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Analysis of outcomes for single-incision laparoscopic surgery (SILS) right colectomy reveals a minimal learning curve

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Abstract
Background Single-incision right colectomy has emerged as a safe and feasible alternative to standard laparoscopic resection. As with any new surgical approach, definition of the number of procedures required to optimize the technique is an important goal. Data on this learning curve for single-incision right colectomy are lacking; therefore, we report the outcomes of consecutive single-incision right colectomies to identify the procedural learning curve.
Methods We retrospectively reviewed consecutive single-incision right colectomies performed by a single surgeon from May 2010 to May 2013. Patients were evaluated in groups of ten to minimize individual patient variability and selection bias. Demographics and peri-operative outcomes among groups were evaluated using ANOVA or Kruskal–Wallis. Statistical improvement was assessed between groups using Student *T* tests or Mann–Whitney *U* tests.
Results Seventy consecutive single-incision right colectomies were performed during the study period. There were no differences in patient demographics over the course of the experiences, suggesting that the selection bias did not influence the outcomes. There was a statistical improvement in operative time after the first 10 cases (103 vs. 130 min, $p = 0.01$). A second statistical improvement in operative time occurred after 40 cases (97 vs. 114 min, $p = 0.03$). There was no statistical improvement in estimated blood loss, lymph node harvest, conversion rate, length of stay, or post-operative morbidity throughout the experience.
Conclusions Analysis of our large series of consecutive cases indicates that for a surgeon trained in advanced laparoscopic techniques and given adequate case volume, the outcomes from the procedure are quickly optimized with a minimal learning curve. Operative time is optimized following 40 procedures. Identification of the learning curve is critical for surgeons wishing to implement a single-incision approach and to ensure that the outcomes are optimized prior to thorough comparison with standard laparoscopic or open approaches.

Keywords Single-incision laparoscopic surgery · Right colectomy · Learning curve · Outcomes

Minimally invasive approaches have revolutionized colon and rectal surgery. Laparoscopic colectomy, first reported in the 1990s, has reduced post-operative pain, expedited return to oral intake, and shortened length of stay without compromising oncologic outcome [1–6]. Laparoscopic right colectomy, specifically, has become a standard procedure. With this precedent, increasingly less-invasive techniques have been pursued, including the development of single-incision laparoscopic surgery, in which a camera and two laparoscopic working ports are placed through a single umbilical incision. Both dissection and extraction of the surgical specimen are carried out through this same incision. Within colorectal surgery, single-incision techniques have accordingly emerged as an alternative to standard laparoscopic techniques—being utilized for right and left colectomy, sigmoid colectomy, low anterior resection, and total proctocolectomy [7–14].

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Single-incision right colectomy has been the most frequently reported of these procedures, first described in 2008, and subsequently demonstrated by a number of centers [15–18]. Both retrospective and prospective analyses, as well as meta-analyses and systematic reviews have shown the technique to be safe and feasible when compared to standard laparoscopic techniques [19–30]. Case–control studies have also demonstrated equivalence, with a small cosmetic benefit [31–33]. As previously reported, the technique remains safe and feasible not only in a highly selected patient population, but also among elderly, obese, and complex patients, as well as those with prior abdominal surgery, and those with large and advanced tumors [34]. Additional potential advantages include decreased post-operative pain, shortened hospital stay, and fewer complications. Disadvantages include the cost of advanced instruments and potential for longer operative time, however, costs have been reported to be similar to standard laparoscopy [34].

Any new surgical procedure has a certain number of cases required to become proficient and to optimize the technique, which is known as the learning curve. Because of the increased technical demand of the single-incision approach, there is a considerable concern that the learning curve is significant. Here, we report the demographics and outcomes of 70 consecutive single-incision right colectomies to identify the procedural learning curve.

Materials and methods

Patient selection

All single-incision colectomies performed by a single surgeon between May 2010 and May 2013 were studied. All patients with benign and malignant indications for right colon resection were offered single-incision right colectomy. Patient demographics and outcomes were evaluated by retrospective chart review of pre-operative medical records, operative and anesthesia reports, and post-operative notes. Morbidity and mortality were evaluated at 90 days. Surgical complications were graded according to the Clavien–Dindo classification [35]. The Institutional Review Board at the University of Pittsburgh and the University of Pittsburgh Medical Center (PRO11020362) approved the study.

Surgeon, setting, and training

Reported outcomes are from a single primary surgeon who is highly trained and experienced in complex open abdominal procedures as well as advanced laparoscopic and robotic surgical techniques. Of note, the series occurred in a specialized center for surgical oncology with high annual case volume.

Surgical technique

Our single-incision laparoscopic right colectomy begins with the patient in supine position. A 3- to 4-cm incision is made through the umbilical skin and fascia. The Gelpoint device (Applied Medical, Orange County, CA, USA) wound protector is placed and tightened. Three 10-mm trocars are placed through the Gelpoint and secured to the wound protector. A 45° 10-mm extra-long laparoscope (Stryker, San Jose, CA, USA) is used for visualization. The patient is then positioned in Trendelenburg with a right-side up tilt. Our preference is a lateral-to-medial approach, mobilizing the colon by taking down the fascia of Toldt up to the hepatic flexure. The patient is then placed in reverse Trendelenburg position. The hepatic flexure is mobilized laterally from the middle colic vessels. Once mobilization is complete, the ileocolic vessels are identified, dissected, and divided with a vascular stapler (upsizing one trocar to 12 mm in the Gelpoint device to facilitate the stapler). During extended right colectomy, the middle colic vessels are divided with the LigaSure device (Covidien, Boulder, CO, USA). The colon is exteriorized through the wound protector, and the terminal ileum and proximal transverse colon transected with staplers. An extracorporeal side-to-side, functional end-to-end stapled anastomosis is then created, closing the common enterotomy with a stapler. Staple lines are routinely oversewn. The anastomosed bowel is reintroduced into the abdominal cavity, the Gelpoint replaced, and the abdomen re-insufflated. We then inspect the surgical field for hemostasis. The fascia is re-approximated with simple interrupted sutures. Skin is closed with absorbable suture and skin glue.

Statistical analysis

Patients were placed into cohorts of ten in order to minimize individual patient variability and selection bias. Demographics and peri-operative outcomes among groups were evaluated using ANOVA or Kruskal–Wallis, as appropriate for parametric or non-parametric data. Mean or median outcomes over 10 cases were plotted, and exponential regression was used to demonstrate slope. Statistical improvement was assessed between groups using Student T tests or Mann–Whitney U tests, again as appropriate for parametric or non-parametric data. Results were considered statistically significant for p-values <0.05.

Results

Seventy consecutive patients underwent single-incision right colectomy by a single surgeon at our institution between May 2010 and May 2013. Patient demographics

were evaluated among groups of ten consecutive patients to ensure that no selection bias occurred throughout our experience that would influence our results (Table 1). There was no difference between any demographics over the course of the experience.

Mean age was 66.7 years, with 60 % female patients. Patients had a mean BMI of 28 ± 5.5 kg/m^2. The majority of patients were American Society of Anesthesiologists (ASA) class 3. 68.6 % of procedures were performed for a diagnosed malignancy, with a mean tumor size being 3.5 ± 2.2 cm. Tumors were located in various locations, from ileum through transverse colon. Greater than 50 % of the patients had undergone prior abdominal surgery, and the median Charlson Comorbidity Index was five [36]. Previous surgeries included appendectomy ($n = 18$), cholecystectomy ($n = 17$), total abdominal hysterectomy ($n = 10$), caesarian section ($n = 2$), and tubal ligation ($n = 2$), and individual patients had undergone exploratory laparotomy, minimally invasive esophagectomy, gastrectomy, roux-en-y gastric bypass, salpingo-oophorectomy, nephrectomy, splenectomy, bladder suspension, and abdominal aortic aneurysm repair.

Operative outcomes over the experience are listed in Table 2. There was no significant difference in results throughout the experience as a whole. Mean operative time was 107 ± 32 min. To assess the improvement in operative time with increasing experience, logarithmic regression analysis was performed and it revealed a decrease in mean operative time over the course of the experience (depicted in Fig. 1). There was a mean operative time of 130 ± 54 min for the first 10 cases, versus 102 ± 25 min for the remaining cases ($p = 0.013$). There was also a mean operative time of 114 ± 36 min for the first 40 cases, versus 97 ± 22 min for the remaining cases ($p = 0.026$).

Estimated blood loss (EBL), lymph node harvest, and length of stay (LOS) are also depicted in Fig. 2A, B, and C, without trend toward improvement over the experience. Median blood loss was 50 (IQR 20–50) milliliters, mean lymph node harvest among cases performed for malignancy was 21.7 ± 7.2 nodes, and median length of stay was six (IQR 5–7) days. Complications were graded according to the Clavien–Dindo classification, with 8.6 % of the complications being clinically significant, defined as those being greater than or equal to grade 3. Two patients had grade 4 complications: one with post-operative small bowel obstruction requiring re-operation and small bowel resection (surgical pathology revealed metastatic colorectal cancer), and one with post-operative unstable atrial fibrillation and rapid ventricular response requiring admission to the intensive care unit. There were no grade 5 complications in the series. Conversion to an open procedure occurred twice in the series, once in the first ten cases and once in the last 20 cases.

Table 1 Patient demographics of 70 consecutive single-incision right colectomies

Groups	Age	Gender	BMI	CCI	Prior surgery	ASA class, *n* (%)				Tumor size	Malignancy
(Cases)	(years)[a]	*n* = *F* (%)		*n* = median (IQR)	*n* (%)	1	2	3	4	(cm)	*n* (%)
All	66.7 ± 14.5	42 (60)	28 ± 5.5	5.5 (4–8)	41 (58.6)	1 (1.4)	17 (24.3)	47 (67.1)	5 (7.1)	3.5 ± 2.2	48 (68.6)
1 (1–10)	71.6 ± 9.1	5 (50)	27.2 ± 6.6	5.5 (4–8)	5 (50)	0 (0)	2 (20)	6 (60)	2 (20)	2.8 ± 1.6	7 (70)
2 (11–20)	66.1 ± 20.5	8 (80)	25.7 ± 4.1	7 (5–10)	7 (70)	0 (0)	5 (50)	5 (50)	0 (0)	3.9 ± 2.3	7 (70)
3 (21–30)	66.6 ± 16	4 (40)	29.1 ± 7.3	6 (4–7)	5 (50)	1 (10)	2 (20)	6 (60)	1 (10)	3.9 ± 2.7	8 (80)
4 (31–40)	69.9 ± 13.7	8 (80)	29 ± 6.3	6.5 (3–11)	5 (50)	0 (0)	1 (10)	9 (90)	0 (0)	2.7 ± 1.4	6 (60)
5 (41–50)	65.6 ± 12.1	6 (60)	29.7 ± 4.1	4 (3–4)	5 (50)	0 (0)	3 (30)	7 (70)	0 (0)	3.5 ± 2.2	6 (60)
6 (51–60)	58.8 ± 17.8	7 (70)	28 ± 5.3	5.5 (3–8)	7 (70)	0 (0)	2 (20)	7 (70)	1 (10)	4.2 ± 3.3	8 (80)
7 (61–70)	68.5 ± 10	4 (40)	27.3 ± 4.3	5.5 (5–7)	7 (70)	0 (0)	2 (20)	7 (70)	1 (10)	4 ± 2	6 (60)
p	0.59	0.29	0.72	0.64	0.85			0.51		0.69	0.91

[a] Data are listed mean ± standard deviation (SD) unless otherwise noted

Table 2 Outcomes of 70 consecutive single-incision right colectomies

Groups (Cases)	OR time (min)	EBL n = median (IQR)	Nodes[a]	LOS (d) n = median (IQR)	Complications, n (%)		Conversions n (%)
					Any grade	Grade ≥3	
All	106.6 ± 31.8	50 (20–50)	21.7 ± 7.2	6 (5.0–7.0)	33 (47.1)	6 (8.6)	2 (2.9)
1 (1–10)	129.5 ± 54.1	50 (21–50)	25.7 ± 8.3	6.9 (5.3–6.9)	4 (40)	0 (0)	1 (10)
2 (11–20)	107.4 ± 35.2	25 (20–56)	21.7 ± 7.1	6 (5.9–9.1)	4 (40)	1 (10)	0 (0)
3 (21–30)	105.7 ± 20.1	50 (25–50)	19 ± 4.5	5.1 (4.2–5.3)	4 (40)	0 (0)	0 (0)
4 (31–40)	113.2 ± 27.2	50 (50–88)	20.7 ± 5.3	5 (5.0–7.5)	5 (50)	2 (20)	0 (0)
5 (41–50)	94.9 ± 24.9	37.5 (21–50)	21.3 ± 5.7	6 (5–8.3)	4 (40)	2 (20)	0 (0)
6 (51–60)	95.4 ± 22.5	20 (10–50)	17.8 ± 3.4	6 (5–7)	4 (40)	1 (10)	0 (0)
7 (61–70)	100.4 ± 19.3	50 (10–50)	27 ± 12.2	7 (5–7)	8 (80)	0 (0)	1 (10)
p	0.2	0.49	0.17	0.37	0.52	0.42	0.55

[a] Total nodes harvested in cases performed for malignant indications only

Discussion

With any new technology, determining safety and feasibility is an important prerequisite to its widespread implementation. Establishment of the learning curve is crucial to the utilization of new technologies, including single-incision laparoscopic surgery. Critics of the technique have cited concerns over the learning curve associated with the procedures [37, 38]. In this analysis of 70 single-incision laparoscopic right colectomies, the outcomes were optimized very early in the experience. In a setting with adequate case volume, this suggests a widely feasible learning curve, especially in regards to quality-based parameters: estimated blood loss, complication rates, conversions to open procedures, lymph node harvest as an indicator of oncologic adequacy, and length of hospital stay. Operative times did improve significantly after 10 cases, in accord with our prior published improvement in operative time within the first 7 cases [34]. Operative time was further optimized after 40 cases. This demonstrates that a learning curve exists, but can be overcome quickly by a surgeon trained in traditional laparoscopic techniques, without affecting the surgical outcomes.

Identification of the learning curve allows for comparison to standard laparoscopy, to identify benefits once outcomes are optimized. The learning curve is also critically important for new surgeons or centers that wish to implement the single-incision approach. These data add to the limited existing literature studying the learning curve for single-incision right colectomy. In accord with the early improvement in operative time demonstrated after 10 cases, Hopping and Bardakcioglu demonstrated decreased operative time after 10 cases in their series of 20 consecutive single-incision right colectomies [39]. Haas et al. evaluated the learning curve for single-incision right colectomy in 54 consecutive patients over a 2-year period, and identified the achievement of the learning phase

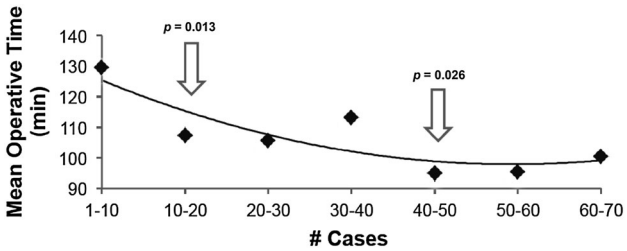

Fig. 1 Operative time over case series

between 30 and 36 cases, which corroborates our findings of optimization of operative time after the first 40 cases [40]. Supporting our findings, Haas et al. also failed to identify any increased conversion rate, length of stay, or post-operative morbidity during the early phases of the learning curve [40]. Hopping and Bardakcioglu noted decreased estimated blood loss and length of stay over their 20-case series [39]. Our findings were similar within the first 10 cases (two cases with EBL ≥ 200 cc and median LOS of 6.9 days), yet our much larger series of 70 cases revealed that such outliers did not result from a learning curve.

It should be noted that the outcomes of 70 consecutive single-incision right colectomies were comparable to large reviews of standard laparoscopic right colectomy. The complication rate demonstrated in this series was similar to that seen in randomized trials comparing open and standard laparoscopic colectomy, as well as to other series of single-incision laparoscopic colectomy [2, 3, 6, 17, 26, 31]. With an average lymph node harvest of 21.7 nodes among cases performed for malignancy, our data suggest that oncologic principles are achieved as well with single-incision laparoscopic colectomy as compared to standard laparoscopy [41, 42]. Our estimated blood loss and average length of hospital stay (50 mL and 6 days) were also similar to

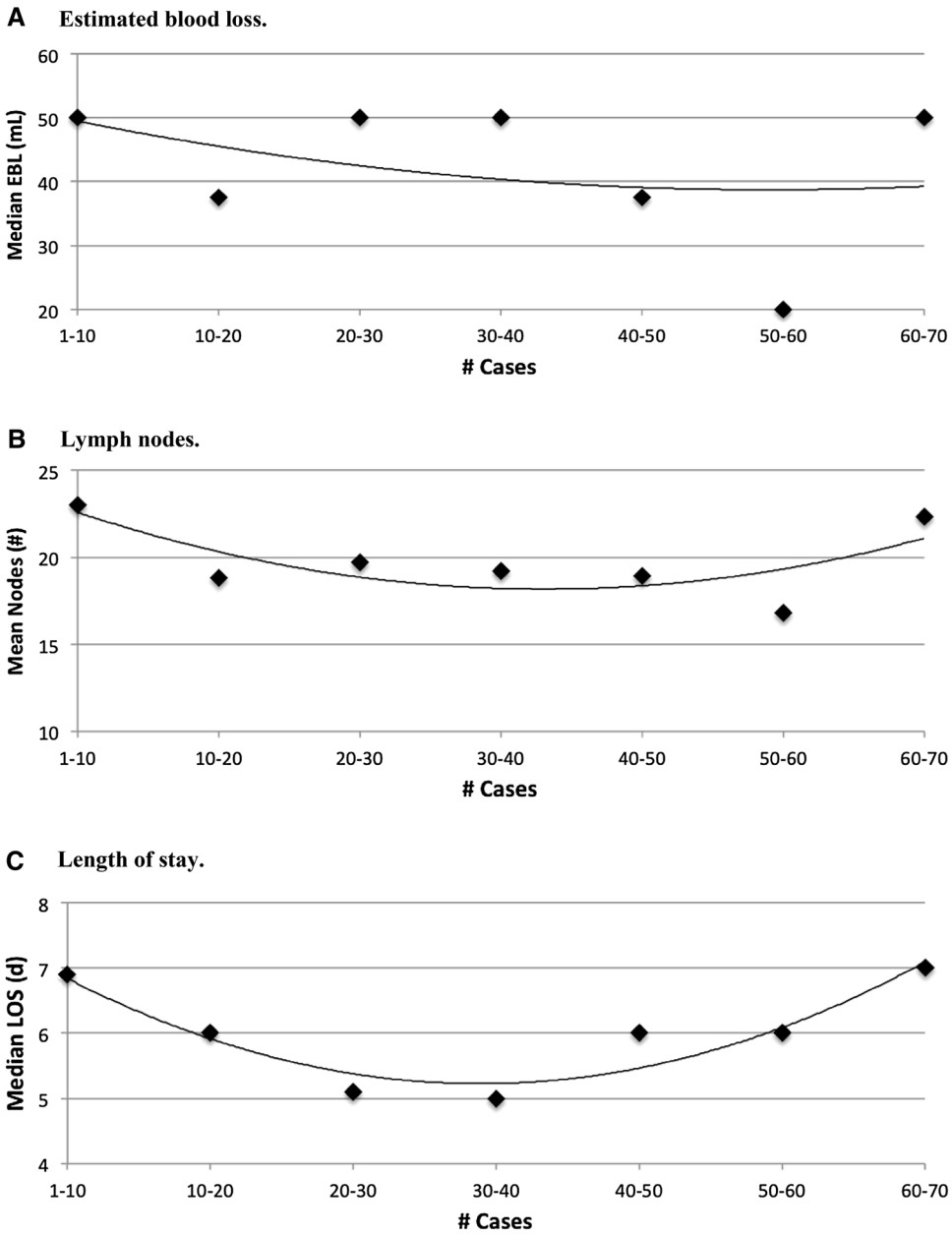

Fig. 2 Other outcomes over case series

published data regarding traditional laparoscopy, as well as prior publications on single-incision colectomy [2, 3, 6, 8, 17, 26]. Operative time, even prior to optimization at 40 cases, was comparable to current data on standard laparoscopic techniques at a mean time of 114 min [17, 28, 29].

These results are those of a surgical oncologist highly trained and skilled in advanced laparoscopic techniques and complex abdominal procedures. They may not be applicable to the general surgery community at large. It is also possible that the learning curve has not yet been appreciated and that the outcomes will be improved further after performing additional procedures. With this being the largest series examining learning curve in single-incision right colectomy to date, however, and the fact that our outcomes are already comparable to standard laparoscopic right colectomy, we would expect to have captured the learning curve if it did exist. The large series also highlights the high case volume of the center. This frequency of SILS right colectomies may contribute to ongoing proficiency and safety after achievement of the learning curve.

Limitations of the procedure itself are highlighted by the two conversions to open hemicolectomy during the series. In cases with dense intra-abdominal adhesions or distorted anatomy (e.g., a particularly retrohepatic and cephalad hepatic flexure), conversion may be required for adequate exposure and tissue manipulation. As our series evidences,

this is infrequent, and standard laparoscopy may also have required conversion in these cases. The SILS approach is appropriate to offer in all surgical indications for laparoscopic right colectomy.

In conclusion, this largest series to date reveals that single-incision laparoscopic right colectomy is feasible and safe, with an achievable learning curve. For a surgeon experienced in standard laparoscopic techniques, the learning curve is demonstrable in operative time only, without detriment to surgical or oncologic outcomes. These findings are critical as single-incision laparoscopic surgery gains wider implementation and acceptance.

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