Single Incision versus Conventional Multiport Laparoscopic Appendectomy: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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Key Words

Single-incision · Laparoscopic · Appendectomy · Systematic review · Meta-analysis

Abstract

Background: The efficacy of single incision laparoscopic appendectomy (SILA) in comparison with conventional multiport laparoscopic appendectomy (CMLA) has not been conclusively determined. **Methods:** A systematic literature review (Medline, EMBASE, Science Citation Index, and Cochrane Central Register of Controlled Trials) was performed. Meta-analyses of randomized controlled trials (RCTs) comparing SILA with CMLA were carried out by RevMan 5.0 software. **Results:** Eleven RCTs comparing SILA and CMLA were included. Overall, 1,216 patients were operated on: 611 cases by SILA versus 605 cases by CMLA. Compared with CMLA, SILA was associated with increased procedural difficulty, prolonged procedural duration, shorter length of hospital stay, earlier return to normal activity and better cosmesis. There were no significant differences in postoperative pain scores and complication rates between SILA and CMLA. **Conclusion:** The current best evidence shows SILA holds the promise of improving postoperative recovery and cosmetic result with equal efficacy and safety, whereas it is associated with higher surgical difficulty with longer surgical time when compared with CMLA.

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Introduction

Conventional multiport laparoscopic appendectomy (CMLA) has gained broad acceptance among general surgeons because of several advantages, such as smaller incision, reduced postoperative pain, less wound infection, more rapid recovery and better cosmetic result when compared with open appendectomy (OA), for both uncomplicated and complicated appendicitis, across the most illness severity groups [1–3]. Therefore, CMLA is recommended as the preferred technique for acute appendicitis.

Since the advent of laparoscopic surgery in the early 1980s, minimally invasive surgery has undergone an accelerated process of evolution. Natural-orifice transluminal endoscopic surgery (NOTES) and single incision laparoscopic surgery (SILS) are two recent surgical innovations [4, 5]. The SILS approach is also known as embryonic natural orifice transumbilical endoscopic surgery (E-NOTES), because instruments are commonly introduced through a single incision blinded in the embryologic scar of the umbilicus. It primarily uses standard laparoscopic instruments through a familiar visual approach and is thus more easily adopted than

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NOTES [6]. Various procedures have been performed through SILS approach [5]. Among them, single incision laparoscopic appendectomy (SILA) is gaining quite an interest in the surgical community. The presumed benefits of SILA include those of CMLA together with reduced surgical trauma, improved postoperative recovery, cosmetic result, and patient satisfaction [7]. However, the efficacy of SILA in comparison with the CMLA has not been conclusively determined. Several trials have been conducted to address the controversy and concerns, yet the sample sizes of those studies are not large enough to produce statistically valid findings. As there is still some controversy with regard to the use of SILA [8] and several new randomized controlled trials (RCTs) are available, we conduct an up-to-date systematic review and meta-analysis to provide the current best evidence on this topic.

Methods

Search Strategies

Relevant studies were identified and selected by searching the databases, including: (1) Medline, EMBASE, Science Citation Index, and Cochrane Central Register of Controlled Trials (updated to June 2014) under the search words 'single incision laparoscopic appendectomy' or 'SILA' or 'single-port access appendectomy' or 'SPAA' or 'single-port laparoscopic appendectomy' or 'SPLA' or 'single-site laparoscopic appendectomy' or 'SSLA' or 'single-site access laparoscopic appendectomy' or 'SSALA' or 'transumbilical single-port laparoscopic appendectomy' or 'TUSPLA' and 'appendectomy' and 'laparoscopy'. (2) A review of reference bibliographies from original research articles and reviews. No language or date limitations were imposed.

Inclusion and Exclusion Criteria

We defined SILA as a laparoscopic appendectomy (applied an intracorporeal appendectomy technique) performed through a single skin incision, regardless of the surgical device used, and CMLA as the standard multi-port laparoscopic appendectomy.

All included studies should be prospective randomized comparative studies of SILA versus CMLA for patients with appendicitis; only the full-text available, peer-reviewed literature was included because it could provide detailed information about the methodology, implementation, and outcome measures to be assessed. All studies should report at least one or more of the outcomes of interest (as specified below). Excluded studies were of NOTES, hand-assisted laparoscopic surgery, gasless laparoscopic surgery, robotic surgery, and laparoscopic-assisted extracorporeal appendectomy surgery. Studies in which the baseline of both groups was serious inequivalence or studies in which outcome data could not be extracted were also excluded.

When multiple articles published by the same team from the same institute within the same study interval were identified, only the latest or the most detailed and informative article, or the one with the best quality in methodology, was included.

Outcomes

Two authors (H.Z. and K.J.) independently extracted the following data from each study: year of publication, study type, the number of patients operated on with each technique, the characteristics of patients, perioperative outcome, and postoperative results. Surgical indications and the inclusion criteria for SILA eligibility were reviewed, as well as the surgical instruments and techniques used for SILA. Two authors (H.Z. and K.J.) recorded data independently and then crosschecked the information.

The following outcomes of interest were recorded and assessed in this meta-analysis: (1) Operative outcomes: conversion rates, operative time; (2) Postoperative morbidity: overall morbidity, wound seroma, wound infection, abdominal abscess, ileus, bleeding, incisional hernia, stump leak, reoperation; (3) Postoperative recovery: length of hospital stay, pain within 24 h from the operation (evaluated by visual analog scale (VAS) from 0 to 10, where 0 indicated no pain and 10 indicated the maximum pain), time to liquid diet (h), time to regular diet (h), day to normal activity, and (4) cosmetic satisfaction (evaluated by satisfaction score from 0 to 10, where 0 indicated no satisfaction and 10 complete satisfaction) and operative charges.

Statistics

Meta-analysis was carried out by Review Manager Version 5.0 (RevMan 5.0) software downloaded from Cochrane Library (<http://ims.cochrane.org/revman/download>). Weighted mean difference (WMD) with 95% confidence intervals (95% CI) was calculated for continuous variables. Odds ratio (OR) with a 95% CI was calculated for categorical variables. Summary WMDs or ORs and their corresponding 95% confidence intervals (CI) were estimated by the fixed effect (Mantel-Haenszel) or random effect (DerSimonian and Laird) models [9]. Tests for heterogeneity were performed with each meta-analysis using the Cochran Q statistic and the I^2 test, with $p < 0.05$ indicating significant heterogeneity. If the test of heterogeneity was statistically significant, then the random effect model was used. To check for publication bias, a funnel plot was constructed. The p value threshold for statistical significance was set at 0.05.

Results

Characteristics of Included Studies

The flow chart for systematic review is shown in figure 1. Twelve Potentially appropriate RCTs comparing SILA and CMLA were identified [10–21]. Among them, one study that applied a laparoscopic-assisted extracorporeal appendectomy technique was excluded [10]. Finally, 11 RCTs comparing SILA and CMLA were included [11–21]. Overall, 1,216 patients were operated on 611 cases by SILA versus 605 cases by CMLA. Patients undergoing SILA and CMLA had similar ages and body mass index. In performing SILA, the surgical techniques were not standardized among the included studies. Conventional port, specialized single-port apparatus, and self-made

Fig. 1. Flow chart for the review.

glove port were used in different studies. Some studies used articulate instruments, while the others used straight instruments (table 1).

Results of Meta-Analyses

Operative Outcomes

The conversion rate to laparotomy was similar in both groups (1.6 vs. 0.7% for SILA and CMLA, respectively; $p = 0.13$); however, in SILA group, 19 patients (3.1%) need add ports or convert to CMLA (table 1). Operative time was significantly longer in the SILA group than in the CMLA group (WMD = 6.62; 95% CI: 3.42–9.82; $p < 0.0001$) (fig. 2).

Postoperative Morbidity

There was no significant difference in overall morbidity, wound seroma, wound infection, abdominal abscess, ileus, bleeding, incisional hernia, stump leak, and reoperation rates between SILA and CMLA (table 2).

Postoperative Recovery

Length of hospital stay was shorter in the SILA group than in the CMLA group (WMD = -0.11 ; 95% CI: -0.22 to -0.01 ; $p = 0.04$). Day to normal activity was significantly shorter in the SILA group than in the CMLA group (WMD = -0.58 ; 95% CI: -1.02 to -0.14 ; $p = 0.01$). There was no significant difference in pain within 24 h after the operation, time to liquid diet, time to regular diet between SILA and CMLA (table 3).

Cosmetic Satisfaction and Operative Charges

Cosmetic satisfaction was significantly higher in the SILA group than in the CMLA group (WMD = 0.76; 95% CI: 0.53–0.99; $p < 0.00001$) (fig. 3). Only one RCT evaluated the costs of SILA and CMLA [21]. Costs were significantly higher for SILA, due to the high price of specialized single-port apparatus and roticulator endograsp instruments.

Fig. 2. Forest plot comparing operative time of SILA versus CMLA.

Table 1. Demographic characteristics of patients as reported in the included studies

Reference	Year	Study design	No. of patients		Age, years		Surgical technique of SILA			Add ports or convert to CMLA		
			SILA	CMLA	SILA	CMLA	Port	Instrument	Appendectomy	SILA	SILA	CMLA
Park et al. [11]	2010	RCT	20	20	25.0	27.2	Glove port	Articulate	Intracorporeal	1	0	0
Vilallonga et al. [12]	2012	RCT	46	41	34.2±13.3	37.7±13.2	SILS port and TriPort	Articulate	Intracorporeal	0	1	0
Teoh et al. [13]	2012	RCT	98	97	39.2±15.6	40.6±15.7	Conventional port	Articulate	Intracorporeal	0	8	3
Frutos et al. [14]	2013	RCT	91	93	28.0±11.0	31.0±12.4	SILS port	Articulate	Intracorporeal	1	0	0
Lee et al. [15]	2013	RCT	116	113	28.4±15.4	28.5±17.2	Octoport	Straight	Intracorporeal	12	0	0
Kye et al. [16]	2013	RCT	51	51	27.6±12.4	29.2±14.0	Glove port	Articulate	Intracorporeal	1	1	1
Perez et al. [17]	2013	RCT	25	25	8.7±0.6	8.9±0.6	Conventional port	NR	Intracorporeal	0	0	0
Pan et al. [18]	2013	RCT	42	42	34.1±14.5	34.9±14.9	Conventional port	Straight	Intracorporeal	2	0	0
Sozutek et al. [19]	2013	RCT	25	25	30.6±12.4	30.0±11.0	SILS Port	NR	Intracorporeal	1	0	0
Carter et al. [20]	2014	RCT	37	38	34.0±11.0	35.0±12.0	SILS Port	Straight	Intracorporeal	1	0	0
Villalobos et al. [21]	2014	RCT	60	60	28.1±9.3	30.0±9.2	SILS Port	Articulate	Intracorporeal	0	0	0
Total		11	611	605						19 (3.1%)	10 (1.6%)	4 (0.7%)

SILA = Single incision laparoscopic appendectomy; CMLA = conventional multiport laparoscopic appendectomy; RCT = randomized controlled trial; NR = not reported.

Fig. 3. Forest plot comparing cosmetic satisfaction of SILA versus CMLA.

Table 2. Meta-analyses of postoperative morbidity

Outcome	No. of study	Experimental events total		Control events total		Analysis mode	Pooled effects (95% confidence interval)	Test for heterogeneity, chi-square test	p	Z test for pooled effect size	p
Overall morbidity	10	61	586	54	580	Fixed	1.13 (0.77, 1.67)	5.04	0.83	0.64	0.53
Wound seroma	3	5	153	2	156	Fixed	2.08 (0.51, 8.46)	0.23	0.89	1.02	0.31
Wound infection	8	18	449	25	446	Fixed	0.71 (0.38, 1.30)	4.37	0.63	1.12	0.26
Abdominal abscess	7	15	407	7	404	Fixed	2.02 (0.86, 4.79)	0.91	0.97	1.61	0.11
Ileus	7	7	407	10	404	Fixed	0.72 (0.29, 1.81)	1.34	0.93	0.70	0.48
Bleeding	2	0	128	2	131	Fixed	0.34 (0.03, 3.27)	0.00	1.00	0.94	0.35
Incisional hernia	8	3	377	0	375	Fixed	4.13 (0.46, 37.39)	0.05	0.82	1.26	0.21
Stump leak	1	0	116	1	113	Fixed	0.32 (0.01, 7.98)	NA		0.69	0.49
Reoperation	4	0	292	2	291	Fixed	0.33 (0.03, 3.19)	0.00	0.98	0.96	0.34

NA = Not available.

Table 3. Meta-analyses of postoperative recovery

Outcome	No. of study	Experimental events	Experimental total	Control events	Control total	Analysis mode	Pooled effects (95% confidence interval)	Test for heterogeneity, chi-square test	p	Z test for pooled effect size	p
Length of hospital stay	11	NA	611	NA	605	Fixed	-0.11 (-0.22, -0.01)	7.17	0.41	2.10	0.04
Day to normal activity	3	NA	186	NA	186	Fixed	-0.58 (-1.02, -0.14)	2.85	0.24	2.59	0.01
Pain within 24 h	6	NA	310	NA	308	Random	-0.06 (-0.61, 0.48)	40.72	<0.00001	0.22	0.83
Time to liquid diet	4	NA	151	NA	146	Fixed	0.01 (-0.32, 0.34)	0.41	0.81	0.06	0.95
Time to regular diet	1	NA	98	NA	97	Fixed	-19.00 (-44.83, 6.83)	NA		1.44	0.15

NA = Not available.

Fig. 4. Publication bias funnel plot for wound infection.

Heterogeneity

Significant heterogeneity was found among included studies with respect to operative time and pain within 24 h after the operation.

Publication Bias

We assessed the publication bias based on the results of wound infection. The funnel plot was symmetric and this indicated that no evidence of publication bias existed in the included studies (fig. 4).

Discussion

SILS represents a new advance in minimally invasive surgery and has been applied to several abdominal operations with the main aim to reduce the trauma of surgical access and to improve cosmetic results [5]. SILS has also been used for the treatment of acute appendicitis, despite the lack of consensus that this approach is an appropriate alternative to CMLA [8].

SILA is indeed more technically demanding than CMLA at present. Our results showed that the operative time was significantly longer in the SILA group than in the CMLA group. Difficulties are related to the lack of triangulation, to the clashing of instruments, and to the handling of curved instruments by crossing them as in a mirror image [22]. Although the conversion rate to laparotomy was similar in both groups (1.6 vs. 0.7% for SILA and CMLA, respectively), 19 patients (3.1%) needed add ports or converted to CMLA in the SILA group. If we consider the port addition as a procedure failure, then the procedural failure rate for SILA is significantly higher

than for CMLA (4.7 vs. 0.7% for SILA and CMLA, respectively), which is in accordance with the results of single incision laparoscopic cholecystectomy (SILC) [23]. Improvements in instrumentation and ergonomics, such as a flexible endoscope or single-site robotic platform will allow both the resolution of these problems and a wide diffusion of SILA, as well as other SILS surgeries [24, 25]. In addition, with the experience cumulating, complicated cases such as obesity or abnormal anatomical locations can be accomplished successfully and safely [26, 27].

There were no significant differences in postoperative wound infection, abdominal abscess, ileus, bleeding, stump leak, and reoperation rates between SILA and CMLA. Perhaps, delicate surgical techniques, such as high-quality diagnostic examination of the entire peritoneal cavity, adequate appendicular vessel and stump management, and accurate peritoneal irrigation were more important regardless of the specific laparoscopic technique used.

A big concern of SILA is that the increased length of the fascial incision to insert a multiport device may result in an increased incidence of incisional hernia. The prevalence of incisional hernia was 0.8% in the SILA group versus 0.0% in the CMLA group, without statistically significant difference. However, this result must be approached with caution because of the too-short follow-up of the included studies. It is rational that direct suturing of the fascial defect and avoiding wound infection should be mandatory and might reduce the rate of incisional hernia [28].

The length of hospital stay and day to normal activity were shorter in the SILA group than in the CMLA group according to the present meta-analysis. However, caution should be given that the evaluation of normal activ-

ity was not clearly defined in the original studies, and subjective bias might exist. Although some authors argued that the longer fascial incision and the greater wound irritation due to the insertion of all surgical instruments through one skin incision may increase the intensity of pain sensation in the SILA group, it was not evident in the present meta-analysis. However, it should be noted that statistically significant heterogeneity was found among included studies with respect to pain within 24 h after the operation, which may be due to the heterogeneity of surgical technique and postoperative analgesia management among included studies. Cosmetic satisfaction was significantly higher in the SILA group than in the CMLA group. A single incision at the umbilicus is typically performed vertically and hidden in the normal groove of the umbilicus, which leads to a good cosmetic result. However, drawing a conclusion about cosmetic results is not easy, as the satisfaction score may be age and sex related and must be verified by a long-term follow-up [29].

The main limitation of our investigation is the heterogeneity of included studies. For example, different clinical conditions (acute or chronic, mild or severe appendicitis) were included, and the SILA procedures were not standardized among included studies.

In conclusion, the current best evidence shows SILA holds the promise of improving postoperative recovery

and cosmetic result with equal efficacy and safety, whereas it is associated with higher surgical difficulty with longer surgical time when compared with CMLA. Because of the heterogeneity of included studies, methodologically high-quality comparative studies are needed for further evaluation when mature and standardized SILA technique is available.

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Author Contribution

Haiyang Zhou and Zhiqian Hu designed study. Haiyang Zhou, Kaizhou Jin, Jian Zhang, Weijun Wang, Yanping Sun, and Canping Ruan collected and analyzed data. Haiyang Zhou wrote the draft. Kaizhou Jin, Jian Zhang, Weijun Wang, Yanping Sun, Canping Ruan, and Zhiqian Hu revised it critically. All the authors approved the version to be published.

Disclosure Statement

None.

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