

Single-incision robotic cholecystectomy versus single-incision laparoscopic cholecystectomy

A systematic review and meta-analysis

Ning Sun, MD, Jia Lin Zhang, MD*, Cheng Shuo Zhang, MD, Xiao Hang Li, MD, Yue Shi, MD

Abstract

Background: Single-incision laparoscopic cholecystectomy (SILC) is the result of the ongoing trend to minimally invasive of laparoscopy, but some surgeons thought that the SILC can increase the risk of bile duct injury or bile spillage, and the single-incision robotic cholecystectomy (SIRC) can overcome the drawbacks of SILC. Some articles described that the SIRC had longer operative time and more cost than SILC. The advantages and disadvantages of SIRC have still not been extensively studied. We aimed to investigate the outcomes of SIRC compared to SILC and evaluate the safety and feasibility of SIRC.

Methods: To find relevant studies, the electronic databases PubMed, MEDLINE, The Cochrane Library, and EMBASE were searched to seek information in English literature from 2011 to 2017. Studies comparing SIRC to SILC, for any indication, were included in the analysis. This systematic review and meta-analysis were performed with RevMan Version 5.3.

Results: Six comparative studies (n=633 patients) were included in our analysis. The data showed that the SIRC and SILC had equivalent outcomes for operative time [mean difference (MD)=17.32, 95% confidence interval (CI): -8.93–43.57, $P=.20$], intraoperative complications [odds ratio (OR)=0.48, 95% CI: 0.17–1.39, $P=.18$], postoperative complications (OR=0.62, 95% CI: 0.21–1.86, $P=.39$), hospital stay (MD=-0.01, 95% CI: -0.21–0.19, $P=.90$), readmissions rate (OR=0.70, 95% CI: 0.09–5.63, $P=.74$), and conversion rate (OR=0.52, 95% CI: 0.14–1.96, $P=.33$), but total cost was statistically significant (MD=3.7, 95% CI: 3.61–3.79, $P<.00001$).

Conclusion: SIRC is a safe and feasible procedure for cholecystectomy, and the operative time is same as SILC, but the total cost of SIRC is significantly higher than SILC.

Abbreviations: CI = confidence interval, MD = mean difference, NTD = New Taiwan dollar, RCT = randomized control trial, SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

Keywords: meta-analysis, single-incision laparoscopic cholecystectomy, single-incision robotic cholecystectomy

1. Introduction

Conventional laparoscopic cholecystectomy is considered the criterion standard for cholecystectomy,^[1,2] which has been proved to be safe and effective, but increasing patients demand for less invasive and cosmetic purposes have led to the development of reduced-port laparoscopic cholecystectomy. Single-incision laparoscopic cholecystectomy (SILC) is the result

of the ongoing trend to minimally invasive of laparoscopy and has emerged as a new technical concept to improve cosmetic.^[3–5] However, some studies found that the SILC increased the complexity of the surgery and the risk of bile duct injury or bile spillage.^[6,7]

Recently, single-site robotic surgical system, the da Vinci Si Surgical System (Intuitive Surgical inc, Sunnyvale, CA) has been introduced to improve upon the advantages of minimally invasive surgery of the gallbladder.^[8,9] Although there are already many studies that described the successful experiences with the robotic single-site system when used for cholecystectomy procedures, some articles described that the robotic procedure involves a longer operative time and more cost.^[10,11] Until now, the advantages and disadvantages of single-incision robotic cholecystectomy (SIRC) have not been extensively studied. The aim of our study was to investigate the outcomes of SIRC compared to SILC and evaluate the safety and feasibility of SIRC.

2. Materials and methods

2.1. Literature search

Relevant randomized control trials (RCTs) and comparative studies about SIRC and SILC were identified. To find relevant studies, the electronic databases PubMed, MEDLINE, The Cochrane Library, and EMBASE were searched to seek information in the English literature from 2011 to 2017. The

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search term included “single-incision robotic cholecystectomy” (or “single-site robotic cholecystectomy”) and “single-incision laparoscopic cholecystectomy” (or “single-site laparoscopic cholecystectomy”) or “one wound laparoscopic cholecystectomy” or “one incision laparoscopic cholecystectomy”). Literatures were examined to identify appropriate articles, and redundant literatures were finally removed. In our study, review of full-text articles and quality assessment were carried out by 2 reviewers, and a third reviewer was available to adjudicate on any conflicts arising between the 2 reviewers.

2.2. Selection criteria

Inclusion criteria were the selection criteria included all studies were comparing SIRC with SILC, and including at least one outcome of interest, such as operative time, intraoperative complications, postoperative complications, readmissions rate, hospital stay, and total cost. Exclusion criteria were only 1 treatment method (SILC or SIRC) was used and no contrastive study was performed; data could not be used for statistical analysis. Because the data included in our study were extracted from published literatures, no approval was required from the institutional review board and patient consent was not necessary.

2.3. Data extraction

All data were extracted and assessed independently; all authors discussed the differences in opinion and reached a consensus. The following outcomes were evaluated: operative time (min),

intraoperative complications, postoperative complications, readmissions rate, conversion rate, hospital stay (day), and total cost. Operative time was defined as the time calculated from skin incision to skin closure.

2.4. Statistical analysis

This systematic review and meta-analysis was performed with RevMan Version 5.3. A P value of .05 was applied as criterion for statistical significance. The mean differences (MDs) with 95% confidence interval (CI) of the continuous data were calculated. The pooled relative risk was performed using the Mantel-Haenszel method. Odd ratios (ORs) and weighted mean difference with 95% CI were calculated to describe the results of dichotomous outcomes. The χ^2 test and I^2 statistics were used to assess heterogeneity with $P \leq .05$ or $I^2 > 50\%$ were considered as significant heterogeneity.^[12] When the hypothesis of homogeneity was not rejected, the fixed effects model was used to estimate the cases with homogeneity, and the random effects model was used for the cases with significant heterogeneity.

2.5. Quality assessment

The Newcastle-Ottawa scale for assessing the quality of nonrandomized studies in our meta-analysis was applied to evaluate the quality of comparative studies.^[13] The total score for this assessment tool ranged from 0 to 9. No studies were excluded based on the quality score. Studies with a score of ≥ 5 were considered as of higher quality.^[14]

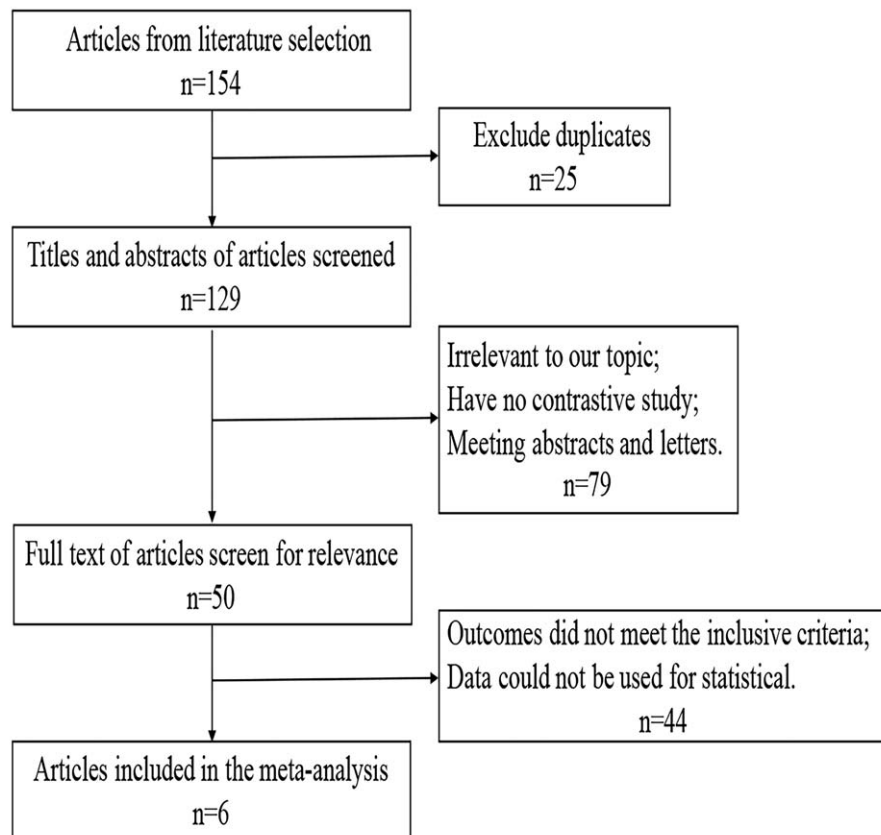


Figure 1. Selection of the studies included in the meta-analysis.

Table 1**Basic study and patient characteristics.**

Ref.	Year	Sample size		Mean age, yr		Sex (male/female)		BMI, kg/m ²		Score (NOS)
		SIRC	SILC	SIRC	SILC	SIRC	SILC	SIRC	SILC	
Spinoglio et al ^[15]	2012	25	25	54.2±17.1	52.5±17.9	5/20	3/22	23.7±3.9	24.5±4.7	4
Gonzalez et al ^[16]	2013	166	166	51.6±15.9	44.5±14.3	35/131	37/129	29.4±6.2	29.1±5.6	4
Buzad et al ^[17]	2013	20	10	47.8±14.9	43.3±13.7	7/13	0/10	27.1±4.7	28.4±6.2	5
Lee et al ^[10]	2015	5	20	37.6±9.4	44.4±12.8	1/4	5/15	21.9±2.1	23.1±2.4	5
Su et al ^[11]	2016	51	63	53.64±15.54	50.94±13.79	18/33	23/40	23.6±3.8	24.6±3.11	5
Gustafson ^[18]	2016	38	44	48±14	45±15	8/30	10/34	30±5	26±4	5

BMI = body mass index, NOS = Newcastle-Ottawa scale SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

2.6. Risk of bias

The Newcastle-Ottawa scale was used to assess the quality of nonrandomized cohort studies. Funnel plots were constructed to assess the risk of publication bias across the series for all outcome measures.

3. Results

3.1. Summary of the literature search

There were 154 studies published between 2011 and 2017, 25 articles were excluded because they were duplicates, and 79 articles were excluded after we reviewed the titles and abstracts, 50 studies were considered to be potentially eligible, but after we retrieved the full-text, 44 studies were excluded because they did not meet the inclusion criteria (Fig. 1). Finally, we evaluated 6 comparative studies and included in our analysis, with a total of 633 patients. All comparative studies were retrospective, 4 studies scored 5 points and 2 studies scored 4 points (Table 1).

3.2. Patient selection and preoperative diagnosis

In the 6 studies, patient characteristics included sex, age, and body mass index (Table 1). Preoperative diagnosis is listed in Table 2.

3.3. Operative time (min)

There were significant heterogeneity in the 5 studies combined^[10,11,15-17] ($I^2=97%$), so in the random effects model, the operative time in SIRC and SILC groups were similar (MD = 17.32, 95% CI: -8.93-43.57, $P=.20$) (Fig. 2A).

3.4. Intraoperative complications

There were no heterogeneity ($I^2=0%$) revealed in the 4 studies,^[10,11,15,17] and in the fixed effects model, no significant difference between SIRC and SILC groups was detected (OR = 0.48, 95% CI: 0.17-1.39, $P=.18$) (Fig. 3A).

3.5. Postoperative complications

There were 6 studies that reported postoperative complications,^[10,11,15-18] and no heterogeneity was detected ($I^2=0%$). In the fixed effects model, no significant difference between SIRC and SILC groups was detected (OR = 0.62, 95% CI: 0.21-1.86, $P=.39$) (Fig. 4A).

3.6. Hospital stay (day)

The I^2 statistics revealed no heterogeneity in the 4 studies^[10,11,15,16] ($I^2=0%$) and in the fixed effects model, we found

Table 2**Preoperative diagnosis of patients.**

	Preoperative diagnosis	SIRC	SILC	P
Spinoglio et al ^[15]	Symptomatic gallstones	23	2	—
	Polyps	23	2	
Gonzalez et al ^[16]	Symptomatic cholelithiasis	27	133	.203
	Acute cholecystitis	20	11	
	Biliary dyskinesia	7	14	
	Gallbladder polyps	4	8	
	Biliary pancreatitis/choledocholithiasis	8	3	
Buzad et al ^[17]	Acute cholecystitis	2	—	.129
	Biliary pancreatitis	1	—	
	Gallbladder polyps	1	—	
	Chronic cholecystitis	16	10	
Lee et al ^[10]	Gallbladder stone	2	11	.644
	Gallbladder polyps	2	4	
	Adenomyomatosis	1	5	
Su et al ^[11]	Gallbladder stone	33	37	.751
	Gallbladder stone with acute cholecystitis	10	15	
	Gallbladder polyp	8	15	
Gustafson et al ^[18]	NR	—	—	—

SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

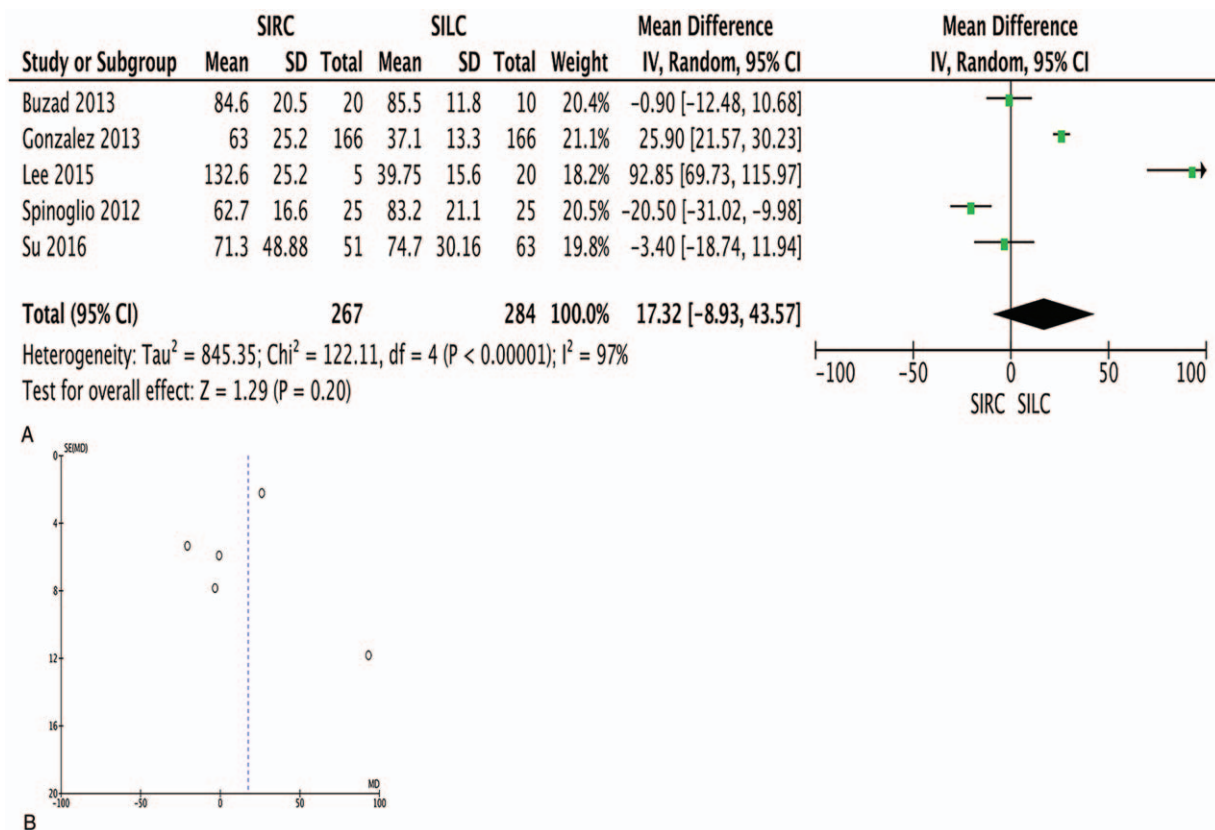


Figure 2. Operative time (min). A, Forest plot. B, Funnel plot. CI = confidence interval, SD = standard deviation, SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

that the length of hospital stay in the SIRC and SILC groups was similar (MD = -0.01, 95% CI: -0.21–0.19, $P = .90$) (Fig. 5A).

3.7. Readmissions rate

A total of 3 studies evaluated the readmissions rate.^[15–17] There was no heterogeneity detected ($I^2 = 0\%$), and the fixed effects model showed that the readmissions rate was not significantly different between SIRC and SILC groups (OR = 0.70, 95% CI: 0.09–5.63, $P = .74$) (Fig. 6A).

3.8. Conversion rate

There were 5 studies that reported conversion rate,^[10,11,15,17,18] and there was no heterogeneity detected ($I^2 = 0\%$) and no significant difference between the 2 groups was detected by the fixed effects model (OR = 0.52, 95% CI: 0.14–1.96, $P = .33$) (Fig. 7A).

3.9. Total cost

Only the studies by Su et al^[11] and Gustafson et al^[18] reported the cost of SIRC and SILC.^[11,18] The I^2 statistics revealed no heterogeneity in the 2 studies, and in the fixed effects model, the data shown significant difference between 2 groups (MD = 3.7, 95% CI: 3.61–3.79, $P < .00001$) (Fig. 8).

3.10. Publication bias

In our analysis, only funnel plot of operative time revealed asymmetry, because of the operative time of SIRC was more

longer in Lee et al's^[10] study than others (Fig. 2B). Funnel plots were constructed for intraoperative/postoperative complications, hospital stay, readmissions rate, and conversion rate, which showed symmetry, suggesting that the funnel plots for publication bias did not exhibit asymmetry (Figs. 3–7B). Thus, no evidence of publication bias was detected except for operative time. In addition, because there were only 2 studies about total cost in our data, we did not calculate its publication bias.

4. Discussion

Although conventional laparoscopic cholecystectomy is considered the standard treatment for gallbladder diseases, the latest evolution in cholecystectomy is single-incision surgery. Many surgeons who tested SILC and published their experience suggested that the surgical procedure was safe and effective,^[19–22] whereas the others pointed out that there were still some limitations and drawbacks in this technique, such as the narrow working space, a longer operative time, a lack of triangulation, and more intraoperative complications.^[23–25] Some surgeons thought that the da Vinci Single-site Surgical System can overcome these limitations of SILC, because the robotic single-site instruments allow the surgeon to associate their hands with the instrument tips regardless of the robotic arm that holds the instrument; provided a 10 times magnified, stable, and high-definition 3-dimensional images, and tremor suppression,^[26–29] which avoid biliary and artery damage during operation. Therefore, for single-incision cholecystectomy, although some articles compared the outcomes between SIRC and

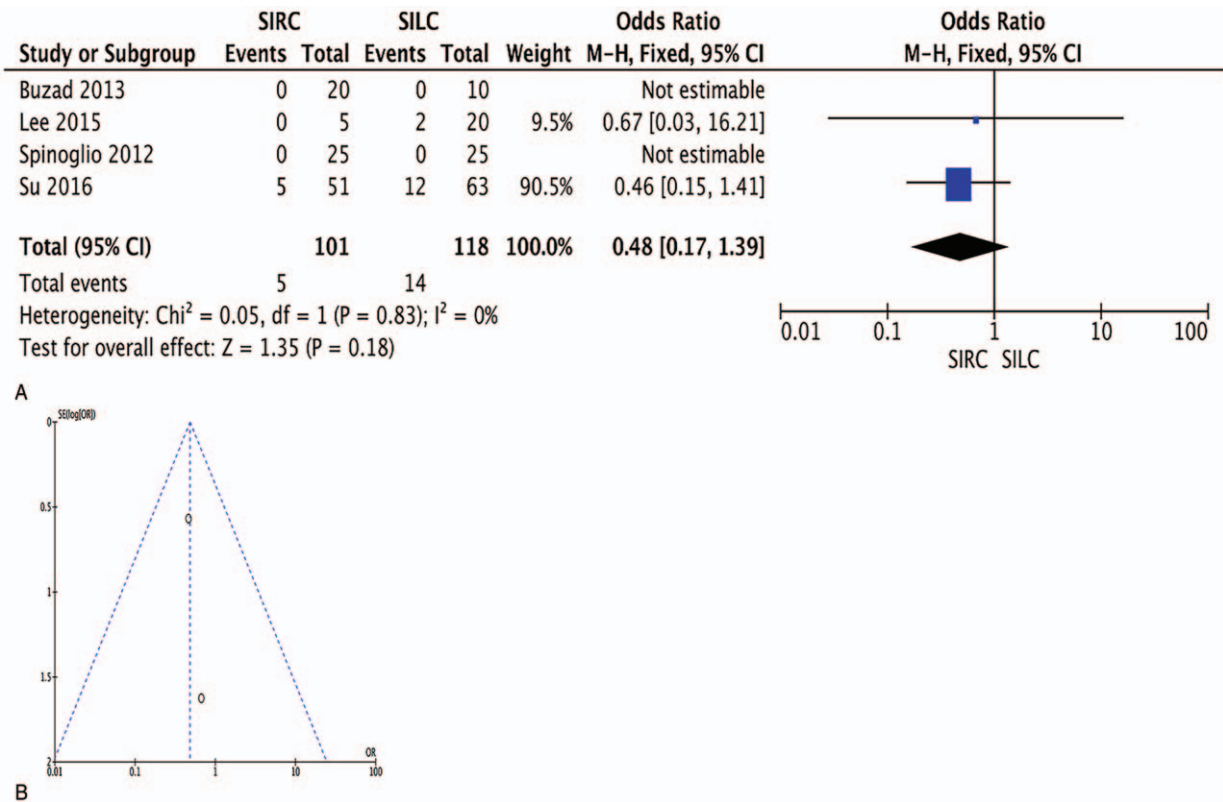


Figure 3. Intraoperative complications. A, Forest plot. B, Funnel plot. CI = confidence interval, SD = standard deviation, SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

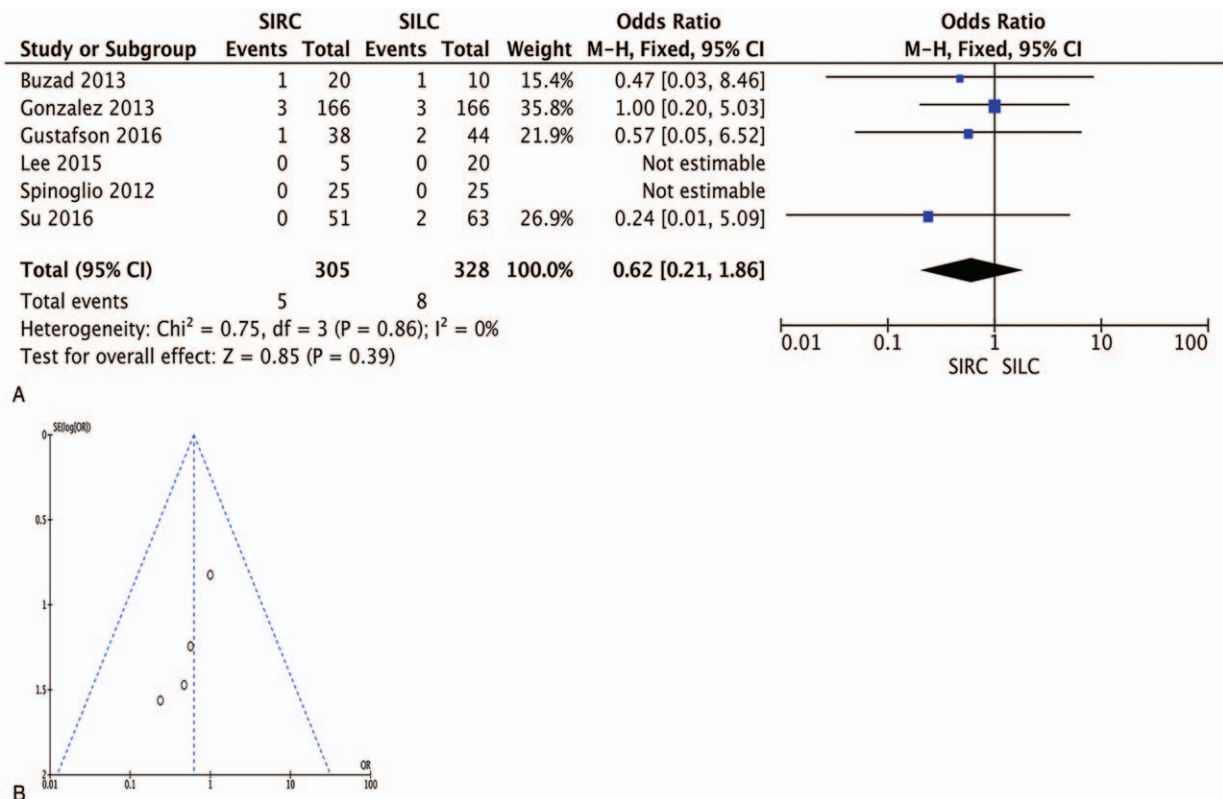
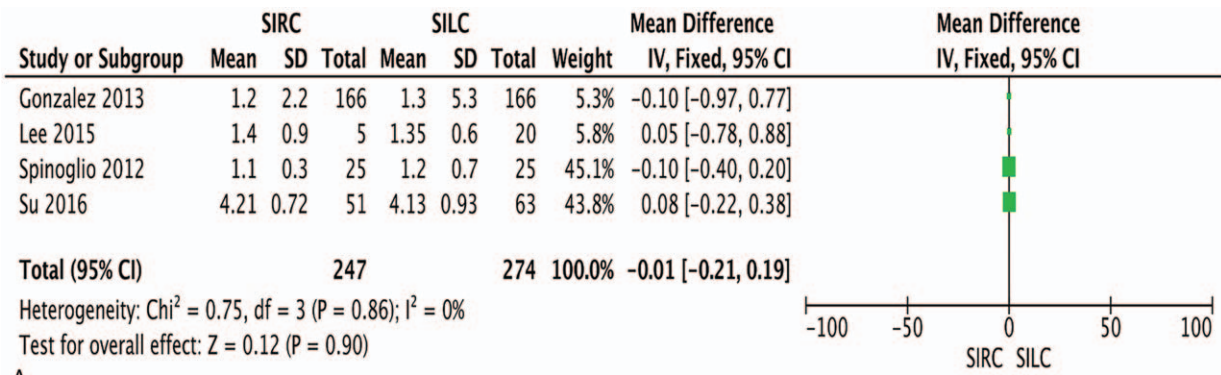
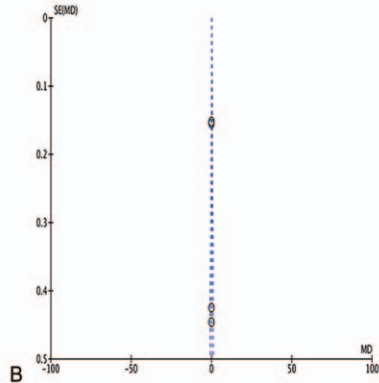


Figure 4. Postoperative complications. A, Forest plot. B, Funnel plot. CI = confidence interval, SD = standard deviation, SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

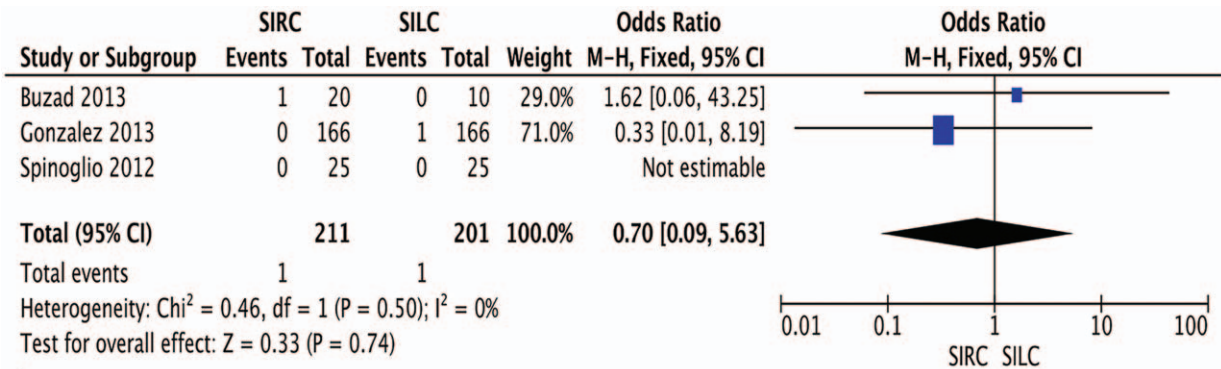


A

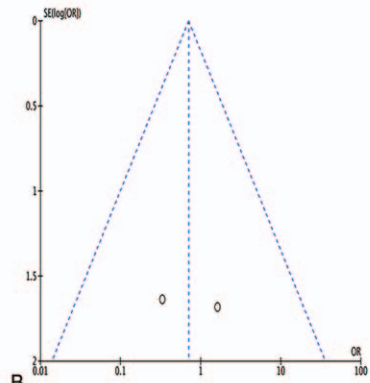


B

Figure 5. Hospital stay (day). A, Forest plot. B, Funnel plot. CI = confidence interval, SD = standard deviation, SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.



A



B

Figure 6. Readmissions rate. A, Forest plot. B, Funnel plot. CI = confidence interval, SD = standard deviation, SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

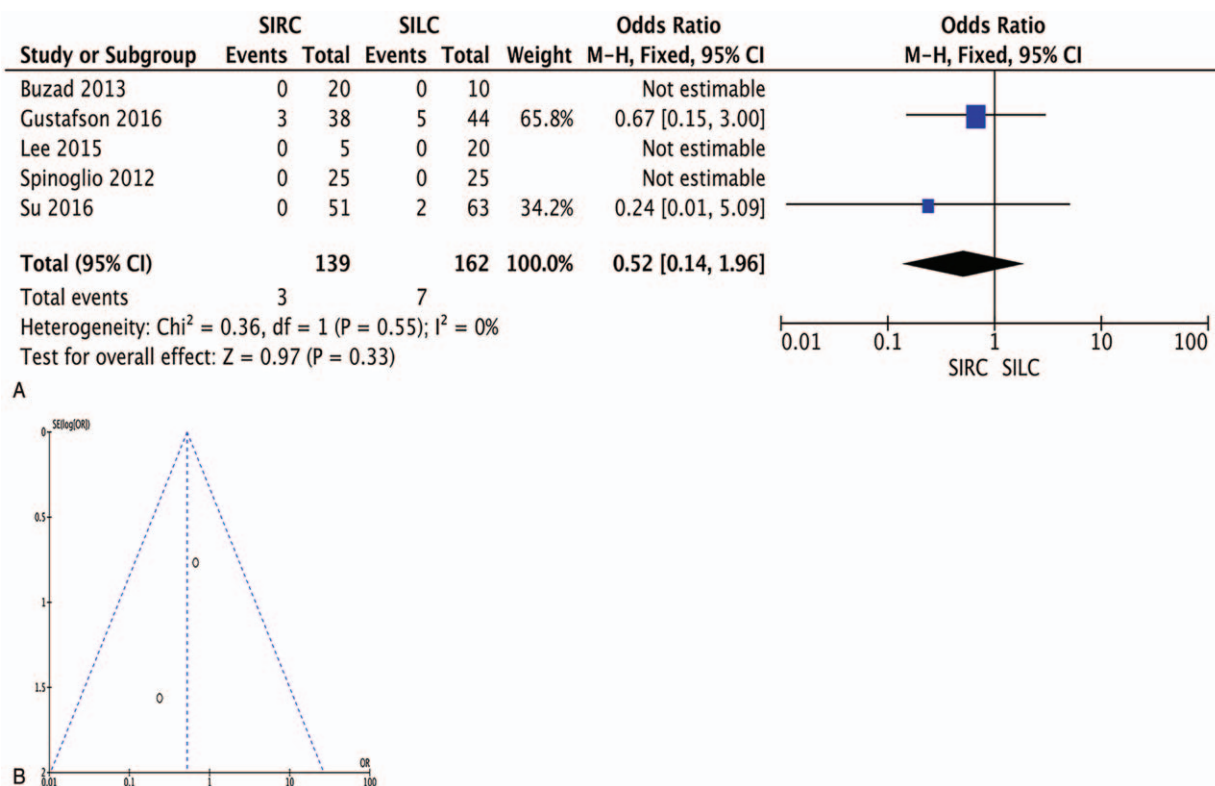


Figure 7. Conversion rate. A, Forest plot. B, Funnel plot. CI = confidence interval, SD = standard deviation, SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

SILC, but whether SIRC is better than SILC, there is still controversy.

In our systematic review we evaluated the included 6 studies with a total of 633 patients to assess safety and feasibility of SIRC. Spinoglio et al's^[15] study reported that the operative time taken in SILC was significantly longer than SIRC, but in Lee et al's^[10] study the operative time in SILC was significantly shorter than SIRC. In our results, the operative time (skin to skin) for SIRC was similar to the SILC. In addition, some surgeons thought SILC increased the risk of intraoperative and postoperative complications such as bile duct injury during operation or bile leakage after operation, and the SIRC can avoided those

complications. Indeed, Lee et al's^[10] and Su et al's^[11] studies found that in SILC group there are some cases of bile spillage and bile leakage, but in their articles there were no significant differences. Sometimes patients' disease also has some impacts on intraoperative or postoperative complications, such as acute cholecystitis can cause obvious edema in local tissues, and increase the risk of intraoperative or postoperative bile leakage; chronic cholecystitis can cause local tissue adhesion, and increase the risk of intraoperative or postoperative bile injure. In Table 2, we list all the preoperative diagnosis of SIRC group and SILC group of the 6 studies, but all of these have no significant difference. In our data, for the intraoperative complications and postoperative

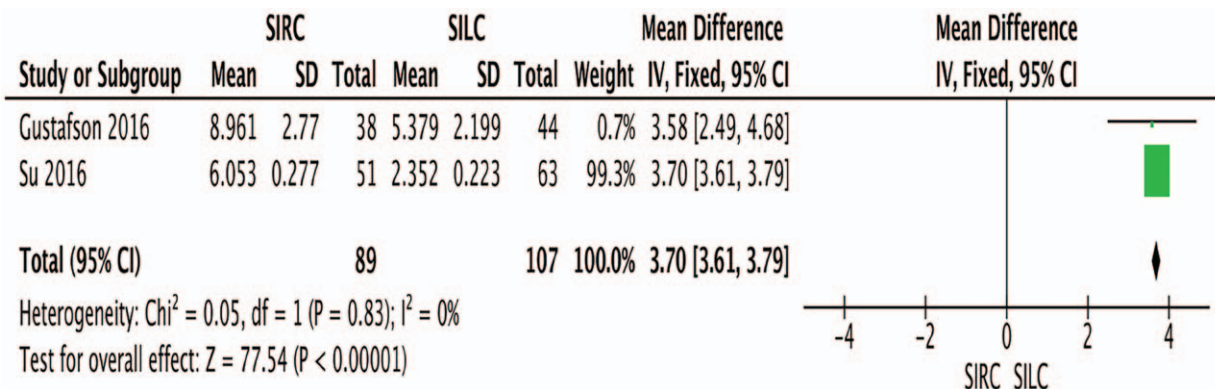


Figure 8. Total cost. Forest plot. CI = confidence interval, SD = standard deviation, SILC = single-incision laparoscopic cholecystectomy, SIRC = single-incision robotic cholecystectomy.

complications, there were still no obvious differences between SIRC and SILC groups, there was no statistical significance, which means that SIRC did not decrease the risk of intraoperative and postoperative complications. Meanwhile, in our analysis, there was no significant difference in readmissions rate, hospital stay, and conversion rate between the 2 groups; SIRC has similar outcomes as SILC.

Medical cost is an important factor for SIRC, because surgical value is defined as outcome divided by cost. Su et al^[11] reported that the total costs of SIRC was significantly higher than SILC, 196,543 vs 76,387 New Taiwan dollars (NTD), which approximately amount to 6053.53 vs 2352.72 US dollars (USD) (1 USD=32.4675 NTD). Gustafson et al^[18] reported that the higher total costs of SIRC was attributed to the higher fixed cost, and the indirect cost (such as increased operative time). All these data revealed that SIRC was more expensive than SILC, and the surgical value seems higher in the SILC group.

In our analysis, we have some weaknesses: first, all the studies were nonrandomized and comparative, we could not completely exclude publication bias (In Lee's study the operative time of SIRC group was more longer than SILC group, which led to publication bias in operative time.), so we still need more powerful randomized trials to be investigated; second, in some studies, calculated operative time of the SIRC groups included docking time and console time, which prolonged the operative time potentially, so we suggested that in future research, surgeons can calculate the pure surgical dissection time (calculate the time from the dissection of Calot's triangle to the retrieval of the specimen or the time from skin incision to skin closure) in SIRC and SILC, which can make comparison more meaningful; third, we hope in the future, the cost analysis can be included in more researches.

In conclusion, SIRC is a safe and feasible procedure for cholecystectomy, and the outcomes as same as SILC. However, the total cost of SIRC shows significantly higher than SILC. We thought the higher costs would be the proof of clinically relevant benefits for the patients, such as shorter operative time, less complications, or shorter hospital stay, which is a prerequisite for the implementation of this technology in surgery. Obviously, in our analysis, the robotic surgery does not seem to offer additional clinical benefit in terms of cholecystectomy. In the future, we still need more well-designed RCTs with high-quality evidence to confirm the clinical benefits of SIRC.

Author contributions

Data curation: Ning Sun, Cheng Shuo Zhang, Xiao Hang Li.

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Investigation: Ning Sun, Jia Lin Zhang.

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Resources: Yue Shi.

Software: Ning Sun, Cheng Shuo Zhang, Xiao Hang Li, Yue Shi.

Supervision: Jia Lin Zhang, Xiao Hang Li.

Validation: Jia Lin Zhang.

Writing – original draft: Ning Sun.

Writing – review and editing: Jia Lin Zhang.

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