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ORIGINAL ARTICLE

Single-incision robotic colectomy: are costs prohibitive?

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Abstract

Background The feasibility, safety, and costs of single-incision robotic colectomy (SIRC) are not known.

Methods A retrospective review was conducted, comparing the initial 29 consecutive SIRC procedures performed to 36 multiport laparoscopic colectomies (MLC).

Results The groups did not differ significantly on age, body mass index, gender, ASA classification, smoking status, steroid usage or rate of diabetes. Procedure time, conversion rate, infectious complications and length of stay did not differ significantly. The ratio of observed:expected direct hospital costs statistically favoured MLC, although there was no statistical difference between groups for contribution margin, or for observed and expected direct hospital costs.

Conclusions These results demonstrate safety and technical feasibility for SIRC in selected patients with short-term outcomes and hospital costs comparable to MLC. Contribution margin remained positive and expected costs exceeded observed for SIRC. Increased costs for SIRC are a concern. The comparable but relatively high mortality in both groups may represent an institutional approach to colectomy where significant comorbidity is not a contraindication to minimally invasive surgery. Copyright © 2015 John Wiley & Sons, Ltd.

Keywords single-incision colectomy; robotic colectomy; colorectal surgery

Introduction

Single-incision laparoscopic colectomy (SILC) is increasingly recognized as a safe alternative to traditional multiport laparoscopic colectomy (MLC), with the potential for improved cosmetic results and as a promising bridge towards true natural orifice surgery (1).

SILC reports have largely been the product of specialized institutions with experienced laparoscopic surgeons and assistants, and highly selected patients (1–3). Neither concerns about feasibility and longer operative time when compared to MLC, nor improved short-term outcomes in terms of length of stay and less operative pain, have been substantiated in the literature (1,4). Additionally, the limited case experiences have hampered research evaluating the learning curve, best technique for teaching and mentoring, guidelines for patient selection and potential for widespread use (5).

The robotic surgery platform has unique aspects, such as the surgeon-controlled camera and ergonomic console, that may improve some technical aspects of single-site surgery, as seen with successful single-site adaptions for urological procedures (6). The use of robotics for single-incision robotic colectomy (SIRC) has been described in the literature, but larger experiences, on the order of magnitude seen in initial single-incision laparoscopic colectomy reports, have not been put forth for peer review (7–9). While single-site robotics could potentially broaden the applicability for single-site colectomy and allow for more thorough assessment of single-incision colectomy outcomes, several concerns exist with the robotic approach. Specifically, the inability to traverse multiple abdominal quadrants and reposition the patient without redocking limits robotic applications in colectomy. To some extent, however, the most immediate concern is the financial feasibility of exploring this new technique in an economic and health-care climate that is increasingly cost-conscious (10,11).

We aimed to present our early experience with single-incision robotic colectomy, evaluate technical feasibility and safety and assess hospital costs in comparison to traditional multiport laparoscopy.

Materials and methods

We performed a retrospective chart review of minimally invasive segmental colectomies performed at the University of Iowa Hospitals and Clinics between 1 August 2011 and 1 May 2013. The University of Iowa Institutional Review Board approved this study. The first 29 consecutive single-incision robotic colectomies were performed by one surgeon (J.B.), while the comparison group of standard multiport laparoscopic colectomies ($n = 36$ cases in 35 patients) were performed by nine different surgeons. Cases involving total colectomy and rectal dissections were excluded from the study, including one single-incision robotic total proctocolectomy with end ileostomy and one robotically assisted trans-anal minimally invasive surgery (TAMIS) local excision of a rectal polyp. Patients were selected for a SIRC or MLC based on surgeon discretion and informed consent.

SIRC

The technique of SIRC was adapted from Ostrowitz *et al.* (7) with the crossing of the robotic arms intracorporeally through commercially available laparoscopic single-incision trocars and 'swapping' the handedness of the arm control at the robotic console. This allowed a 'crossed right hand' to be controlled by the surgeon's left hand at the console, and vice versa. For both right and left colectomy, medial-to-lateral dissections were performed with ligation of the main vascular pedicle (ileocolic artery or inferior mesenteric artery), with a vessel-sealing device operated by the bedside assistant. The vessel sealer was placed through a laparoscopic port that was either directly through the commercial laparoscopic single-incision trocar or next to it within the same fascial opening. For right colectomy, mobilization of the mesentery and lateral attachments, including hepatic flexure, was accomplished with robotic-assisted dissection. After mobilization, the specimen was then extracted using a wound protector, the right branch of the middle colic was ligated and resection and anastomosis performed extracorporeally. For sigmoid colectomy, the sigmoid and descending colon mesentery and lateral colonic attachments were mobilized with robotic-assisted dissection. If full splenic flexure mobilization was performed, the robot was either redocked over the patient's left shoulder ($n = 2$) or single-incision laparoscopy was used ($n = 2$). If single-incision laparoscopy was employed to augment splenic flexure mobilization, this was not considered a conversion. The stapling of the rectosigmoid and creation of the colorectal anastomosis was performed with single-incision laparoscopic assistance.

Study variables

Preoperative, operative and postoperative factors of interest were collected and analysed. Direct patient chart review was augmented with institutional data collected as part of participation in the American College of Surgeons National Surgical Quality Improvement Program (ACS-NSQIP; 12) and the University Health System Consortium (UHC). Hospital inpatient cost data were obtained from the University of Iowa Hospitals and Clinics Finance and Accounting services Allscripts EPSi database (Chicago, IL, USA) and the University Health System Consortium (UHC) clinical database. UHC-observed costs are calculated by applying the Centers for Medicare and Medicaid Services (CMS) cost:charge ratio to actual hospital charges generated by individual institutions. UHC calculates risk-adjusted expected costs from the Base Medicare Severity-Diagnosis Related Group (MS-DRG) Model Group for Major Small and Large Bowel Procedures 114. Comorbid patient conditions, hospital occurrences and complications can increase this base expected cost when coded appropriately. The purchase and maintenance of the robot platform was considered an indirect cost and not factored into the direct cost analysis. This assumption was based on institutional-specific factors where the robotic platform is maintained for other surgical services and was under-utilized during the time period when the cases were performed.

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χ^2 tests and Fisher's exact tests for categorical variables, and *t*-tests and Wilcoxon rank sum tests for continuous variables, were used to compare groups (SIRC and MLC) on demographic variables, clinical characteristics and outcomes of interest. Costs were evaluated in multiple ways, including computing the difference between observed minus expected values, and by computing the ratio of observed divided by expected values. Outcome variables were assessed by indication for surgery and by right-sided vs left-sided procedures. All statistical analyses were performed in SAS v. 9.3 (SAS, Cary, NC, USA).

Results

Twenty-nine consecutive single-incision robotic colectomies (SIRC) were performed between 1 August 2011 and 1 May 2013. During this time period, nine different surgeons at the University of Iowa Hospitals and Clinics performed 36 multiport laparoscopic segmental colectomies (MLCs). Table 1 illustrates that the study group populations were similar in terms of preoperative patient characteristics, comorbidities and laboratory values examined. Diagnoses not classified as malignancy, inflammatory bowel disease or diverticulitis in the MLC group included colonic volvulus, chronic ischaemia and endometriosis. Significantly more patients underwent surgery for diverticulitis than malignancy in the SIRC group.

Table 2 illustrates operative outcomes and shows similar results in both groups. Notably, operative time was similar between groups, while length of stay showed a non-statistically significant trend favouring SIRC by 1.7 days.

Conversion rates and blood loss were similar between groups, with low infectious complication rates seen. Three of the nine conversions in the SIRC group were to MLC and the remaining six conversions were to open laparotomy, where the indications for conversion were disease-specific limitations requiring open surgery in five of six patients. One death within 30 days was observed in the SIRC group and two deaths in the MLC group. Deaths in both groups were attributed to cardiopulmonary complications in patients with significant comorbidity. No autopsies were performed for any of the mortalities. Two of the mortalities involved patients found unresponsive and pulseless, one at home and one on the inpatient ward, raising concern for cardiopulmonary collapse. In the third patient a known left ventricular thrombus was being medically managed with therapeutic anticoagulation postoperatively, when an arrhythmia led to otherwise unexplained clinical deterioration, suggesting a thrombo-embolic event. While no such event can be separated from the recent colectomy, none of the mortalities appeared directly attributable to a technical complication of the colectomy.

Table 1. Characteristics of study population by surgical approach

Characteristic	SIRC ($n = 29$)	MLC ($n = 36$)	p*
Continuous variables: mean (SD)			
Age (years)	47.3 (16.7)	47.9 (22.3)	0.90
Body mass index (BMI)	26.2 (5.7)	28.6 (6.6)	0.13
Preoperative albumin	4.2 (0.4)	3.9 (0.5)	0.07
Preoperative haematocrit	37.6 (5.7)	39.4 (4.0)	0.18
Binary variables: % (*n*)			
Male gender	38% (11)	47% (17)	0.45
ASA classification			0.81
1	11% (3)	11% (4)	
2	75% (21)	67% (24)	
3	11% (3)	19% (7)	
4	4% (1)	3% (1)	
History of smoking	28% (8)	25% (9)	0.81
Recent steroid use	24% (7)	31% (11)	0.57
Congestive heart failure	6% (2)	3% (1)	0.42
Chronic obstructive pulmonary disease	3% (1)	10% (3)	0.32
Diabetes mellitus	0% (0)	0% (0)	–
Indication for surgery			0.006
Cancer	31% (9)	53% (19)	
Crohn's disease	41% (12)	33% (12)	
Diverticulitis	28% (8)	3% (1)	
Other	0% (0)	11% (4)	
Right (vs left) colectomy	59% (17)	92% (33)	0.0017
Cancer cases only	$n = 9$	$n = 19$	
CEA: mean, SD	16.1 (38.0)	3.9 (5.2)	0.28
CEA: median (IQR)**	1.9 (1.3, 6.6)	1.5 (1.2, 4.4)	0.39

*p value based on χ^2 tests, Fisher's exact test and *t*-tests, as appropriate.
**One subject in the SILS group had a high CEA value, so median and interquartile range are presented in addition to mean and SD.
SIRC, single-incision robotic colectomy; MLC, multiport laparoscopic colectomy.

Mean observed direct hospital costs were lower in the SIRC group, as were expected costs. Neither mean observed nor mean expected cost differences reached statistical significance between groups. Mean observed and expected cost difference and ratio again did not show statistically significant differences. Due to an outlier in cost in the MLC group (max MLC direct hospital cost = $521 315 vs max SIRC direct hospital cost = $13 911), median cost calculations are also shown in Table 2. When comparing medians of cost variables using non-parametric tests to minimize the leverage of cost outliers in the MLC group, there was not a significant difference in observed costs or expected costs, although the expected costs were nearly significantly higher among MLC cases ($p = 0.06$). Cost differential and observed:expected cost ratios were significantly different, in favour of MLC.

Subgroup comparisons were performed by indication for surgery (Crohn's disease, cancer and diverticulitis) but low numbers in most subgroups limited power and stability. No significant differences were detected in outcomes among groups, with the exception that, among patients with Crohn's disease, operative time was nearly significantly shorter among patients receiving SIRC compared to MLC (119 vs 148 min; $p = 0.06$) and the ratio of observed:

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Table 2. Surgical outcomes and cost by surgical approach

Outcome	SIRC $n = 29$	MLC $n = 36$	p*
Continuous variables: mean (SD)			
Procedure time (min)	150 (52)	149 (79)	0.92
Estimated blood loss (ml)	121 (160)	165 (206)	0.35
Length of stay (days)	5.3 (1.4)	7.1 (7.6)	0.20
Contribution margin ($US)	$3978	$3320	0.88
Direct cost ($US)			
Observed	$10 746 ($4298)	$25 252 ($14 208)	0.32
Expected	$11 152 ($2470)	$23 745 ($61 078)	0.22
Observed – expected	–$406 ($2494)	$1507 ($24 621)	0.68
Observed/expected	0.95	0.83	0.06
Continuous variables: median (interquartile range)			
Direct cost ($US)			
Observed	$9628 ($8760, $10 937)	$8919 ($7344, $12 473)	0.30
Expected	$10,295 ($9604, $11 887)	$11 226 ($10 208, $19 941)	0.06
Observed – expected	–$735 (–$1673, –$19)	–$2780 (–$4528, $1018)	0.003
Observed/expected	0.93	0.77	0.004
Binary variables: % (n)			
Conversion	31% (9)	36% (13)	0.67
UTI	3% (1)	3% (1)	0.88
Superficial SSI	3% (1)	8% (3)	0.62
Organ space or deep SSI	3% (1)	6% (2)	0.69
Mortality	3% (1)	6%(2)	0.69
Cancer cases only	$n = 9$	$n = 19$	
Number of lymph nodes harvested: mean (SD)	18.0 (9.0)	20.1 (9.0)	0.57

*p value based on χ^2 tests, Fisher's exact tests, t-tests and Wilcoxon rank sum tests, as appropriate.
UTI, urinary tract infection; SSI, aurgical site infection; SIRC, single-incision robotic colectomy; MLC, multiport laparoscopic colectomy.

expected direct costs was lower for patients receiving MLC compared to SIRC (0.81 vs 0.92; $p = 0.02$) (Table 3).

Discussion

We present our initial experience with single-incision robotic colectomy and demonstrate the feasibility and safety of SIRC when compared to MLC in our patients. Conversion rates were comparable to MLC, and infectious complications, including no anastomotic leaks, were low. The substantial conversion rate (31% SIRC, 36% MLC) and presence of three mortalities in a small cohort likely points to a patient population that is relatively uniform in their poor candidacy for surgery and their significant comorbidity.

Table 3. Sub-analysis of outcomes by indication for colectomy

	Cancer			Crohn's disease			Diverticulitis		
	SIRC ($n = 9$)	MLC ($n = 19$)	p*	SIRC ($n = 12$)	MLC ($n = 12$)	p*	SIRC ($n = 8$)	MLC ($n = 1$)	p*
Outcome, mean (SD)									
Procedure time (min)	162 (62)	139 (68)	0.39	119 (23)	148 (44)	0.06	185 (48)	88 (–)	0.10
Length of stay (LOS; days)	5.4 (1.3)	7.4 (5.6)	0.31	5.4 (1.6)	4.4 (2.0)	0.19	4.9 (1.3)	3 (–)	0.20
Contribution margin	$2556 ($5968)	$9071 ($8556)	0.30	$5125 ($3760)	$4719 ($3623)	0.79	$3856 ($8256)	$11 378 (–)	0.42
Direct cost ($US)									
Observed	$12 288 ($6678)	$13 067 ($7286)	0.79	$9141 (2046)	$8743 ($3302)	0.73	$11 420 ($2891)	$7096 (–)	0.20
Expected	$11 954 ($3604)	$15 854 ($6323)	0.10	$9900 (1036)	$10 757 ($2526)	0.29	$12 129 ($1806)	$12 745 (–)	0.76
Observed LOS – expected LOS	$334 ($3434)	–$2786 ($5996)	0.16	–$759 ($1428)	–$2014 ($1744)	0.07	–$709 ($2680)	–$5649 (–)	0.13
Observed LOS/ expected LOS	0.99 (0.19)	0.83 (0.33)	0.19	0.92 (0.14)	0.81 (0.15)	0.02	0.95 (0.21)	0.56 (11)	0.12
Outcome, % (n)									
Conversion to open procedure	33% (3)	53% (10)	0.43	25% (3)	17% (2)	1.0	38% (3)	0% (0)	1.0
Superficial SSI	0% (0)	16% (3)	0.53	0% (0)	0% (0)	–	13% (1)	0% (0)	1.0
Organ space/deep SSI	0% (0)	5% (1)	1.0	0% (0)	8% (1)	1.0	13% (1)	0% (0)	1.0

SIRC, single-incision robotic colectomy; MLC, multiport laparoscopic colectomy; SSI, surgical site infection.
*p value based on χ^2 tests, Fisher's exact tests and t-tests, as appropriate.

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Due to the small sample size, few of the observed cost trends reached statistical significance, the exceptions being median direct hospital observed:expected cost ratio and median cost differential, where MLC appeared to show cost savings over SIRC. On further subgroup analysis, with even more sample size limitation, the mean direct hospital cost ratio also favoured MLC for patients with Crohn's disease.

Assessing cost in a limited, retrospective cohort is problematic, due to wide case variation (13). It is hard not to conclude, however, that even in selected patients SIRC represents a more costly approach. Because the contribution margin remained positive in the SIRC cases, it is equally difficult to declare the technique cost-prohibitive, and this report may provide a starting point for institutions and surgeons considering exploring this technique. The financial viability of a surgeon or surgical service is based on a complex interaction of variables, including, but not limited to, case volume, operating times, operating room efficiency and purchase price for the most frequently used disposable instrumentation (13). The individual surgeon or institution must weigh these considerations.

The tension needed for surgical dissection is created by tissue triangulation in laparoscopic surgery. In single-incision laparoscopy, this tension is created by one of two methods. First, the instrumentation can be crossed with a direct laparoscopic view or the surgeon can work in a near–far plan, using camera angulation or articulation to 'look around the corner' of the grasped tissue. Single-incision robotic surgery may improve upon this technique by crossing the robotic instruments, removing the surgeon from the operative field and placing him/her at the console, where the 'handedness' of the robotic arms is swapped via console software. While robotic arm collisions can occur and limit the range of motion of the robotic instruments, ergonomics are improved and the surgeon-controlled camera platform minimizes the need for a skilled assistant for camera driving.

It is possible that the wide adoption of single-incision laparoscopic colectomy will continue to be limited because it is technically difficult. The paucity of published literature on laparoscopic single-incision colectomy, which is limited to small case series in highly selected patients at specialized institutions, seems to support this notion (1,2,4). Furthermore, even in these specialized populations, the literature has failed to illustrate clear advantages for single-incision laparoscopic colectomy over traditional multiport laparoscopy (1,4). Exploring the technical advantages of robotics in single-incision colectomy may make sense as a pathway to wider adoption of single-site surgery, where single-incision benefits could be illustrated over a less homogeneous patient population. Additional forces may also be at work, both surgeon lead- and market-motivated, that may bring robotics into the single-incision colectomy discussion. For these reasons, we performed analyses to address feasibility and safety and address hospital costs upfront.

This review is subject to the limitations inherent to a single-institution, retrospective medical record review. Specifically, we could not correct for the surgeon bias that exists in technique (MLC or SIRC) selection for a given patient case or the technical and postoperative management idiosyncrasies of individual surgeons. It is possible that significant differences in case complexity and patient comorbidity existed between study groups. Specifically, our expected cost calculation methodology allows for increases in expected costs based on comorbidity coding by our institution. The intra-group variation and differences between groups in expected direct costs could highlight cohort discrepancies that are inadequately accounted for within our study method. Additionally, with nine surgeons contributing cases to the MLC group, which had a conversion rate at the high end of the acceptable range, learning curve-specific factors may have biased MLC group outcomes. Cost analysis is known to be both institution-specific and prone to wide case/volume/surgeon variation (13,14). The consideration of the purchase and maintenance of the robotic platform as an indirect cost, if not applied to other experiences with this technique, for example, would significantly alter cost analysis. We chose to perform a direct cost analysis for the entire hospital stay in the hope of addressing our institution's 'bottom-line' costs for these procedures. Our methodology did not allow us to determine operating room charges directly attributable to the use of the robot, but this will be an area of important future investigation. Certainly, with a small cohort and a single institution, this cost analysis may not translate to all institutions. However, to our knowledge, this evaluation represents one of the largest groups of patients receiving SIRC and thus provides valuable benchmarks for other surgeons and institutions currently performing, or considering performing, SIRC.

While not necessarily a limitation, we find the overall mortality rate and cost outlier in the MLC group worth further comment. We reviewed the mortality cases and cost outliers closely and felt it imperative to not limit our cases in a manner where the mortalities or high cost patients were inadvertently excluded from either group, although they may have impacted our results significantly. We consider the consecutive and unselected nature of our patient cases a strength that would have been compromised by excluding outliers. We report a mortality rate slightly higher than expected (4.6%) but we find it well within reason if one considers the patient-specific morbidity and presence of mortalities in both groups. In addition, the patient with a $521 315 hospitalization in the MLC group is clearly an outlier. In this case we were unable to remove surgical admission costs from preoperative

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costs and costs not attributable to the colectomy. The patient had an extended length of stay and spent extensive time in the intensive care unit, due to cardiac procedure-related morbidity. During this hospital course, the patient required colectomy that was planned semi-electively for smoldering, ischaemic colitis. We again opted to include the patient and then adjust our cost data by using medians when appropriate.

Conclusion

In conclusion, we present our initial experience with single-incision robotic colectomy as compared to traditional multiport colectomies performed within the same time period. The technique appears safe and feasible in selected patients and when compared to traditional MLC, and represents a technique with increased observed:expected direct hospital costs. In light of positive contribution margins and the institution-specific nature of cost assessment, the determination of whether these increased costs are prohibitive will require both further study and individualized institutional decision making.

Conflict of interest

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

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