Single-Incision Laparoscopic Right Hemi-Colectomy: a Systematic Review

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Abstract As surgeons became more adept with laparoscopic colon surgery, other less invasive procedures, such as single-incision laparoscopic right hemi-colectomy (SIL-RH), have been applied. The objective of this study was to evaluate the safety of SIL-RH as well as its intraoperative and postoperative outcomes for right-sided colon diseases. A detailed search in PubMed for citations that included SIL-RH from 2000 to 2014 revealed 21 studies fulfilling the criteria of the present review. A total of 684 patients were analyzed. Of the patients, 50.2 % were men. Mean patient age was 64.8 years. Of the patients, 36.1 % had already undergone an abdominal operation before the performance of SIL-RH, while 69 % of the patients underwent SIL-RH for colon cancer. Relatively low rates of overall morbidity (15 %) and mortality (0.75 %) were reported in the included studies. Mean length of postoperative hospital stay (LOS) was 5.5 days. Bowel motility return had a mean value of 2.8 days. Mean number of harvested lymph nodes (LN) was 19.2 LN. All resection margins were tumor-free. SIL-RH was a safe alternative to multiport laparoscopic right hemi-colectomy (ML-RH) in terms of morbidity and mortality, postoperative gastrointestinal function recovery, LOS, as well as oncological radicalness.

Keywords Single incision · Right hemi-colectomy · Oncological · Laparoscopic

Introduction

An appropriate amount of skepticism accompanies the introduction of any novel surgical technique. As surgeons strive to develop and modify operations to achieve the most benefit with the least negative impact on the patient, it is critical that continuous and rigorous examination of outcomes is performed. The first and most important criterion that any new approach must satisfy is safety.

Laparoscopic methods are now routinely applied in the surgical treatment of a wide range of colon diseases. Many large multicenter prospective randomized controlled trials (RCTs) have clearly demonstrated short-term benefits in comparison with open surgery, in terms of earlier postoperative recovery, decreased postoperative pain, reduced pulmonary dysfunction, and shorter hospitalization [1–3]. Moreover, it has also been proven to be oncologically safe in the treatment of colon cancer [4, 5]. However, its benefits are not as dramatic as expected. A refinement of laparoscopic surgery, single-incision laparoscopic surgery (SILS), has more advantages over conventional multiport laparoscopic surgery (MLS), in that existing laparoscopic instruments can be used and relatively minor adjustments from the current multiport laparoscopic technique are needed. Thus far, it has been used for various abdominal procedures including cholecystectomy [6], appendectomy [7], and nephrectomy [8], and recently, this technique has been applied to colorectal surgery [9–12].

Potential advantages of SILS over conventional MLS are determined as an improvement in cosmetic outcome and incisional pain, as well as the avoidance of port site-related complications. Because of the limited number of studies reporting on single-incision laparoscopic colectomy (SILC) and especially single-incision laparoscopic right hemi-colectomy (SIL-RH), its clinical significance remains to be elucidated. The purpose of this review is to study the safety

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of SIL-RH as well as its intraoperative and postoperative outcomes for right-sided colon diseases.

Materials and Methods

Search Strategy

A detailed search in PubMed for citations that included SIL-RH from 2000 to 2014, using the keywords “single incision, single port, single access, laparoscopic colectomy, and SILS right hemi-colectomy,” revealed >50 studies.

Selection Criteria

Studies reporting exact data on SIL-RH patients and not average data regarding the SILC population of each study were included. Literature in languages other than English, case reports (<5 patients), studies reporting on technique only, studies reporting on robotic SIL-RH, studies reporting on SIL-RH with the addition of another surgical operation, as well as review articles were not included. Sub-studies of larger series by the same group were not included in our analysis of the total procedures performed, to avoid duplication of data.

After an initial review of these studies, only 21 reports seemed to match our criteria; a review of these reports was conducted and the full text was reviewed (Fig. 1).

Statistical analyses were performed only on the extracted data from the selected studies. Basic descriptive statistics (means and standard deviations) were used to summarize all available data.

Results

Study Characteristics

A total of 21 studies [13–33] were extracted for the present review. Of the 21 studies, 7 were from Europe, 7 were from the USA, and 6 were from Asia, while the remaining one originated in Australia. Sixteen studies were from a single institution, while the remaining five were multi-institutional. Of the 21 studies, 10 were prospectively designed, while the remaining 11 were retrospective studies. All studies reported on SIL-RH (Table 1).

Patient Characteristics

The total number of patients enrolled in these studies was 684. In all cases, an informed consent for SIL-RH was taken preoperatively. Nineteen studies reported on the patient gender and 50.2 % of the patients were men. The mean patient age was 64.8 years (21 studies, $n=684$ patients). The mean

preoperative body mass index (BMI) was 26.1 kg/m² (19 studies, $n=640$ patients). Eleven studies ($n=306$ patients) reported on the American Society of Anesthesiology (ASA) score [34], and 78.1 % of the patients had an ASA score ≤ 2 . Data regarding performance of previous abdominal operations were reported in 13 studies ($n=500$ patients), and 36.1 % of the patients had already undergone an abdominal operation before the performance of SIL-RH (Table 2).

The indications for SIL-RH included colon cancer (69 %), colon polyps deemed unresectable by colonoscopy (21.8 %), inflammatory bowel diseases (4.9 %), as well as other colon lesions, including colon lipomas and mucocoele (4.3 %; Table 1).

The contraindications for SIL-RH included the intolerance of pneumoperitoneum, a history of multiple previous abdominal operations, patient's non-compliance, pregnancy, emergency surgery, as well as the presence of a T₄ colon cancer, as staged preoperatively [35].

Intraoperative Outcomes

Mean operative time (OT) was 128.2 min. Mean estimated blood loss (EBL) was exactly reported in 10 studies and was 79 ml. Regarding the surgical approach used, a medial-to-lateral approach was used in 17 studies, while in the remaining 4 studies, a lateral to medial approach was performed. The anastomosis was performed extra-corporeally in 19 studies, either with the use of a stapling device (15 studies) or manually (4 studies) and intra-corporeally with the use of a stapling device in the study from Morales-Conde et al. [23]. The remaining study from Yun et al. [28] did not report on the anastomotic technique performed. Initial skin incision length ranged from 1.5 to 6 cm, with the mean initial length being 2.9 cm. Final skin incision length ranged from 2 to 12 cm, with the mean final length being 3.8 cm (Table 3). Mean conversion rate of SIL-RH was 3.9 %. Conversion was either to conventional ML-RH, to hand-assisted laparoscopic right hemi-colectomy (HAL-RH), or to open right hemi-colectomy (O-RH). The vast majority of conversions were necessitated by technical difficulties (3.3 %), including extensive adhesions, inadequate visualization and/or traction, as well as difficulties regarding the pneumoperitoneum.

Postoperative Outcomes

Mean length of postoperative hospital stay (LOS) was 5.5 days. The mean reoperation rate was reported in 16 studies and was 1.7 %. Regarding the first day after the surgical operation as the first postoperative day, bowel motility return defined as flatus passage, ranged from the first to seventh postoperative day, with a mean value of 2.8 days (Table 4).

Only three studies [27, 28, 30] reported on the follow-up period after SIL-RH, which ranged from 30 days in the study

Fig. 1 Flow chart of literature selection

from Vestweber et al. [30] to 772 days in the study from Velthuis et al. [27]. Data regarding cancer recurrence were reported only in the study from Yun et al. [28], which demonstrated that during a mean follow-up period of 24.5 ± 6.2 months, only 9.1 % of patients experienced cancer recurrence. SIL-RH-associated mortality ranged from 0 to 5.9 %, with the average mortality rate being 0.75 %. The perioperative morbidity rate ranged from 0 to 38 %, with an average value of 15 % (Table 4). Eighty-eight out of 511 patients (16.8 %; range=0–38 %) suffered any kind of complications. In order of descending frequency, postoperative complications included wound-related complications (5.3 %), postoperative ileus (3.5 %), other causes of morbidity (3.3 %), anastomotic leak and/or abscess formation (2 %), cardiac complications (1.6 %), hemorrhage (1 %), and bowel obstruction (0.6 %; Table 5).

Concerning postoperative mortality, a single death was reported by Adair et al. [16], which occurred on the 10th postoperative day due to pulmonary embolism. Waters et al. [20] reported a single death caused by substantial intra-operative

bleeding. A single death also occurred in the study from Velthuis et al. [27], caused by patient's significant comorbidities, while Keshava et al. [32] also reported on a single perioperative death caused by neutropenic sepsis. Haas et al. [31] also reported on a single death on the third postoperative day, caused by respiratory failure in the setting of pulmonary metastasis. Only the single death reported by Waters et al. [20] was firmly associated with the surgical technique of SIL-RH, rendering SIL-RH a safe surgical operation.

Data regarding the magnitude and duration of postoperative pain were reported in only five studies. In the study from Chew et al. [29], a median maximum pain score of 4 was measured (pain score range=2–8), with the median length of narcotic use being 2 days (range 0–3). Lim et al. [15] demonstrated a median pain score of 2 (pain score range=0–10) on the same day of SIL-RH and a pain score of 2 on the first postoperative day, with all patients having no significant pain after the second postoperative day. Papaconstantinou et al. [18], using a visual analogue scale, measured the mean maximum postoperative pain score, which was 4.7 ± 2.0 and $3.8 \pm$

Table 1 Study characteristics and indication for SIL-RH, according to the preoperative work-up and histologic examination

Author	Type of study	Patients (n)	Colon cancer	Colon polyp	Inflammatory bowel disease	Other colon lesions
Ramos-Valadez et al. [13]	Prospective	13	5	7	0	1
Boni et al. [14]	Retrospective	36	32	4	0	0
Lim et al. [15]	Retrospective	7	6	1	0	0
Adair et al. [16]	Retrospective	17	11	4	1	1
Chen et al. [17]	Prospective	18	16	0	0	2
Papaconstantinou et al. [18]	Retrospective	29	15	12	2	0
Lai et al. [19]	Prospective	14	10	0	4	0
Waters et al. [20]	Retrospective	100	57	35	6	2
Ceppa et al. [21]	Retrospective	8	3	5	0	0
Egi et al. [22]	Prospective	9	9	0	0	0
Morales-Conde et al. [23]	Prospective	38	25	12	0	1
Boone et al. [24]	Retrospective	30	17	10	0	3
Mufty et al. [25]	Prospective	25	25	0	0	0
Curro et al. [26]	Prospective	10	10	0	0	0
Velthuis et al. [27]	Prospective	50	41	2	0	7
Yun et al. [28]	Retrospective	66	66	0	0	0
Chew et al. [29]	Retrospective	40	23	9	0	8
Vestweber et al. [30]	Prospective	30	3	16	9	2
Haas et al. [31]	Retrospective	54	25	NR	NR	NR
Keshava et al. [32]	Prospective	75	50	17	8	0
Lin et al. [33]	Retrospective	15	0	NR	0	NR
Mean (excluding the studies from Haas et al. [31] and Lin et al. [33], which did not report on the exact preoperative indications for SIL-RH)	Prospective=10, Retrospective=11	684	424/615 (69 %)	134/615 (21.8 %)	30/615 (4.9 %)	27/615 (4.3 %)

NR not reported

2.1 on the first and second postoperative day, respectively, while on discharge, mean maximum pain score was 1. Lin et al. [33] reported a mean pain score of 2.8 ± 0.9 (pain score scale range=1–10), while Vestweber et al. [30] demonstrated a mean postoperative pain score of 2 (pain score scale range=0–10).

Specimen Outcomes

The length of the resected surgical specimen was reported in nine studies and ranged from 4 to 65 cm, with the mean surgical specimen length being 27.7 cm. Mean number of harvested lymph nodes (LN) ranged from 3 to 62 LN, with an average value of 19.2 LN. Tumor size in its maximum diameter ranged from 0 to 10 cm, with a mean value of 3.6 cm. All resection margins were tumor-free, indicating an R₀ resection in 100 % of patients. The minimum length of tumor-free

resection margins was 3 cm in the study from Lim et al. [15], while the maximum was 43 cm in the study from Yun et al. [28]. As depicted in Table 4, no uniformity was present across studies for the method of reporting the mean length of tumor-free resection margins.

Discussion

Conventional ML-RH has aroused interest among many surgeons since its inception and has gradually become one of the most widely performed surgical procedures in the treatment of colon cancer [3, 24]. ML-RH has been proven as a safe technical alternative to O-RH for patients with colon cancer, in terms of minimal invasion, faster postoperative recovery, and lower rates of wound infection. Moreover, ML-RH can

Table 2 Patient characteristics

Author	Mean age in years (range)	Male/female (% male ratio)	Median ASA score [30] ($\leq 2 > 2$)	Mean preoperative BMI (kg/m ²)	Percentage of patients with prior abdominal operations (%)
Ramos-Valadez et al. [13]	51.2±8.5 (29–61)	7/6 (53.8 %)	2 (9/13–4/13)	27.5±5.4 (17.7–40)	46.2 %
Boni et al. [14]	69±5	NR	NR	NR	36 %
Lim et al. [15]	62	4/3 (57.1 %)	NR (7/7–0/7)	22 (20.1–30)	NR
Adair et al. [16]	66.6±10	5/12 (29.4 %)	NR	26.2±4.3	NR
Chen et al. [17]	69.44	10/18 (35.7 %)	NR (8/18–10/18)	23.34 (18.29–28.6)	NR
Papaconstantinou et al. [18]	60.3±13.6 (33–87)	13/16 (44.8 %)	2 (16/29–13/29)	30±5.9 (22.8–41.7)	34.5 %
Lai et al. [19]	72 (20–90)	4/10 (28.6 %)	2 (12/14–2/14)	24 (21–27)	NR
Waters et al. [20]	63 (25–90)	61/39 (61 %)	2.9 (NR)	28 (18–46)	43 %
Ceppa et al. [21]	69	4/4 (50 %)	NR	NR	NR
Egi et al. [22]	68.5 (61–81)	NR	NR (9/9–0/9)	22.5 (19.6–24.6)	20 %
Morales-Conde et al. [23]	68.39 (45–84)	22/16 (57.9 %)	NR	27.88 (19.81–41.5)	31 %
Boone et al. [24]	66.7±15.8 (16–89)	14/16 (46.7 %)	3 (9/30–21/30)	28.5±6.5 (17.6–43.8)	60 %
Muffy et al. [25]	69 (36–89)	10/15 (40 %)	NR	24.5 (19.1–34.2)	68 %
Curro et al. [26]	60 (38–78)	4/6 (40 %)	NR	25 (24–35)	20 %
Velthuis et al. [27]	73±13.2	21/29 (42 %)	NR (40/50–10/50)	25 (20–32)	22 %
Yun et al. [28]	61±11	33/33 (50 %)	2 (9/7–3 %)	23.8±2.8	19.7 %
Chew et al. [29]	63 (41–84)	22/18 (55 %)	2 (39/40–1/40)	22.3 (16.1–34.9)	5 %
Vestweber et al. [30]	56.1±19.1 (19–89)	15/15 (50 %)	2 (26/30–4/30)	24.7±5.2 (16–39)	NR
Haas et al. [31]	63.6±11.5	27/27 (50 %)	2	27.3±3.9	59.3 %
Keshava et al. [32]	68 (18–99)	35/40 (47 %)	NR	27 (19–42)	NR
Lin et al. [33]	54.5±12.2	10/5 (67 %)	NR	24.9±3.1	NR
Mean	64.8 (21 studies, <i>n</i> =684 patients)	321/318 (50.2 % male) (19 studies, <i>n</i> =639 patients)	ASA score ≤ 2 =239/306 (78.1 %), ASA score > 2 =67/306 (21.9 %) (11 studies, <i>n</i> =306 patients)	26.1 (19 studies, <i>n</i> =640 patients)	36.1 % (13 studies, <i>n</i> =500 patients)

ASA Score American Society of Anesthesiology score, BMI body mass index, NR not reported

Table 3 Intraoperative outcomes

Author	Mean OT (min)	Mean EBL (ml)	Conversion rate (%)	Initial skin incision length in cm (range)	Final skin incision length in cm (range)
Ramos-Valadez et al. [13]	131.5±36.2 (79–180)	<150	15.4 % (to HAL-RH)	3.1±1.1 (2.5–6.0)	2.5
Boni et al. [14]	145±21 (110–172)	NR	0 %	3	2.6±0.4
Lim et al. [15]	90 (60–150)	<20	0 %	1.5–2.0	2 (2.0–2.5)
Adair et al. [16]	139±29.7 (96–215)	NR	12 % (2 EP)	3	NR
Chen et al. [17]	175 (145–280)	75 (20–700)	16.7 %	3	4 (3–6)
Papaconstantinou et al. [18]	128.8±33.2 (53–187)	60.2±37.7 (20–150)	3.4 % (HAL-RH)	NR	4.5±1.3 (2.5–7.0)
Lai et al. [19]	120 (90–135)	NR	0 %	2–3	NR
Waters et al. [20]	114 (64–270)	106 (5–3,000)	6 % (4 O-RH, 2 ML-RH ⁷)	2–3.5	NR
Ceppa et al. [21]	60–120	15	0 %	4	NR
Egi et al. [22]	192 (156–231)	48 (0–110)	0 %	3	3 (2–3)
Morales-Conde et al. [23]	117.42 (75–190)	118.48	0 %	3.25 (2.5–5.2)	NR
Boone et al. [24]	107±26 (65–159)	63.4±79 (10–300)	3.3 % (O-RH)	3.0–4.0	4.0±0.9 (3–6)
Mufty et al. [25]	110 (70–148)	NR	0 %	1.5–2.0	3.5
Curro et al. [26]	170 (135–200)	35 (20–65)	0 %	3 cm	4.3 (3.5–6)
Velthuis et al. [27]	97 (60–148)	NR	4 % (ML-RH)	3 cm	NR
Yun et al. [28]	155±45 (97–455)	NR	1.5 %	2.5–3	3.5 (3–6)
Chew et al. [29]	95 (45–180)	NR	12.5 % (3 EP, 2 O-RH)	NR	5 (3–12)
Vestweber et al. [30]	142.3±55.4 (44–242)	NR	10 %	2.5 cm	NR
Haas et al. [31]	123.5±28.9	56.3±60.4	0 %	2.5	NR
Keshava et al. [32]	NR	NR	1.3 % (O-RH)	3 cm	4.3 (3–6)
Lin et al. [33]	159.1±40.8	34.2±22.1	0 %	2.5–3 cm	3.5±0.6
Mean	Mean OT=128.2 min (20 studies, <i>n</i> =609 patients)	Mean EBL=79 ml (10 studies, <i>n</i> =311 patients)	Mean conversion rate=3.9 % (21 studies, <i>n</i> =684 patients)	Mean=2.9 cm (12 studies, <i>n</i> =358 patients)	Mean=3.8 cm (13 studies, <i>n</i> =373 patients)

OT operative time, EBL estimated blood loss, HAL-RH hand-assisted laparoscopic right hemi-colectomy, NR not reported, EP extra ports, O-RH open right hemi-colectomy

achieve the same degree of oncological radicalness and short-term prognosis as compared with O-RH [36].

Concerning the characteristics of patients enrolled in the present study, it becomes obvious that SIL-RH is feasible even in patients with increased BMI, ASA score ≥ 3 , history of prior abdominal operations, advanced age, as well as for tumors of a large diameter.

Regarding intraoperative outcomes, the mean OT was 128.2 min, with only 6 studies comparing the mean OT between SIL-RH and ML-RH. In all the aforementioned studies, SIL-RH was associated with a shorter mean OT compared with ML-RH, but statistically significant difference was demonstrated only in the study from Velthuis et al. [27] ($p < 0.001$). Concerning EBL, only three studies compared the mean EBL between SIL-RH and ML-RH, without demonstrating any statistically significant difference.

The type of anastomosis following ML-RH is still a matter of debate. A recent Cochrane systematic review [37] reported

that stapled end-to-end ileocolic anastomosis was associated with a lower incidence of leakage compared with a hand-sewn one. However, the marked heterogeneity between the included studies leads to the conclusion that there is no evidence for one procedure being better than the other. Nevertheless, due to the obvious technical complexity of manual anastomosis during laparoscopic surgery, the procedure of choice is the stapled method. Some authors have assessed and demonstrated the feasibility of this type of anastomosis, in terms of safety, recording an incidence of major surgical complications between 2 and 11 % [38–40]. Two meta-analyses [41, 42] have been published so far, comparing intra-corporeal (IA) versus extra-corporeal (EA) anastomosis during ML-RH. The meta-analysis published by Feroci et al. [41] suggested that IA after ML-RH for colon cancer results in better postoperative recovery outcomes, such as shorter LOS, faster bowel movement recovery, faster passage of flatus, faster time to solid diet, and lesser analgesic usage. On the other hand, the meta-analysis

Table 4 Postoperative and specimen outcomes

Author	LOS in days (range)	Pain score	Morbidity rate	Postoperative mortality (30 days) %	Reoperation rate (%)	Bowel movement/ flatus passage in days (range)	Mean length of surgical specimen in cm (range)	Mean number of harvested lymph nodes (LN) (range)	Mean tumor size in its maximum diameter in cm (range)	Mean rate of positive resection margins (%)	Mean tumor-free resection margins in cm (range)
Ramos-Valadez et al. [13]	2.5±0.7 (2–4)	NR	8 %	0 %	0 %	NR	22.1±7 (11–37)	26.7±14.5 (14–47)	NR	0 %	NR
Boni et al. [14]	5±1.2 (4–14)	NR	5 %	0 %	0 %	2	NR	24±7 (15–29)	NR	0 %	8±3 (6–12)
Lim et al. [15]	7 (5–11)	Max pain score=2	14 %	0 %	0 %	NR	NR	24 (20–34)	3.5	0 %	Proximal margin=7 (3–14.5) Distal margin=5 (3.5–12)
Adair et al. [16]	3.9±3.7 (1–18)	NR	29 %	5.9 %	0 %	NR	NR	20.1±11.3 (12–39)	NR	NR	NR
Chen et al. [17]	5 (3–15)	NR	17 %	0 %	0 %	2 (1–7)	NR	19.5 (3–42)	2 (0.5–6)	0 %	16 (5–21)
Papacostantinou et al. [18]	3.4±1.7 (1–8)	Max pain score=4.7±2	20 %	0 %	3 %	NR	NR	16.4±8.3 (4–38)	NR	NR	NR
Lai et al. [19]	3.5 (2–5)	NR	0 %	0 %	NR	NR	23.8 (19.4–30.9)	14.5 (9.8–19.5)	3.9 (2.9–5.5)	0 %	Proximal margin=NR Distal margin=6.6 (4.5–12)
Waters et al. [20]	5 (2–48)	NR	13 %	1 %	1 %	NR	21 (6–65)	18 (11–42)	NR	0 %	NR
Ceppa et al. [21]	5.3	NR	38 %	0 %	0 %	3	NR	17	NR	0 %	NR
Egi et al. [22]	8 (6–13)	NR	0 %	0 %	0 %	NR	NR	15 (3–30)	NR	NR	NR
Morales-Conde et al. [23]	5.2	NR	13 %	0 %	5.2 %	NR	NR	>12 (12–27)	NR	0 %	>5
Boone et al. [24]	6±2 (3–14)	NR	37 %	0 %	NR	2.4±1 (1–7)	20±5.9 (10–27.8)	20±5.2	3.6±2.1 (0.7–7)	0 %	Proximal margin=10.6 Distal margin=7.4
Mufy et al. [25]	7.5	NR	0 %	0 %	0 %	NR	20.9	13.5 (5–19)	3.9	0 %	>3
Curro et al. [26]	6 (5–13)	NR	20 %	NR	0 %	2 (1–4)	NR	25 (18–32)	2.6 (2–4.5)	0 %	Proximal margin=NR Distal margin=15.5 (5–20)
Volthuis et al. [27]	6 (2–41)	NR	34 %	2 %	8 %	NR	26.1±6.9	14 (10–28)	4.8±1.6	0 %	NR
Yun et al. [28]	8±4 (5–27)	NR	9.1 %	0 %	0 %	3±1 (1–7)	NR	24±11 (7–62)	4±2.7 (0–10)	NR	Proximal margin=14.4±8.4 (4–43) Distal margin=16.6±6.2 (6–37)
Chew et al. [29]	5 (4–15)	Max pain score=4	22 %	0 %	0 %	4 (2–6)	19 (8.5–64.5)	19 (10–43)	2.5 (1–7)	0 %	Proximal margin=8.5 Distal margin=6.5
Vestweber et al. [30]	8.4±4 (3–20)	2	NR	NR	NR	NR	20.6±11.9 (4–40)	NR	NR	NR	NR

Table 4 (continued)

Author	LOS in days (range)	Pain score	Morbidity rate	Postoperative mortality (30 days) %	Reoperation rate (%)	Bowel movement/flatus passage in days (range)	Mean length of surgical specimen in cm (range)	Mean number of harvested lymph nodes (LN) (range)	Mean tumor size in its maximum diameter in cm (range)	Mean rate of positive resection margins (%)	Mean tumor-free resection margins in cm (range)
Haas et al. [31]	3.9±2.4	NR	11.1 %	1.9 %	0 %	NR	NR	21.8±9.3	NR	0 %	NR
Keshava et al. [32]	5 (3–43)	NR	11 %	1.3 %	NR	NR	NR	17	NR	0 %	>5
Lin et al. [33]	7.1±3.9	2.8±0.9	0 %	0 %	NR	2.4±0.5	28.9±10.5	NR	2.5±1.3	NR	NR
Mean	Mean LOS=5.5 days (21 studies, n=684 patients)	NA	Mean morbidity=15 % (20 studies, n=654 patients)	Mean mortality=0.75 % (19 studies, n=644 patients)	Mean reoperation rate=1.7 % (16 studies, n=520 patients)	Mean=2.8 days (8 studies, n=223 patients)	Mean=27.7 cm (9 studies, n=252 patients)	Mean=19.2 LN (18 studies ^a , n=601 patients)	Mean=3.6 cm (10 studies, n=275 patients)	Mean=0 % (15 studies, n=518 patients)	NA

LOS length of stay, NR not reported, NA not available, NR not reported, NA not available

^a Excluding three studies [23, 30, 33] which did not exactly report on the mean number of harvested LN

published by Cirocchi et al. [42] failed to solve the controversies between IA and EA anastomosis after ML-RH. Regarding the small number of patients undergoing IA after SIL-RH, no conclusion could be reached regarding the most appropriate type of anastomosis after SIL-RH.

Conversion of a laparoscopic procedure is associated with increased postoperative morbidity [43] as well as LOS [44], compared with planned open procedures. Vettoretto et al. [45] in their meta-analysis found no statistically significant difference in the conversion rate between SIL-RH and ML-RH patients. In the present study, 26 out of 618 patients (3.9 %) required any kind of conversion. In contrast with the homogeneity across the included studies as for the definition of conversion of SIL-RH to ML-RH, HAL-RH or O-RH, no uniformity was present regarding the insertion of an additional port in SIL-RH patients, a state which may be thought of as an intermediate between SIL-RH and ML-RH, concerning the cosmetic outcome as well as the invasiveness of the procedure. At this point, it should be mentioned that conversion should definitely not be regarded as a surgical complication, as patient's safety should be surgeon's uppermost care. Thus, careful preoperative patient selection is of utmost importance [4].

Postoperative gastrointestinal function has been proven to recover earlier in ML-RH compared with O-RH [36]. However, time to oral intake as a measure of recovery of gastrointestinal function is prone to bias, as surgeons with an interest in laparoscopic surgery are likely to feed their patients earlier than those who perform open surgery [46]. Regarding SILC, in 39 cases of multi-institutional studies reviewed [47], average time to flatus and bowel movement was 2.2 and 2.9 days, respectively, a finding also supported by a single other report [48] (postoperative day 2–3 of first flatus). In the present study, there were only a few reports providing relevant data regarding recovery of gastrointestinal function after SIL-RH, defined as flatus passage, with only three studies comparing the median time to flatus passage between SIL-RH and ML-RH, concluding that the two surgical approaches are equivalent in terms of postoperative gastrointestinal function recovery, with no statistically significant difference between them.

Length of hospital stay (LOS), defined as the time passed from the first postoperative day till patient's discharge from hospital, ranged from 1 to 48 days, with the mean value being 5.5 days. Statistically significant decrease in the median LOS between SIL-RH and ML-RH was demonstrated in only two out of seven studies as well as in the meta-analysis from Vettoretto et al. [45]. Moreover, a statistically significant difference was also found between SIL-RH and HAL-RH [18]. These findings are further confirmed by the study from Gandhi et al. [49], which demonstrated that the mean LOS was significantly shorter in SILC than in HALC patients ($P<0.02$).

Although conventional multiport laparoscopic colectomy (MLC) is less invasive than open colectomy (OC) and results in less postoperative pain [50–52], it still requires several

Table 5 Causes of postoperative morbidity in SIL-RH patients

Author	Wound-related complications	Ileus	Anastomotic leak/abscess	Hemorrhage	Bowel obstruction	Cardiovascular complications	Other
Ramos-Valadez et al. [13]	0	0	0	0	0	0	1
Boni et al. [14]	0	1	0	0	0	0	1
Lim et al. [15]	0	0	0	0	0	1	0
Adair et al. [16]	1	2	0	0	0	0	1
Chen et al. [17]	1	1	0	0	0	1	0
Papaconstantinou et al. [18]	5	0	1 (Ro)	0	0	0	0
Lai et al. [19]	0	0	0	0	0	0	0
Waters et al. [20]	3	4	2	3 (1 Ro)	0	0	1
Ceppa et al. [21]	2 (1 Ro)	1	0	0	0	0	0
Egi et al. [22]	0	0	0	0	0	0	0
Morales-Conde et al. [23]	0	0	1 (Ro)	1	1 (Ro)	0	0
Boone et al. [24]	5	0	2	0	2	2	3
Mufty et al. [25]	0	0	0	0	0	0	1
Curro et al. [26]	1	0	1	0	0	0	0
Velthuis et al. [27]	5 (1 Ro)	5	3 (3 Ro)	0	0	1	3
Yun et al. [28]	3	1	1	1	0	0	0
Chew et al. [29]	3	1	0	0	0	3	4
Vestweber et al. [30]	NR	NR	NR	NR	NR	NR	NR
Haas et al. [31]	0	4	1	0	0	1	0
Keshava et al. [32]	1	3	0	1	0	0	2
Lin et al. [33]	0	0	0	0	0	0	0
Mean ^a	30/654 (4.6 %)	23/654 (3.5 %)	12/654 (1.8 %)	6/654 (0.9 %)	3/654 (0.45 %)	9/654 (1.4 %)	17/654 (2.6 %)

Ro reoperation, NR not reported

^a Excluding the study from Vestweber et al. [27], which did not report on postoperative morbidity

incisions for port placement as well as a specimen extraction site, many of which are sited separately on the abdominal wall [52–54]. Only five studies [55–59] reported less postoperative pain after ML-RH than after O-RH, with the difference being statistically significant in three [55, 57, 58] of them. A promising potential advantage of SIL-RH over ML-RH was the expected decrease in the magnitude and duration of postoperative pain. However, as depicted in Table 4, no uniformity was present across the included studies concerning the analgesic requirements and pain evaluation, thus not yielding a definitive conclusion regarding this hot topic in minimally invasive colon surgery.

The primary potential advantage of SILS over MLS is the expected better cosmetic outcome accompanying SILS. The present study demonstrated that the mean length of the final skin incision was greater than the initial one in all reports providing relevant data, with the former being approximately 1 cm greater than the latter one. Moreover, it became obvious that the length of the final skin incision was strongly correlated with the size of the resected colon lesion. The possible cosmetic benefits of SIL-RH should be objectively based on

a cosmetic scale or body image scale, which, so far, nobody has examined after SIL-RH procedures.

Colon cancer is a common and lethal disease. Regarding SIL-RH, approximately 69 % of patients underwent SIL-RH for colon cancer (Table 1). Conventional MLC has been proven to be oncologically equivalent to OC, in terms of recurrence and survival [53, 60–62]. Therefore, any new surgical treatment against colon cancer has to be evaluated in terms of oncological radicalness, compared with MLC, which till nowadays serves as a gold standard [50, 63–66]. In the present study, all resection margins were free from tumor. Regarding the LN harvesting in colon cancer surgery, the International Union Against Cancer, the American Joint Committee on Cancer, and a National Cancer Institute consensus panel have all recommended evaluation of at least 12 LN to ensure adequate sampling [67–69]. Moreover, the College of American Pathologists has, for many years, recommended pathologic examination of at least 12 LN in order to accurately predict node negativity [70]. In the present study, the mean number of harvested LN was 19.2, a result at least adequate in terms of oncological radicalness. Given this fact as well as the findings

from various included studies and a meta-analysis [45], which revealed no statistically significant differences between SIL-RH and ML-RH as for LN harvesting, it becomes obvious that SIL-RH is as safe and equivalent as ML-RH in oncological radicalness and may be performed not only in benign but also in malignant diseases of the right colon.

Concerning the recurrence rate after minimally invasive colon surgery for colon cancer, a recently published meta-analysis from Ding et al. [36] revealed no statistically significant difference between ML-RH and O-RH as for the recurrence rate. Moreover, Yun et al. [28] demonstrated that during a mean follow-up period of 24.5 ± 6.2 months after SIL-RH, only 9.1 % of patients experienced cancer recurrence, without demonstrating any statistically significant difference between SIL-RH and ML-RH patients in terms of recurrence and disease-free survival at 24 months after surgery. However, data regarding the recurrence rate after SIL-RH are sparse, necessitating conduction of further clinical studies evaluating this topic.

For every new technique, safety is the main attribute that has to be respected. Relatively low rates of overall morbidity and mortality were reported in the included studies, with the morbidity being 15 % and the mortality 0.75 %, a finding also supported by the meta-analysis from Makino et al. [71] regarding SILC. Regarding reoperation rate, a total of nine patients were reoperated. In order of descending frequency, the causes leading to reoperation were anastomotic leaks and/or abscess formation, wound-related complications, and finally hemorrhage as well as bowel obstruction with equal frequency. Nonetheless, it is important to emphasize that despite extensive experience of participating surgeons in ML-RH, most surgeons have thus far performed only limited cases of SIL-RH. It is possible that further experience in SIL-RH may improve surgical outcomes in the future.

As with any new technology, associated cost prompts an assessment. Three out of 21 studies reported on the SIL-RH-related cost. Ceppa et al. [21] reported that SIL-RH was associated with a slightly higher cost than ML-RH, with the difference in cost being eliminated by the multiple use of the reusable optical system. Boone et al. [24] concluded that SIL-RH was associated with a 27 % lower mean operative cost and a 10 % lower mean total cost compared with ML-RH. On the other hand, Mufty et al. [25] concluded that SIL-RH was associated with a higher cost than ML-RH, with the single-incision extra port being responsible for the extra cost. In general, the initial increases in operative costs related with laparoscopic techniques are mitigated by the reduction in morbidity and LOS associated with minimally invasive surgery. SILS requires purchase of proprietary access devices and additional equipment in some cases. A lower conversion rate, a shorter postoperative LOS, as well as lower SIL-RH associated morbidity will definitely render SIL-RH more cost-effective.

Conclusion

SIL-RH is associated with relatively low rates of overall morbidity and mortality. SIL-RH is feasible in patients with increased BMI, ASA score ≥ 3 , history of prior abdominal operations, advanced age, as well as for tumors of a large diameter. SIL-RH is as safe and equivalent as ML-RH in postoperative gastrointestinal function recovery and LOS as well as in oncological radicalness and may be performed not only in benign but also in malignant diseases of the right colon.

Conflict of Interest Apostolou KG, Orfanos SV, Papalois AE, Felekouras ES, Zografos GC, and Liakakos T declare that they have no conflict of interest.

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