Published in final edited form as:

Dis Colon Rectum. 2015 September ; 58(9): 862–869. doi:10.1097/DCR.0000000000000435.

Single-site Laparoscopic Colorectal Surgery Provides Similar Clinical Outcomes Compared to Standard Laparoscopic Surgery: An Analysis of 626 Patients

William Sangster, MD¹, Evangelos Messaris, MD, PhD², Arthur S. Berg, PhD³, and David B. Stewart Sr., MD⁴

¹Surgical Resident, Department of Surgery, The Pennsylvania State University, College of Medicine, Hershey, PA

²Assistant Professor, Department of Surgery, The Pennsylvania State University, College of Medicine, Hershey, PA

³Associate Professor, Department of Public Health Sciences, The Pennsylvania State University, College of Medicine, Hershey, PA

⁴Associate Professor, Department of Surgery, The Pennsylvania State University, College of Medicine, Hershey, PA

Abstract

BACKGROUND—Compared to standard laparoscopy, single-site laparoscopic colorectal surgery may potentially offer advantages by creating fewer surgical incisions and providing a multi-functional trocar. Previous comparisons, however, have been limited by small sample sizes and selection bias.

OBJECTIVE—To compare 60-day outcomes between standard laparoscopic and single-site laparoscopic colorectal surgery patients undergoing elective and urgent surgeries.

DESIGN—This was an unselected retrospective cohort study comparing patients who underwent elective and unplanned standard laparoscopic or single-site laparoscopic colorectal resections for benign and malignant disease between 2008 and 2014. Outcomes were compared using univariate analyses.

SETTING—This study was conducted at a single institution.

PATIENTS—A total of 626 consecutive patients undergoing laparoscopic colorectal surgery were included.

MAIN OUTCOME MEASURES—Morbidity and mortality within 60 postoperative days.

Corresponding Author and Request for Reprints: David B. Stewart, MD, The Pennsylvania State University, College of Medicine, Department of Surgery, Division of Colon and Rectal Surgery, 500 University Drive, H137, P.O. Box 850, Hershey, PA 17033-0850, PH: (717) 531-5164, FX: (717) 531-0646, dstewart@hmc.psu.edu.

Contributions:

William Sangster – analysis and interpretation of data, drafting the article and final approval.

Evangelos Messaris – acquisition of data, critical revision of the article and final approval.

Arthur Berg – analysis and interpretation of data, critical revision of the article and final approval.

David Stewart – acquisition of data, drafting the article and final approval.

RESULTS—318 (51%) and 308 (49%) patients underwent standard laparoscopic and single-site laparoscopic procedures, respectively. No significant difference was noted in mean operative time (Standard laparoscopy 182.1 ± 81.3 vs. Single-site laparoscopy 177 ± 86.5 , $p=0.30$) and postoperative length of stay (Standard laparoscopy 4.8 ± 3.4 vs. Single-site laparoscopy 5.5 ± 6.9 , $p=0.14$). Conversions to laparotomy and 60-day readmissions were also similar for both cohorts across all procedures performed. A significant difference was identified in the number of patients who developed postoperative complications (Standard laparoscopy 19.2% vs. Single-site laparoscopy 10.7%, $p=0.004$), especially with respect to surgical-site infections (Standard laparoscopy 11.3% vs. Single-site laparoscopy 5.8%, $p=0.02$).

LIMITATIONS—This was a retrospective, single institution study.

CONCLUSIONS—Single-site laparoscopic colorectal surgery demonstrates similar results to standard laparoscopic colorectal surgery in regards to operative time, length of stay and readmissions. Single-site laparoscopic colorectal surgery may provide advantages in limiting the development of certain complications such as superficial surgical-site infections.

Keywords

Colorectal Surgery; Single-site; Single-incision; Laparoscopy; Multi-port laparoscopy

INTRODUCTION

When compared to open surgical approaches, laparoscopic colorectal surgery has been associated with decreased mortality and an expedited postoperative recovery, including shorter lengths of hospital stay.^{1,2} The largest volume of clinical research in this area has been gathered using a standard laparoscopic (SDL) approach with multiple trocars of varying number; this approach to surgery has been shown to be safe and advantageous among experienced practitioners and for a diverse selection of indications and procedures, including for colorectal cancer.³⁻⁵

One recent example of an effort at furthering a minimally invasive approach is the development of single-site laparoscopy (SSL), which attempts to use laparoscopic instrumentation via several ports clustered through the same fascial aperture. There have been several case reports and case series which have attempted to make the case that SSL is safe and feasible, even for advanced surgical procedures such as cancer resections and the construction of pouch-anal anastomoses in ulcerative colitis.⁶⁻¹¹ Though comparative studies between SDL and SSL colorectal surgery have shown similar results in operative times, perioperative outcomes and cost, these studies have been significantly limited by both a small sample size as well as limitations in generalizability due to careful selection of which patients are offered SSL.¹²⁻¹⁷ The value, if any, of an SSL technique in terms of patient outcomes remains to be proven, as do concerns that the technique may serve only a niche role due to perceived technical challenges with this approach.

The aim of this study was to compare outcomes between a large and consecutive series of SDL and SSL patients undergoing a wide variety of surgeries, including elective and unplanned surgeries, spanning a several year period.

METHODS

This retrospective cohort study was conducted exclusively at the Penn State Hershey Medical Center with approval from the Institutional Review Board. Review of a prospectively collected and maintained institutional database identified 626 consecutive patients undergoing laparoscopic colorectal resections performed by five surgeons between 1/14/2008 and 7/1/2014.

Prior to 2010, four surgeons in the division of colorectal surgery were performing SDL only. From 2010 onward, two surgeons began to perform SSL as their laparoscopic technique of choice and the others surgeons continued to perform SDL. One surgeon joined the division in 2014 and for the study period involved had only performed SSL. During the study period, laparoscopy was the preferred technique offered to patients who were not on vasopressor medications, had fewer than three previous laparotomies and/or had a body mass index ≤ 50 kg/m² regardless of whether the surgery was elective or emergent; if the patient met any of these criteria, they were offered laparotomy. The decision to offer SDL versus SSL was based on surgeon preference and experience with the technique. All cases were performed at the Penn State Hershey Medical Center, and in both techniques the attending surgeons were assisted either by general surgery residents or colorectal fellows.

Patients were stratified into those undergoing an elective or urgent SDL or SSL colorectal resection. Urgent surgeries were defined as those which either occurred during an unplanned hospital admission, or which were performed under exigent circumstances, including reoperations on patients with complications. For elective surgeries, patients in each cohort received preoperative bowel preparations, skin preparations and prophylactic antibiotics. SDL operations were performed using two or three bladeless 5 mm trocars and one bladeless 12 mm trocar. SSL operations were performed using an SSL trocar that was placed through an approximately 3-cm to 4-cm fascial incision at either the umbilicus or at a future stoma site. In SDL cases, specimen extraction was performed by extending one trocar site up to 4-cm to 5-cm. In SSL cases, specimen extraction was performed through the SSL trocar. SSL extraction sites were closed with running absorbable subcuticular sutures. For SDL surgeries, the skin of the extraction site was typically closed with staples while the remaining surgical-sites were closed with suture.

Demographic data was collected prospectively for all patients including American Society of Anesthesiology (ASA) classification, body mass index (BMI), indication for surgery, operation performed, operative time, estimated blood loss (EBL), conversions, time to passage of flatus, time to tolerance of a low residue diet, 60-day readmission rate, 60-day post-operative complications, and unplanned re-operations. Diagnoses were categorized as colon cancer, rectal cancer, diverticulitis, Crohn's disease, ulcerative colitis, and other disease (i.e. benign polyps, rectal prolapse, or colonic inertia). Resections were classified as total colectomy/proctocolectomy (including total proctocolectomy with ileal pouch-anal anastomosis), enterectomy/ileocolectomy, left colectomy, right colectomy, transverse colectomy and proctectomy (including abdominoperineal resection and low anterior resection).

For SSL resections, conversions to conventional laparoscopy or to laparotomy were recorded; in SDL surgeries, conversions to laparotomy were also recorded. Conversion to conventional laparoscopy was defined as the placement of one or more additional ports. Conversion to laparotomy was defined as a lengthening of the incision beyond that needed to extract the specimen. All patients were analyzed on an intent-to-treat basis.

Postoperative complications included development of an ileus, surgical site infections (superficial, deep and organ space), anastomotic leak, postoperative bleeding, venous thromboembolism (deep vein thrombosis, portal vein thrombosis and pulmonary embolus), other infections (health-care acquired pneumonia, urinary tract infection and *Clostridium difficile* infection), other complications (such as perioperative cardiovascular events and postoperative pancreatitis) and death.

Patient follow-up was based on the surgical indication. Within our institution, all patients are scheduled for two follow-up visits with the operative surgeon, the first at approximately three weeks and the second at approximately six weeks after surgery. The patient's care is then transitioned to the primary care provider of record, with the exception being cancer patients who receive extended surveillance with their operative surgeon.

The primary outcome of interest was the development of any complication within 60 days of surgery. Secondary outcomes of interest included operative time, estimated blood loss (EBL), conversions, time to passage of flatus, time to a low residue diet, length of hospital stay and 60-day readmission rate.

Continuous data were expressed as mean $\pm$ standard deviation. SDL and SSL cohorts were compared using Mann-Whitney and Kruskal-Wallis tests for continuous variables and Chi-squared tests (or Fisher's exact tests for comparisons of smaller patient sets) for categorical variables. All analyses were performed using the open source *R Project* statistics program.¹⁸ Statistical significance was defined as $p < 0.05$.

RESULTS

There were 318 consecutive patients (51%) who underwent an SDL procedure and 308 consecutive patients (49%) who underwent an SSL procedure. Patient age, sex, BMI and diagnosis were similar between the two cohorts (Table 1). Approximately 97% of patients within the SDL cohort and 98% of patients in the SSL cohort had an ASA classification of 2. A similar mixture of elective and urgent cases were performed within each cohort ($p = 0.51$).

Operative details are outlined in Table 2. There were no significant differences in mean operative time and mean hospital stay between the cohorts. Conversions were also comparable between the cohorts and all were pre-emptive as opposed to reactive conversions, with adhesive disease being the most common indication for conversion in both cohorts. Mean EBL was 127.8 milliliters (mL) in the SDL cohort and 96.8 mL in the SSL cohort ($p = <0.001$). Patients in the SSL cohort were more likely to have a stoma created during their surgery (SDL 33% vs. SSL 47.1%, $p = 0.004$). Within the SSL cohort, 40 of the 145 stomas (27.6%) were created using the incision for the single-site port; in the remaining

SSL resections where a stoma was created (105/145; 72.4%), the single-site port was placed at the umbilicus and the stoma was created at a new site. When evaluating colon and rectal cancer patients undergoing oncologic resections, a greater number of lymph nodes were harvested during SSL procedures (SDL 17.4 vs. SSL 21.2, $p = 0.007$).

Surgical outcomes are summarized in Table 3. Time to the passage of flatus, time to tolerance of a low residue diet, development of an ileus and readmission rates were comparable in the SDL and SSL cohorts. Five SDL patients and 9 SSL patients required re-operation within the immediate postoperative period (SDL 1.6% vs. SSL 2.9%, $p = 0.29$). The indication for re-operation in the SDL cohort included anastomotic leak (two patients), postoperative bleeding (two patients) and a necrotizing soft tissue infection of the abdominal wall (one patient). Within the SSL cohort, the indication for re-operation included anastomotic leak (three patients), postoperative bleeding (four patients), stoma ischemia (one patient) and a necrotizing soft tissue infection of the abdominal wall (one patient). Overall, 61SDL patients and 33 SSL patients developed a complication of some type within 60 days of surgery (SDL 19.2% vs. SSL 10.7%, $p = 0.004$). Six patients in the SDL cohort developed two complications within 60 days and one patient developed three separate complications (a pulmonary embolus, *Clostridium difficile* infection and a superficial surgical site infection). In the SSL cohort, two patients developed two complications within 60 days of surgery.

No statistically significant differences were observed between the cohorts with respect to the incidences of anastomotic leaks, postoperative bleeding, venous thromboembolism or other complications such as cardiovascular events or pancreatitis. The incidence of anastomotic leaks was also calculated for each cohort after excluding patients with stomas; in the SDL cohort there was a 1.4% [3/213] anastomotic leak rate and a 1.2% [2/163] anastomotic leak rate in the SSL cohort ($p = 1$). There were also no differences noted in the number of unexpected deaths (SDL 0.3% vs. SSL 0.6%, $p = 0.62$).

Significant differences were noted in the number of superficial surgical site infections (S-SIs) and other infections, such as pneumonia, urinary tract infections and *Clostridium difficile* infection. In the SDL cohort, 17 patients developed other infections; 11 (65%) were due to a urinary tract infection, 4 (24%) were due to *Clostridium difficile* infection, and 2 (12%) represented a pneumonia. In the SSL cohort, 3 patients developed other infections of which 2 were due to a urinary tract infection and the other was a pneumonia. A postoperative surgical site infection occurred in 36 SDL patients and 18 SSL patients (11.3% vs. 5.8%, $p = 0.02$). In both the SDL and SSL cohorts, the most common surgical site infections were superficial with 32 SDL patients and 13 SSL patients developing this complication. Deep surgical site infections (two SDL patients vs. one SSL patient) and organ space infections (two SDL patients vs. four SSL patients) were similar between the cohorts.

Table 4 provides data for a comparison of outcomes between the cohorts stratified by the type of surgery performed. No significant differences were noted within any surgery type regarding operative time, rate of conversions or readmissions, including those patients with stomas. Significant differences were noted in estimated blood loss for the total colectomy/

proctocolectomy, enterectomy/ileocolectomy and right colectomy groups, favoring the SSL cohort. More stomas were created in the SDL cohort during total colectomies/proctocolectomies, while significantly more stomas were created in the SSL cohort during enterectomies/ileocolectomies and proctectomies. A statistically significant difference in complications was noted within the proctectomy group (SDL 30.6% vs. SSL 2.4%, $p = <0.001$).

DISCUSSION

The results of the present study demonstrate that when applied to a variety of elective and non-elective colorectal procedures, SSL has outcomes which are comparable to SDL. Comparative studies evaluating SDL and SSL colorectal surgery are relatively few in number and even the largest of these previous studies has limitations in generalizability due to the selectivity with which patients and procedures were approached by SSL; frequently small study sample sizes have also been a frequent hindrance. The present study may provide a more accurate assessment of the outcomes to be expected with SSL, including in the setting of unplanned surgeries, and to the authors' knowledge, this study represents one of the largest consecutive studies of SSL colorectal cases to date.

Similar to prior studies, the overall and individual operative times within this study did not demonstrate any significant differences between the two cohorts.^{12,14,19} Mean length of stay and 60-day readmissions were also comparable. Estimated blood loss did reach a statistically significant difference with the SSL cohort demonstrating less blood loss for each type of procedure with the exception of left colectomies and proctectomies. However, this latter finding only represented a mean difference of approximately 20 – 70 mL of blood loss, and as previously observed in other studies, this may not be of clinical significance.¹²

Within this study, the overall rate of complications for all patients was 19.2% in the SDL cohort and 10.7% in the SSL cohort ($p = 0.004$). This difference was primarily due to disparities in the incidences of minor complications, such as S-SSIs and urinary tract infections. The incidence of major complications such as anastomotic leaks, postoperative bleeding, venous thromboembolism and mortality were comparable between the two techniques. In the SDL cohort, 30 of the 32 S-SSIs (93.8%) occurred at the specimen extraction site; the remaining two S-SSIs were at a non-extraction port site. In the SSL cohort, the umbilicus was the site for specimen extraction in 268 of 308 patients (87%), while 40 SSL patients (13%) had their specimen extracted through a single-site port that was placed at a non-midline site to facilitate stoma creation through the same incision. All S-SSIs within the SSL cohort occurred at the umbilical incision. The lower incidence of S-SSIs seen in the SSL cohort may be attributable to the fact that the single-site access device used within our institution has a wound protector, a technique which has been suggested to reduce the incidence of surgical site infections after gastrointestinal and biliary surgery.²⁰ During SSL resections, this wound protector likely functioned to safeguard the point of specimen extraction from contamination. In contrast, when performing SDL resections, two of the surgeons in this study did not routinely use a wound protector when extracting the specimen and 14 of the 32 S-SSIs in the SDL cohort (43.8%) occurred following surgeries where a wound protector was not utilized. Furthermore, SDL requires the additional step of

extracting the specimen by extending the length of one of the incision hours after the administration of prophylactic antibiotics provided at the beginning of surgery, and theoretically after the peak antibiotic tissue concentration had been attained. This factor may promoted a higher risk for the development of an S-SSI within the SDL cohort; by comparison, the incision created at the start of an SSL surgery (prior to peak antibiotic tissue concentration) does not routinely require extension for specimen extraction, which may serve as a protective factor against S-SSIs. Though the additional number of port sites in SDL operations may also hypothetically increase the risk of developing a S-SSI, in our study only two S-SSIs within the SDL cohort occurred at a non-extraction port site indicating that the manner in which the specimen was extracted likely played a larger role in the observed S-SSI difference between the SDL and SSL cohorts than the number of incisions. Despite the fact that the incidence of S-SSIs was found to be significantly different between SSL and SDL in the current study, variations in wound protector utilization, differences in closure methods and different incidences of diverting stomas could have influenced our observed difference to a greater degree than the choice of laparoscopic technique.

Within this study, the SDL cohort also experienced a higher incidence of other infectious complications when compared to the SSL cohort (SDL 5.3% vs. SSL 1%, $p = <0.001$). This difference was mainly driven by a higher incidence of urinary tract infections within the SDL cohort. Though the colorectal division currently has a strictly adhered to policy regarding removal of urinary catheters within 48 hours following surgery, during the early period of this study's timeframe, no such policy existed. As a result, urinary catheters were removed at varying times depending on the surgeon, and based on observations during that time, the surgeons who were performing SSL procedures were typically more aggressive with urinary catheter removal, which may have resulted in the lower incidence of urinary tract infections within the SSL cohort.

Additionally, the current study demonstrated a significant difference in the incidence of diverting stomas, particularly in the form of ileostomies (SDL 26.4% vs. SSL 38%). This difference in the incidence of ileostomy creation was most notable in the groups of patients undergoing enterectomy/ileocelectomy (SDL 8.2% [5/61] vs. SSL 44.2% [23/52]); a group which was primarily composed of Crohn's disease patients on immunosuppressive medications. The decision to divert was often multifactorial in nature, reflecting the nature of the disease requiring resection as well as taking into consideration the patient's overall health status.

Among previous studies evaluating outcomes with SDL in colorectal patients, rates for conversion to laparotomy have ranged from 11.2% to 15.8%.²¹⁻²³ Our SDL conversion rate was 16%, which is similar to other published series. SSL colorectal surgery conversion rates have been tentatively estimated to involve conversion to conventional laparoscopy in 4% to 7% of surgeries, and to involve conversion to a laparotomy in 1% to 2% of surgeries. However, these rates were primarily based on analyses of studies in which only right colectomies were studied.^{24,25} Our SSL conversion rates to conventional laparoscopy and to laparotomy were 1.3% and 17.2%, respectively. Though no statistical difference in conversions was found between our SDL and SSL cohorts, our high SSL to laparotomy conversion rate was related to patient selection, especially with respect to the application of

SSL techniques to urgent surgeries such as Hartmann's procedures for perforated diverticulitis (i.e. preemptively converting to laparotomy in the setting of feculent peritonitis, as this cannot be adequately addressed laparoscopically). As the SSL experience of the surgeons in our institution matured, the selection of cases within the institution became broader and more patients with histories of previous laparotomies and more complex disease processes were offered SSL surgery with the full understanding that conversion was more likely, which also contributed to our conversion rate.

Though this study was not designed to comment on long-term complications such as hernia rates, port-site hernias are considered to be a concern after SSL procedures.²⁶⁻²⁸ Based on medical provider documentation of the abdominal examination during postoperative clinic visits, we determined that our 60-day port-site hernia rate was 4.1% [13/318] in SDL and 4.7% [12/253] in SSL ($p = 0.84$). Forty patients in the SSL cohort had a stoma created at their site of incision and were excluded from the port-site hernia at-risk population. Though comparable between the cohorts, this study's limited follow-up is unlikely to represent the true port-site hernia rate for SSL. Our group has recently published a review of hernias associated with SSL colorectal surgery, in which we did observe a higher incidence of port-site hernias in the SSL cohort.²⁹ However, in the referenced study, the hernia rates appeared to decrease over time, which may be due to improvements in facility with SSL lending to the creation of smaller fascial apertures. One issue regarding SSL which may contribute to an inherent tendency toward incisional hernia formation is the ease of access to the peritoneal cavity via placement of the SSL port through the umbilicus. The fact that this is the thinnest region of the anterior abdominal wall makes this an attractive site for port placement, while simultaneously making this surgical site higher risk for hernia formation.

This study does have limitations as it is a retrospective, single institution study. One limitation present within many previous studies on SSL has been related to the selection of which patients are offered SSL. In the practice of the surgeons at our institution who utilize SSL, those patients deemed to be laparoscopic candidates, whether in elective or non-elective settings, were offered SSL, and it is felt that a consecutive series of SSL patients should provide for more accurate outcomes with the technique. The decision to perform either SSL or SDL was based on the preference of the surgeon, and as mentioned within the manuscript, each surgeon did not utilize uniform practices in regard to specimen extraction and urinary catheter removal, which may have potentially introduced bias into the study. However, the patients within each cohort had similar comorbidities and characteristics, and therefore, we believe that the current analysis still represents a fair comparison between the two techniques even though multiple surgeons were included. Additionally, a multivariate analysis was initially utilized to further assess differences between the cohorts by controlling for various patient related factors, primarily focusing on the incidence of SSI and other infections. A statistically significant difference was noted in favor of SSL. However, given the relatively rare occurrence of infections amid our study cohorts, the logistic regression models analyzing SSIs and other infections may have been over-fitted since the study sample size was not quite large enough to support our covariates. As a result, the authors opted not to include the results of these models, since though they appeared to further

support the results of our univariate analysis, they were not critical to the conclusions of the study and their validity was in question.

Despite the limitations of this study, the present work demonstrates that in colorectal surgery SSL provides similar postoperative results to SDL for many types of procedures, including some which have not been described in great detail within the current literature (proctectomy and left colectomy). With comparable operative times and major complication rates compared to SDL, SSL colorectal surgery can be performed in a safe and time efficient manner.

Acknowledgments

Conflicts of Interest and Source of Funding: Statistical analysis was supported in part by NIH grant UL1 TR000127 to Arthur Berg.

REFERENCES

1. Braga M, Vignali A, Gianotti L, et al. Laparoscopic versus open colorectal surgery: a randomized trial on short-term outcome. *Ann Surg.* 2002; 236:759–767. [PubMed: 12454514]
2. Schwenk W, Haase O, Neudecker J, et al. Short term benefits for laparoscopic colorectal resection. *Cochrane Database Syst Rev.* 2005; 3:Cd003145. [PubMed: 16034888]
3. Martel G, Crawford A, Barkun JS, et al. Expert opinion on laparoscopic surgery for colorectal cancer parallels evidence from a cumulative meta-analysis of randomized controlled trials. *PLoS One.* 2012; 7:e35292. [PubMed: 22532846]
4. McKay GD, Morgan MJ, Wong SK, et al. Improved short-term outcomes of laparoscopic versus open resection for colon and rectal cancer in an area health service: a multicenter study. *Dis Colon Rectum.* 2012; 55:42–50. [PubMed: 22156866]
5. Kuhry E, Schwenk WF, Gaupset R, et al. Long-term results of laparoscopic colorectal cancer resection. *Cochrane Database Syst Rev.* 2008; 2:Cd003432. [PubMed: 18425886]
6. Vestweber B, Galetin T, Lammerting K, et al. Single-incision laparoscopic surgery: outcomes from 224 colonic resections performed at a single center using SILS. *Surg Endosc.* 2013; 27:434–442. [PubMed: 22806519]
7. Ross H, Steele S, Whiteford M, et al. Early multi-institution experience with single-incision laparoscopic colectomy. *Dis Colon Rectum.* 2011; 54:187–192. [PubMed: 21228667]
8. van den Boezem PB, Sietes C. Single-incision laparoscopic colorectal surgery, experience with 50 consecutive cases. *J Gastrointest Surg.* 2011; 15:1989–1994. [PubMed: 21796459]
9. Geisler DP, Kirat HT, Remzi FH. Single-port laparoscopic total proctocolectomy with ileal pouch-anal anastomosis: initial operative experience. *Surg Endosc.* 2011; 25:2175–2178. [PubMed: 21197548]
10. Gash KJ, Goede AC, Kaldowski B, et al. Single incision laparoscopic (SILS) restorative proctocolectomy with ileal pouch-anal anastomosis. *Surg Endosc.* 2011; 25:3877–3880. [PubMed: 21761270]
11. Stewart DB, Messaris E. Early experience with single-site laparoscopic surgery for complicated ileocolic Crohn's disease at a tertiary-referral center. *Surg Endosc.* 2012; 26:777–782. [PubMed: 21993940]
12. Champagne BJ, Papaconstantinou HT, Parmar SS, et al. Single-incision versus standard multiport laparoscopic colectomy: a multicenter, case-controlled comparison. *Ann Surg.* 2012; 255:66–69. [PubMed: 22104563]
13. Yang TX, Chua TC. Single-incision laparoscopic colectomy versus conventional multiport laparoscopic colectomy: a meta-analysis of comparative studies. *Int J Colorectal Dis.* 2013; 28:89–101. [PubMed: 22828958]

14. Chew MH, Chang MH, Tan WS, et al. Conventional laparoscopic versus single-incision laparoscopic right hemicolectomy: a case cohort comparison of short-term outcomes in 144 consecutive cases. *Surg Endosc.* 2013; 27:471–477. [PubMed: 22806522]
15. Velthuis S, van den Boezem PB, Lips DJ, et al. Comparison of short-term surgical outcomes after single-incision laparoscopic versus multiport laparoscopic right colectomy: a two-center, prospective case-controlled study of 100 patients. *Dig Surg.* 2012; 29:477–483. [PubMed: 23364285]
16. Yun JA, Yun SH, Park YA, et al. Single-incision laparoscopic right colectomy compared with conventional laparoscopy for malignancy: assessment of perioperative and short-term oncologic outcomes. *Surg Endosc.* 2013; 27:2122–2130. [PubMed: 23319285]
17. Stewart DB, Berg A, Messaris E. Single-site laparoscopic colorectal surgery provides similar lengths of hospital stay and similar costs compared with standard laparoscopy: results of a retrospective cohort study. *J Gastrointest Surg.* 2014; 18:774–781. [PubMed: 24408181]
18. Gentleman, R.; Ihaka, R. [September 4, 2014] The R Project for Statistical Computing. Available at: <http://www.r-project.org/index.html>.
19. Stewart DB, Messaris E. Outcomes for consecutive patients undergoing single-site laparoscopic colorectal surgery. *J Gastrointest Surg.* 2012; 1:849–856. [PubMed: 22125171]
20. Edwards JP, Ho AL, Tee MC, et al. Wound protectors reduce surgical site infection: a meta-analysis of randomized controlled trials. *Ann Surg.* 2012; 256:53–59. [PubMed: 22584694]
21. Simorov A, Shaligram A, Shostrom V, et al. Laparoscopic colon resection trends in utilization and rate of conversion to open procedure: a national database review of academic medical centers. *Ann Surg.* 2012; 256:462–468. [PubMed: 22868361]
22. Neudecker J, Klein F, Bittner R, et al. Short-term outcomes from a prospective randomized trial comparing laparoscopic and open surgery for colorectal cancer. *Br J Surg.* 2009; 96:1458–1467. [PubMed: 19918852]
23. Degiuli M, Mineccia M, Bertone A, et al. Outcome of laparoscopic colorectal resection. *Surg Endosc.* 2004; 18:427–432. [PubMed: 14752626]
24. Makino T, Milsom JW, Lee SW. Feasibility and safety of single-incision laparoscopic colectomy: a systematic review. *Ann Surg.* 2012; 255:667–676. [PubMed: 22258065]
25. Maggiori L, Gaujoux S, Tribillon E, et al. Single-incision laparoscopy for colorectal resection: a systematic review and meta-analysis of more than a thousand procedures. *Colorectal Dis.* 2012; 14:e643–654. [PubMed: 22632808]
26. Agaba EA, Rainville H, Ikedilo O, et al. Incidence of port-site incisional hernia after single-incision laparoscopic surgery. *JSLs.* 2014; 18:204–210. [PubMed: 24960483]
27. Alptekin H, Yilmaz H, Acar F, et al. Incisional hernia rate may increase after single-port cholecystectomy. *J Laparoendosc Adv Surg Tech A.* 2012; 22:731–737. [PubMed: 23039699]
28. Marks JM, Phillips MS, Tacchino R, et al. Single-incision laparoscopic cholecystectomy is associated with improved cosmesis scoring at the cost of significantly higher hernia rates: 1-year results of a prospective randomized, multicenter, single-blinded trial of traditional multiport laparoscopic cholecystectomy vs single-incision laparoscopic cholecystectomy. *J Am Coll Surg.* 2013; 216:1037–1048. [PubMed: 23619321]
29. Sangster W, Kulaylat AN, Stewart DB, et al. Hernia incidence following single-site versus standard laparoscopic colorectal surgery. *Colorectal Dis.* 2015; 17:250–256. [PubMed: 25307082]

Table 1

Patient characteristics

Variable	SDL N = 318	SSL N = 308	p-value
Age, mean [stdev]	53.9 ± 16.5	53.1 ± 17.8	0.87
Sex			0.94
Female	165 (51.9)	161 (52.3)	
Male	153 (48.1)	147 (47.7)	
ASA classification			0.01
I	8 (2.5)	4 (1.3)	
II	190 (59.7)	155 (50.3)	
III	111 (34.9)	143 (46.4)	
IV	9 (2.8)	6 (1.9)	
Body mass index (kg/m ²), mean [stdev]	28.2 ± 6.3	27.6 ± 6.6	0.49
Diagnosis			0.45
Colon cancer	66 (20.8)	69 (22.4)	
Rectal cancer	34 (10.7)	34 (11)	
Diverticulitis	74 (23.3)	65 (21.1)	
Crohn's disease	55 (17.3)	58 (18.8)	
Ulcerative colitis	43 (13.5)	25 (8.1)	
Other	46 (14.5)	57 (18.5)	
Admission type			0.51
Elective	270 (84.9)	255 (82.8)	
Urgent	48 (15.1)	53 (17.2)	
Operation			0.05
Total colectomy/proctocolectomy	61 (19.2)	42 (13.6)	
Enterectomy/ileocolectomy	61 (19.2)	52 (16.9)	
Right colectomy	53 (16.7)	75 (24.4)	
Left colectomy	104 (32.7)	98 (31.8)	
Transverse colectomy	3 (1)	0 (0)	
Proctectomy	36 (11.3)	41 (13.3)	

(Values within parentheses represent percentages unless indicated otherwise)

Table 2

Operative details

Variable	SDL N = 318	SSL N = 308	p-value
Operative time (min), mean [stdev]	182.1 ± 81.3	177 ± 86.5	0.30
Estimated blood loss (mL), mean [stdev]	127.8 ± 135.3	96.8 ± 104.8	<0.001
Conversions			
To conventional laparoscopy	NA	4 (1.3)	NA
To laparotomy	51 (16)	53 (17.2)	0.75
Stoma creation	105 (33)	145 (47.1)	0.004
Ileostomy	84 (26.4)	117 (38)	
Colostomy	21 (6.6)	28 (9.1)	
Length of stay (days), mean [stdev]	4.8 ± 3.4	5.5 ± 6.9	0.14
Lymph nodes harvested, mean [stdev] (SDL N = 100; SSL N = 103)	17.4 ± 9.8	21.2 ± 10.4	0.007

(Values within parentheses represent percentages unless indicated otherwise)

Table 3

Perioperative outcomes

Variable	SDL N = 318	SSL N = 308	p-value
Time to return of gastrointestinal function (days), mean [stdev]	3 ± 1.5	3.2 ± 2.7	0.08
Time to low residue diet (days), mean [stdev]	4.5 ± 3.2	4.5 ± 5.6	0.08
Ileus	33 (10.4)	46 (14.9)	0.09
Readmission within 60 days	48 (15.1)	49 (15.9)	0.83
Unexpected reoperation	5 (1.6)	9 (2.9)	0.29
Complications (number of patients)	61 (19.2)	33 (10.7)	0.004
Surgical-site infection	36 (11.3)	18 (5.8)	0.02
Superficial	32 (10.1)	13 (4.2)	
Deep	2 (0.6)	1 (0.3)	
Organ space	2 (0.6)	4 (1.3)	
Anastomotic leak	3 (0.9)	3 (1)	1
Postoperative bleed	2 (0.6)	4 (1.3)	0.44
Venous thromboembolism	3 (0.9)	2 (0.6)	1
Other infections	17 (5.3)	3 (1)	<0.001
Other complications	6 (1.9)	4 (1.3)	0.75
Death	1 (0.3)	2 (0.6)	0.62

(Values within parentheses represent percentages unless indicated otherwise)

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 4

Comparison by operation

Variable	Total colectomy/proctocolectomy			Enterectomy/ileocolectomy			Right colectomy			Left colectomy			Proctectomy		
	SDL N = 61	SSL N = 42	p-value	SDL N = 61	SSL N = 52	p-value	SDL N = 53	SSL N = 75	p-value	SDL N = 104	SSL N = 98	p-value	SDL N = 36	SSL N = 41	p-value
Operative time (min), mean [stdev]	244.8 ± 69.3	238 ± 97.7	0.48	121.6 ± 43.4	124 ± 71	0.47	147.2 ± 58.4	138.9 ± 54.4	0.52	178.2 ± 61.5	189.4 ± 75.7	0.39	246.4 ± 110.8	222.3 ± 94.9	0.41
Estimated blood loss (mL), mean [stdev]	204.3 ± 209.6	133.6 ± 124.6	0.02	93.3 ± 82	78.8 ± 122.7	<0.001	102.2 ± 112.9	69.3 ± 89	<0.001	104.8 ± 69.1	101.5 ± 84.2	0.13	161.9 ± 171.8	120.7 ± 116	0.06
Length of stay (days), mean [stdev]	6.4 ± 5.9	8.2 ± 11	0.83	4.5 ± 1.7	4.6 ± 3.9	0.04	4.6 ± 2.2	5.3 ± 9.2	0.02	4.3 ± 2.1	5.2 ± 3.5	0.11	5 ± 3.4	5 ± 4.8	0.24
Conversions															
To conventional laparoscopy	NA	0	NA	NA	2 (3.9)	NA	NA	1 (1.3)	NA	NA	1 (1)	NA	NA	0	NA
To laparotomy	8 (13.1)	5 (11.9)	1	10 (16.4)	6 (11.5)	0.59	9 (17)	9 (12)	0.45	17 (16.4)	25 (25.5)	0.12	6 (16.7)	8 (19.5)	0.78
Stoma creation	45 (73.8)	38 (90.5)	0.04	7 (11.5)	23 (44.2)	<0.001	6 (11.3)	11 (14.7)	0.79	26 (25)	37 (37.8)	0.11	21 (58.3)	36 (87.8)	0.004
Ileostomy	45 (73.8)	38 (90.5)		5 (8.2)	23 (44.2)		6 (11.3)	11 (14.7)		15 (14.4)	18 (18.4)		13 (36.1)	27 (65.8)	
Colostomy	0	0		2 (3.3)	0		0	0		11 (10.6)	19 (19.4)		8 (22.2)	9 (21.9)	
Readmission within 60 days	11 (18)	13 (31)	0.16	7 (11.5)	9 (17.3)	0.43	8 (15.1)	9 (12)	0.61	15 (14.4)	13 (13.3)	0.84	7 (19.4)	5 (12.2)	0.53
Complications (number of patients)	13 (21.3)	6 (14.3)	0.44	11 (18)	7 (13.5)	0.61	6 (11.3)	9 (12)	1	20 (19.2)	10 (10.2)	0.08	11 (30.6)	1 (2.4)	<0.001

(Values within parentheses represent percentages unless indicated otherwise)