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Clinical and oncologic outcomes of single-incision laparoscopic surgery for right colon cancer: a propensity score matching analysis

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Abstract

Background Single-incision laparoscopic surgery (SILS) for right colon cancer is going to be considered as a new option. The potential benefits, clinical, and oncologic outcomes are still controversial. The aim of this study was to investigate clinical and oncologic outcomes of single-incision laparoscopic surgery (SILS) compared to conventional laparoscopic surgery (CLS) for right colon cancer using propensity score matching analysis.

Methods From December 2013 to June 2017, 174 patients underwent laparoscopic radical right hemicolectomy through a single-incision ($n=32$) or a conventional ($n=142$) approach. The data were prospectively collected and the patients were matched at a radio of 1:1 according to age, sex, body mass index (BMI), previous abdominal surgeries, comorbidities, ASA score ($\leq 2/>2$), and pathologic stage.

Results No significant differences were observed in estimated blood loss, time to diet, postoperative pain score, length of hospital stay between the SILS and CLS groups. However, the SILS group showed longer operation time (175 (40) vs 145 (52.5), $p=0.011$) and shorter incision length (4 (1.4) vs 7 (1.9), $p<0.001$). There were 2 (6.3%) postoperative complications in the SILS group and 5 (15.6%) in the CLS group ($p=0.426$). The pathologic outcomes were similar between two groups. The median follow-up period was 26.5 months in the SILS group and 34.9 months in the CLS group ($p=0.002$). There were 3 recurrences (9.4%) in the SILS group and 3 (9.4%) in the CLS group. The 3-year disease-free survival rates were 92.4 and 93.8% ($p=0.984$), and overall survival rates were 92.3 and 93.0% ($p=0.884$) in the SILS and the CLS groups, respectively. No incisional hernia was observed during the follow-up period.

Conclusions Though single-incision laparoscopic surgery for right colon cancer showed longer operation time in this study, it appears to be a safe and feasible option with comparable clinical and oncologic outcomes to conventional laparoscopic surgery.

Keywords Colon cancer · Single-incision laparoscopic surgery · Conventional laparoscopic surgery · Clinical outcomes · Oncologic outcomes

At present, laparoscopic surgery for colon cancer has been proven safe and effective compared to laparotomy in several randomized controlled trials [1–3]. Moreover, laparoscopic surgery shows benefits in faster recovery, better cosmetic effect, less postoperative pain, shorter hospital stay, lower complications, etc. [4, 5]. In order to improve cosmetic effect and reduce postoperative pain, single-incision laparoscopic surgery (SILS) is attracting increasing attention. SILS is considered to be the next major advance in the progress of minimally invasive surgical approaches to colorectal disease that is more feasible in generalized use [6].

In most previous studies, SILS for colon cancer was feasible and short-term safe compared to conventional laparoscopic surgery (CLS) [7–10]. However, there is still controversy over its potential better cosmetic effect and less

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postoperative pain [11]. Moreover, the long-term oncologic outcomes are still inconclusive as only a few studies showed long-term survival data [12–15].

The aim of this study was to investigate clinical and oncologic outcomes of SILS compared to CLS for right colon cancer, by using propensity score matching analysis.

Materials and methods

Patients and data collection

From December 2013 to June 2017, 185 patients underwent laparoscopic radical right hemicolectomy for right colon cancer in Ruijin Hospital and Ruijin Hospital North, Shanghai Jiaotong University School of Medicine in China. The same very well-experienced and qualified surgical team performed all the operations. The team performed more than 300 laparoscopic radical colectomies per year. Patient data were collected prospectively and reviewed retrospectively. 32 patients underwent laparoscopic radical right hemicolectomy through a single-incision approach and 142 patients through a conventional approach, while 11 patients with metastatic disease were excluded.

The right colon was defined as the colon up to the middle transverse colon. This study was approved by the Institutional Review Board of Ruijin Hospital North and written informed consents for the operations were received from all patients.

The clinicopathologic information and perioperative outcomes were obtained from the medical records, including age, sex, body mass index (BMI), the American Society of Anesthesiologists (ASA) grade, comorbidities, previous abdominal surgery, operation time, estimated blood loss, incision length, postoperative visual analogue score (VAS), time to drink and start diet, length of hospital stay, conversion to laparotomy or CLS, perioperative mortality, postoperative complications, tumor size, cell type, number of harvested lymph nodes, proximal and distal resection margins, lymph node metastasis, neurovascular invasion, and pathologic stage according to the 7th Edition of AJCC Cancer Staging Manual. The incision length was defined as the sum of all incision lengths. The postoperative complications were graded according to the Clavien–Dindo classification.

The follow-up was consistent with the National Comprehensive Cancer Network (NCCN) guidelines. Recurrence was confirmed by radiological or histological methods.

Surgical techniques

All the patients underwent mechanical bowel preparation and oral antibiotic prophylaxis one day before surgery. After general anesthesia, the patients were placed in supine, Trendelenburg, left-tilted position. The pneumoperitoneum in both groups was established with a pressure of 15 mmHg.

In the SILS group, a SILS™ Port (Covidien, Mansfield, MA, USA) with three 5-mm cannulas inserted was installed through a 2.5 cm in length midline periumbilical incision (Fig. 1). This incision was later slightly extended supra- and infraumbilically for specimen extraction. The operator by the patient's left side manipulated two conventional laparoscopic instruments through two 5-mm cannulas. The assistant, between patient's two legs, handled a 0° flexible laparoscope (LTF-VP, Olympus Medical Systems, Tokyo, Japan).

In the CLS group, the surgery was performed with 4 or 5 trocars including a 12-mm trocar for a 30° laparoscope in the infraumbilical site.

All cases were performed the medial-to-lateral approaches keeping the principle of complete mesocolic excision.

The operator's grasper was used to lift up the ileocolic pedicle. The medial dissection began by incising the base of the mesentery. After entering into the right retrocolic space and staying between the embryological planes just anterior to the Gerota's fascia, duodenum, and ureter, the plain over the duodenum and pancreas toward the superior mesenteric vein was carefully expanded. When completely dissected, the ileocolic vessels were clipped at the root and then transected. The duodenum and pancreas as landmark guided the depth of dissection and assisted in maintaining the correct dissection plain. The mesenteric dissection line was then extended further cephalad up to the origin of the right colic artery and toward the middle colic artery.

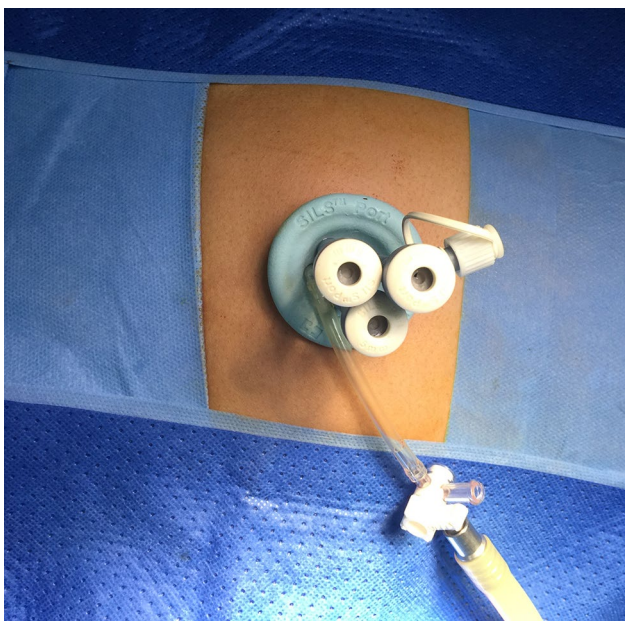

Fig. 1 SILS™ port with three 5-mm cannulas installed through the transumbilical incision

The middle colic artery was always dissected to its origin from the superior mesenteric artery for maximal nodal yield. Lateral to the middle colic artery, the right colic vein, coursing anteriorly from the Henle's trunk, can usually be identified and transected. Along the Henle's trunk, dissection of all bifurcation seemed to be necessary to avoid the intraoperative hemorrhage. All the central nodal tissues were then swept with the specimen. With traction on the colon, the lesser sac was entered and the gastrocolic tissue was divided. The progress was continued along the mobilization plane, drawing the hepatic flexure exteriorly and laterally.

After mobilization, the specimen was retrieved through the wound protector installed through the transumbilical incision (SILS) or a 3–4 cm incision extended from the periumbilical incision (CLS). End-to-side or side-to-side anastomosis was performed extracorporeally by using the staplers. Finally, the draining tube was placed at the right paracolic sulcus and the closure of incisions was well done by absorbable monofilament (Fig. 2).

Matching

We first performed SILS in December 2013. In the early period, only younger patients with early stage underwent SILS. To minimize the differences, we applied 1:1 propensity score matching by using bivariate logistic regression. Age, sex, BMI, ASA grade, comorbidities, previous abdominal surgery, and pathologic stage were selected as covariates.

Statistical analysis

Statistical analysis was performed with SPSS (version 22.0, SPSS Inc. Chicago, IL, USA). Statistically significant differences were evaluated using the Mann–Whitney *U* test, Student's *t* test, χ^2 test, and Fisher exact test, as appropriate. Overall survival and disease-free survival rates were estimated using the Kaplan–Meier method and compared using the log-rank test. A p value < 0.05 was considered statistically significant.

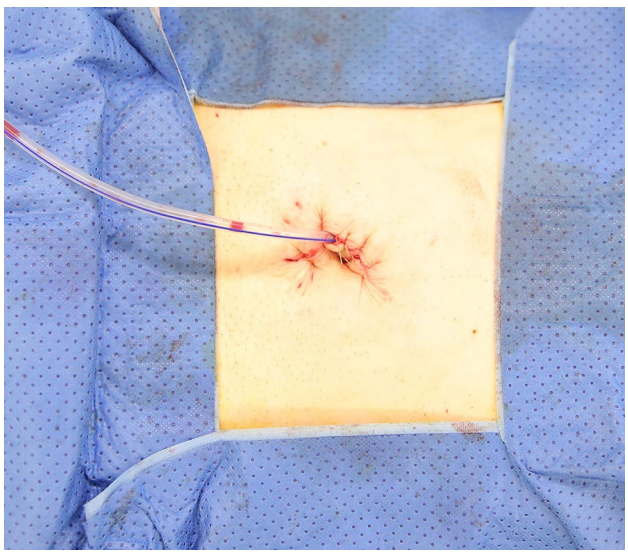

Fig. 2 Abdominal incision at the end of surgery in SILS group

Results

Baseline characteristics

Before matching, patients in SILS group were significant younger than patients in CLS group (59.5 (11.5) vs 65 (13), $p = 0.005$). Patients in CLS group had more comorbidities (47.2 vs 28.1%, $p = 0.075$). Other characteristics did not differ significantly before matching. After matching, each group included 32 patients, and there was no difference in any patient characteristics (Table 1).

Intraoperative and perioperative outcomes

The operation time was significantly longer in the SILS group (175 (40) vs 145 (52.5), $p = 0.011$). The estimated blood loss was comparable between 2 groups ($p = 0.358$).

There were two intraoperative vascular injuries and one conversion to laparotomy in the 2 groups, respectively. The reason for conversion to laparotomy in the SILS group was vascular injury, and in the CLS group was intraperitoneal adhesion. Besides, three patients in the SILS group used additional trocars (two plus one trocar and one plus two trocars). The reason for additional trocars was intraperitoneal adhesion ($n = 2$) and vascular injury ($n = 1$). The incision length was significantly shorter in the SILS group (4 (1.4) vs 7 (1.9), $p < 0.001$). The recovery from surgery and the VAS after surgery did not differ between the 2 groups (Table 2). The overall postoperative complication rates were comparable between 2 groups ($p = 0.426$). The postoperative complications of SILS group included one ileus (Grade I) and one seroperitoneum (Grade IIIa). The postoperative complications of CLS group included one anastomotic leakage (Grade IIIa), two ileuses (Grade I:1, Grade II:1), one wound infection (Grade I), and one seroperitoneum (Grade I). There was no mortality or readmission within 30 days after surgery in either of the two groups.

Pathologic and oncologic outcomes

The tumor size, proximal and distal resection margins, number of harvested lymph nodes, cell type, lymph node metastasis, neurovascular invasion, did not differ between the 2 groups (Table 3). There were 23 patients (71.9%)

Table 1 Baseline characteristics

Characteristics	Overall			After matching	
	SILS ($n=32$)	CLS ($n=142$)	p	CLS ($n=32$)	p
Age, median (IQR) (years)	59.5 (11.5)	65 (13)	0.005	60.5 (9.5)	0.710
Sex, n (%)			0.613		1
Male	16 (50)	64 (45.1)		16 (50)	
Female	16 (50)	78 (54.9)		16 (50)	
BMI, median (IQR) (kg/m^2)	22.73 (4.58)	23.10 (5.03)	0.983	22.80 (5.02)	0.975
ASA grade, n (%)			0.167		1
≤ 2	29 (90.6)	114 (80.3)		30 (93.8)	
>2	3 (9.4)	28 (19.7)		2 (6.2)	
Comorbidities, n (%)	9 (28.1)	67 (47.2)	0.075	11 (34.4)	0.590
Previous abdominal surgery, n (%)	11 (34.4)	43 (30.3)	0.651	9 (28.1)	0.590
Pathologic stage, n (%)			0.122		0.953
0, I	9 (28.1)	19 (13.4)		8 (25.0)	
II	13 (40.6)	70 (49.3)		14 (43.7)	
III	10 (31.3)	53 (37.3)		10 (31.3)	

IQR interquartile range, *BMI* body mass index, *ASA* The American Society of Anesthesiologists

Table 2 Intraoperative and perioperative outcomes

Variable	SILS ($n=32$)	CLS ($n=32$)	p
Operation time, median (IQR) (min)	175 (40)	145 (52.5)	0.011
Estimated blood loss, median (IQR) (mL)	65 (90)	100 (90)	0.358
Intraoperative morbidity, n (%)	2 (6.3)	2 (6.3)	1
Vascular injury	2	2	
Adjacent organ injury	0	0	
Conversion to laparotomy, n (%)	1 (3.1)	1 (3.1)	1
Additional trocar, n (%)	3 (9.4)	–	–
Incision length, median (IQR) (cm)	4 (1.4)	7 (1.9)	<0.001
Time to drink, median (IQR) (days)	4 (1)	5 (1.8)	0.164
Time to liquid diet, median (IQR) (days)	6 (1)	7 (1.8)	0.056
Time to soft diet, median (IQR) (days)	8 (1)	8 (1.8)	0.240
Maximum pain score, median (IQR) (VAS)			
Day of operation	4 (1)	4 (1)	0.421
POD 1	4 (1)	4 (1)	0.855
POD 2	3 (1)	3 (1)	0.483
Length of hospital stay, median (IQR) (days)	10 (2)	10 (2.8)	0.668
Postoperative complications, n (%)	2 (6.3)	5 (15.6)	0.426
Anastomotic leakage	0	1	
Ileus	1	2	
Wound infection	0	1	
Seroperitoneum	1	1	
Grade of complications, n (%)			
I, II	1 (3.1)	4 (12.5)	0.355
III	1 (3.1)	1 (3.1)	1
Readmission within 30 days of surgery, n (%)	0 (0)	0 (0)	–
Mortality within 30 days of surgery, n (%)	0 (0)	0 (0)	–

IQR interquartile range, *VAS* visual analogue score, *POD* postoperative day

Table 3 Pathologic and oncologic outcomes

Variable	SILS ($n=32$)	CLS ($n=32$)	p
Tumor size, median (IQR) (cm)	3.75 (2)	4.5 (2.9)	0.422
Proximal resection margins, median (IQR) (cm)	10.5 (7)	12 (7.9)	0.444
Distal resection margins, median (IQR) (cm)	8.75 (9.1)	12 (10.1)	0.357
Harvested lymph nodes, median (IQR), *n*	17 (12.8)	17 (9.5)	0.995
Cell type, *n* (%)			0.614
WD/MD	17 (53.1)	19 (59.4)	
PD/others	15 (46.9)	13 (40.6)	
Lymph node metastasis, *n* (%)	10 (31.3)	10 (31.3)	1
Vascular invasion, *n* (%)	6 (18.8)	3 (9.4)	0.474
Perineural invasion, *n* (%)	5 (15.6)	3 (9.4)	0.708
Adjuvant chemotherapy, *n* (%)			1
No	9 (28.1)	9 (28.1)	
Yes	23 (71.9)	23 (71.9)	
XELOX	21 (65.6)	19 (59.4)	
Capecitabine	2 (6.3)	4 (12.5)	
Follow-up period, median (IQR) (months)	26.5 (13.3)	34.9 (20.1)	0.002
Recurrence, *n* (%)	3 (9.4)	3 (9.4)	1
Stage 0/I	None	None	
Stage II	Lung:1	Liver:1	
Stage III	Lung:2	Peritoneal seeding:1	
		Multiple lymph nodes:1	
Incisional hernia, *n* (%)	0 (0)	0 (0)	-

IQR interquartile range, *WD* well differentiated, *MD* moderately differentiated, *PD* poorly differentiated, *XELOX* oxaliplatin, capecitabine

who received adjuvant chemotherapy in the 2 groups, respectively.

The median follow-up period was 26.5 (13.3) months in the SILS group and 34.9 (20.1) months in the CLS group ($p=0.002$). During the follow-up period, there were 3 recurrences (9.4%) in the 2 groups, respectively. The SILS group showed one lung metastasis in stage II and two lung metastases in stage III. The CLS group showed one liver metastasis in stage II, while one peritoneal seeding and one multiple lymph nodes recurrence in stage III. One stage III patient in SILS group died due to lung metastases 21 months after surgery. The other stage III patient in SILS group died due to cerebrovascular accident. Two stage III patients in CLS group died due to peritoneal seeding 25 months after surgery and multiple lymph nodes recurrence 2 months after surgery, respectively. No incisional hernia in either of the two groups was observed during the follow-up period. Figure 3 shows the incision at 6 months after surgery.

The 3-year disease-free survival rates did not differ significantly between the SILS and CLS groups (92.4 vs 93.8%, $p=0.984$, Fig. 4). The 3-year overall survival rates were also comparable between the SILS and CLS groups (92.3 vs 93.0%, $p=0.884$, Fig. 5).

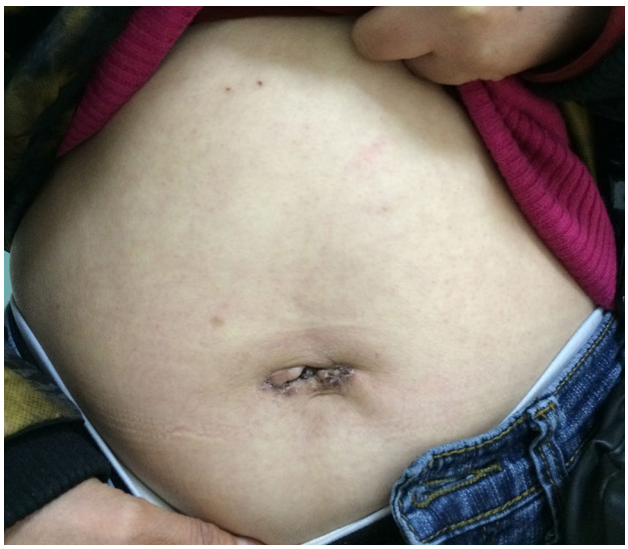

Fig. 3 The abdominal incision at 6 months after surgery

Discussion

After a decade of development, the application of SILS for right colon cancer is still at early stage. Most previous

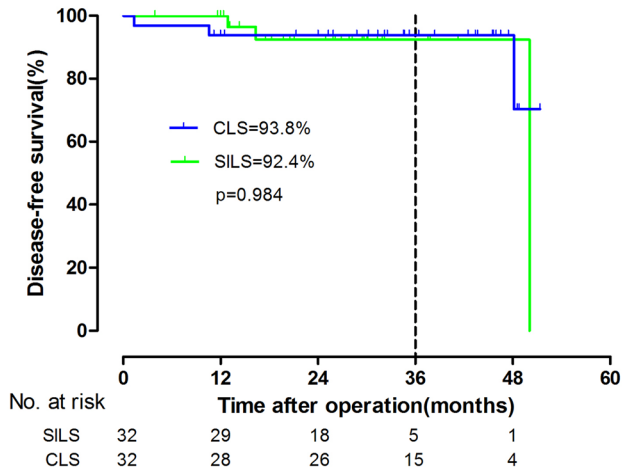

Fig. 4 Kaplan–Meier analysis of disease-free survival

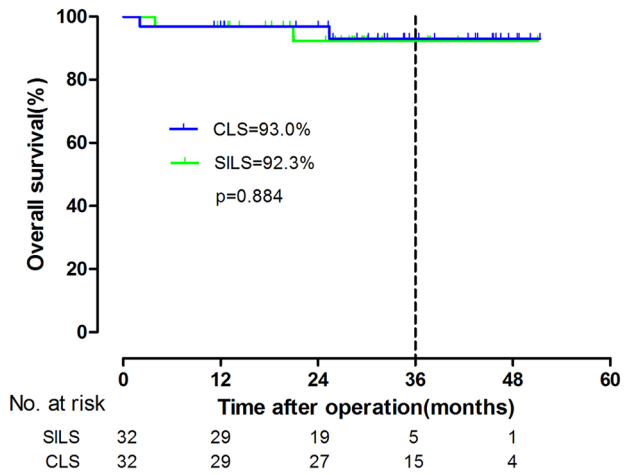

Fig. 5 Kaplan–Meier analysis of overall survival

studies showed SILS for right colon cancer was feasible and safe with comparable short-term outcomes to CLS [7–10].

At present, SILS for right colon cancer does not use widely due to the technical challenges and difficulties, including loss of triangulation, parallel coaxial effect, difficulty of achieving correct exposure and the necessary traction to tissues, shared fulcrum, lack of ergonomic favorable position, and so on. The skill sets and ergonomic demands cannot be directly adapted from existing conventional laparoscopic surgery experience [16]. We have performed 3-port laparoscopic colon surgery for almost 7 years with over 1000 cases experience. That experience could be a shortcut to the SILS. Besides, Trendelenburg and left-tilted position are helpful to expose the surgical field. Hand over hand cross and parallel techniques are needed to achieve the SILS. And the assistant (cameraperson) must be very familiar to manipulate the articulated scope, and must have a good cooperation with the operator.

In the present study, the difference of the variables of short-term outcomes was not statistically significant except for the operation time and incision length. Operation time was significantly longer in SILS group than that in CLS group. Some previous studies showed a similar operation time for the SILS group to the CLS group [9, 10, 17], whereas others required a longer time than the CLS group [18, 19]. We first performed conventional laparoscopic surgery in August 2009 and single-incision laparoscopic surgery in December 2013. The number of SILS for right colon cancer is much fewer than CLS. Obviously, the longer operation time was due to the technical challenges and difficulties during the SILS. With the increasing of number of SILS cases, the operation time became shorter. The comparison of the median operation time of the first 16 SILS cases to the last 16 cases was 180 (66.3) versus 170 (55) ($p=0.147$). More cases have to be accumulated to analyze the learning curve. The operation time of SILS after overcoming the learning curve may be closer to CLS, even without significant difference.

The incision length is widely used to evaluate the cosmetic effect. Meanwhile, tumor size is the most important factor to determine the incision length. In the present study, the incision length of SILS group was significantly shorter than the CLS group (4 (1.4) vs 7 (1.9), $p<0.001$), while the median tumor size of SILS group and CLS group did not differ significantly (3.75 (2) vs 4.5 (2.9), $p=0.422$). However, cosmetic effect is a subjective feeling not only determined by the incision length. Lee et al. [20] used body image score and cosmetic score to evaluate the cosmetic effect and found better scores in cosmetics for SILS.

Less postoperative pain is another potential benefit of SILS, but the results of previous studies are controversial. Poon et al. [7] found a statistically significant reduction in pain in SILS group on POD1 and POD2. On the other hand, Lu et al. [21] reported the SILS group had significantly higher VAS score on the day after surgery (3.07 vs 2.41, $p<0.001$). In the present study, the VAS score did not differ significantly on the operation day, POD 1 or POD2 (Table 2). The absorption of CO_2 gas might cause the soreness on POD1 and POD2, which influenced the VAS score. The soreness might due to the long operation time.

Though only a few studies showed long-term survival data, the DFS and OS reported were similar between the SILS and CLS groups [12–15]. Miyo et al. [12] reported the longest survival data. The median follow-up period was 41.4 months. Rates of 3-year disease-free and overall survival in SILS and CLS groups were 95.5 and 91.3% ($p=0.44$) and 100.0 and 98.7% ($p=0.24$). This is in agreement with the results of our study (Figs. 4, 5).

Several studies reported an increased rate of incisional hernia in SILS [22, 23]. Contrarily, no incisional hernia in either of the two groups was observed during the follow-up period in the present study and Yun et al's study [13]. Longer follow-up period is needed to further confirm the outcome.

The present study was limited to its retrospective nature and small samples. A large-scale, randomized controlled trial in Ruijin Hospital North was started to further evaluate the clinical and oncologic outcomes (ClinicalTrial.gov: NCT03151733).

In conclusion, though SILS for right colon cancer showed longer operation time in the present study, it appears to be a safe and feasible option with comparable clinical and oncologic outcomes to CLS. More studies, especially large-scale, randomized controlled trials are needed to establish the best indications for SILS for right colon cancer.

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Compliance with ethical standards

Disclosures Zijia Song, You Li, Kun Liu, Yimei Jiang, Yiqing Shi, Xiaopin Ji, Tao Zhang, Haoxuan Wu, Yi Shi, and Ren Zhao have no conflicts of interest or financial ties to disclose.

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