienced approximately \$56,000 of savings over this study period.

It has also been proposed that the patient's condition may influence the technique chosen by the surgeon. The concern being that more severe and complicated cases of appendicitis are more likely to be managed with a stapled appendectomy, and that any non-randomized analysis could suffer systematic bias against staplers. To address this concern, this study uniquely grouped surgeons, prior to analysis, by their preferred technique. Grouping the surgeons in this way eliminates this potential systematic bias since it is likely that the surgeons who normally use loop ligatures would shift to staplers when faced with a more difficult case. This is supported by the fact that there was no significant difference in the perforation rate among the two surgeon groups. These findings were robust to two different sensitivity analyses where we first evaluated the cases grouped according to actual technique used, and then excluded cases where the surgeon used the alternative technique that was not their usual practice. In each of these cases, the cost benefit of loop ligature was larger than what was seen in our initial evaluation.

This is a first of its kind analysis and provides a pragmatic view of the potential savings a hospital could incur if a policy of routine loop ligature use was applied with endoscopic staplers being reserved for the more complicated cases. Although we suspect that most surgeons are aware of the increased cost of disposables when staplers are used compared to loop ligatures, arguments in favor of stapling include a potential time savings or a potential reduction in complications. Our data demonstrated

a statistically significant 3-min median increase in OR time among surgeons who routinely used loop ligatures, which is consistent with the prevailing literature [11, 15, 18]. However, considering the increased cost associated with a stapling strategy, this small difference in OR time is unlikely to be clinically meaningful. In addition, there were no differences in complications among the two groups of surgeons, nor was there a difference in length of stay.

Our primary outcome was the cost difference from a hospital payer perspective, that is to say the costs borne by the hospital for providing the service. This was chosen because the decision regarding which technique is used normally occurs at the institutional level. However, there are different financial perspectives to consider including the provincial payer perspective, the patient perspective, and the societal perspective [22]. The relative importance of these perspectives depends to a degree on the health system within which the service is provided. With this in mind, we did an additional analysis from the more conservative position of the provincial payer and observed a \$236 mean cost savings associated with the use of loop ligatures. The main additional contributory costs to the province for providing surgical services are physician billings. Since Ontario hospitals are generally administered in a non-for-profit model, savings identified at the hospital level may be carried through to the provincial payer. It is important to recognize that this observation may not be generalizable to other health systems where hospitals may operate on a profit basis. In those systems, savings at the hospital level are more likely to be captured as profit for the hospital, and therefore not passed on to the individual payer.

## Limitations

As with all retrospective research this study in limited the potential of selection bias. Since patients were not randomized to technique it is possible that significant patient factors contributed to stapler usage. However, it is important to note that this study uniquely compared surgeons by their usual technique of controlling the appendiceal base, a first in the literature, and there is no reason to expect that patient factors contribute to a surgeon's choice of usual technique. Lastly the generalizability of this research to other health care systems may be limited. In Canada's single payer public health system costs are negotiated by large purchasing groups, overhead, and profit margins are kept at a minimum or are non-existent leading to lower per case expenditures than many other health systems.

Our data contributes to the literature by providing evidence that, in addition to being less expensive, loop ligature is equally safe and similarly time efficient to the routine

stapler approach for managing the appendix in the operating room. Importantly, we have demonstrated that an institutional shift towards the routine looping of the appendix, as opposed to stapling, could result in a significant cost savings.

## Compliance with ethical standards

**Disclosures** Dr. Richard Hilsden, Dr. Nadia Khan, Dr. Kelly Vogt, or Dr. Christopher M Schlachta have no conflicts of interest or financial ties to disclose.

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