



Laparoscopic versus robotic cholecystectomy: a systematic review with meta-analysis to differentiate between postoperative outcomes and cost-effectiveness

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Background: Robotic cholecystectomy (RC) has shown promising outcomes in multiple studies when compared with the gold standard laparoscopic cholecystectomy (LC). The objective of this study is to compare the postoperative surgical outcomes and cost in patients undergoing RC versus LC.

Methods: Studies reporting postoperative outcomes and costs in patients undergoing RC versus LC were selected from medical electronic databases and analysis was conducted by the values of systematic review on the statistical software RevMan version 5.

Results: Six trials on 1,013 affected individuals for post-operative outcomes and cost comparison were used. Random effect model analysis was used in the analysis. Duration of operation (mean difference: -10.23, 95% CI: -16.23 to -4.22, $Z=3.34$, $P=0.0008$) was shorter in the LC group with moderate heterogeneity. Bile leak (odds ratio: 3.34, 95% CI: 0.85 to 13.03, $Z=1.73$, $P=0.08$) and no heterogeneity was seen, Postoperative complications (odds ratio: 1.49, 95% CI: 0.50 to 4.46, $Z=0.72$, $P=0.47$) with moderate heterogeneity. Both were statistically similar. LC had reduced cost (standardised mean difference: -7.42, 95% CI: -13.10 to -1.74, $Z=2.56$, $P=0.01$) with significant heterogeneity.

Conclusions: RC failed to prove any clinical advantage over LC for postoperative outcomes including longer duration of operation moreover LC was more cost effective. Due to the paucity of randomised control trial (RCT) and significant heterogeneity, a major multicentre RCT is required to strengthen and validate the findings.

Keywords: Single-site robotic cholecystectomy (SSRC); laparoscopic cholecystectomy (LC); postoperative outcome; cost comparison

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Introduction

One of the most common causes of surgical admissions is due to cholecystitis in any hospital. Acute cholecystitis is defined as an inflammation of the gall bladder usually due

to obstruction of the biliary tree or incomplete emptying of the gall bladder (1). The annual incidence of acute cholecystitis in the USA alone is 200,000/year (2). The global prevalence of gallstones is around 10–15% and 10–15% of these patients primarily present with acute

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cholecystitis (3). There is also a substantial overall mortality (0.9%) and morbidity (17.8%) linked to cholecystectomy (4).

Acute cholecystitis is that stage in cholecystitis which can last up to 10 days, usually followed by sub-acute cholecystitis and chronic cholecystitis. Primary surgical treatment for acute cholecystitis can be subcategorized as an emergency or hot cholecystectomy or an elective or delayed cholecystectomy (5). Laparoscopic cholecystectomy (LC) is a minimally invasive procedure, involving the removal of diseased gall bladder (6). This technique has replaced open cholecystectomy as a part of routine surgical practice since the 1990s. The laparoscopic approach is superior to the open approach and has shown significant improvement in terms of morbidity, mortality and hospital stay (7). Further advancement in surgical techniques led to the use of the robotic approach in surgical practice, with the earliest use documented in the early 2000s (8). Recently a novel approach with single-site robotic cholecystectomy (SSRC) based on the da Vinci platform has been developed (9-11). This could be a viable successor for LC. Robotic surgery is much more minimally invasive when compared with laparoscopic surgery due to tissue trauma and inflammation being less.

The cost of robotic surgeries has always been a topic of concern for surgeons and robotic cholecystectomy (RC) is no different. Breitenstein *et al.* concluded that the cost of RC is high and is not justifiable with the added benefits (12). In comparison, Salman *et al.* demonstrated that when comparing the overall cost of RC, which includes the length of stay, it is as cost-effective as the non-robotic approach (13).

This systematic review will compare the cost of RC

with LC and then we will also be comparing the post-operative outcomes of RC with LC. This will help surgeons in making a choice between RC or LC in a patient. We present this article in accordance with the PRISMA reporting checklist (available at <https://tgh.amegroups.com/article/view/10.21037/tgh-23-56/rc>).

Methods

Data sources and literature search technique

The systematic review has been registered in Research Registry (<https://www.researchregistry.com/>) with the registration number Reviewregistry1720. Research exploration was done in a carefully planned and systematic fashion from electronic databases like EMBASE, MEDLINE, Cochrane Library and PubMed. MeSH search terms were used to identify the relevant articles. Boolean operators (AND, OR, NOT) were used for refining the search and narrowing down the results. The titles were carefully screened for the study selection process. Additionally, careful screening of references was done from the selected articles which were further analysed to identify any additional relevant trials that could be included.

Trial selection

The inclusion criteria were the comparative trials comparing RC with the conventional LC. For cost analysis, trial selection was done primarily with a cost comparison of SSRC with LC, all the available trials were included.

Data collection and management

Reported data was collected from the included studies by independent researchers on a standard data extraction sheet. The collected dataset was compared among the involved researchers and was found to be in satisfactory inter-researcher agreement. The extracted data consisted of a list of the authors, title of the published study, journal of publication, country/region and year of the publication, testing sample size, and the number of patients in each group of LC and RC cohort. Following data extraction, the researchers went through discussing their individual results and a consensus of mutual agreement was reached in case of discrepancies.

Highlight box

Key findings

- Robotic cholecystectomy (RC) failed to prove any clinical advantage over laparoscopic cholecystectomy (LC) for postoperative outcomes including longer duration of operation; moreover LC was more cost effective.

What is known and what is new?

- The cost of robotic surgeries has always been a topic of concerns for surgeons and RC is no different.
- The single-site RC can be a viable replacement for conventional LC, but at present this is an expensive approach.

What is the implication, and what should change now?

- This will help surgeons in making a choice between RC or LC in a patient.

Table 1 Quality of the randomised control trials among the included trials

Study	Randomization technique	Concealment	Blinding	Intention to treat analysis	Ethical approval	Registration number	Power calculation
Grochola, 2019 (17)	Electronic	Not reported	Single	Reported	Declared	NCT02485392	Reported
Kudsi, 2017 (18)	Manual	Sealed envelope	Absent	Not reported	Declared	NCT01932216	Reported
Pietrabissa, 2016 (19)	Electronic	Sealed envelope	Double	Reported	Declared	ACTRN12614000119695	Reported

Endpoint

Postoperative complications or absence of postoperative complications was considered as the principal endpoint in the meta-analysis for comparison of outcomes while cost incurred during the operation was the end point when comparing the cost.

Quality of analysis

The methodological quality of the included trials was initially assessed using published guidelines of Jadad *et al.*, Chalmers *et al.* and Rangel *et al.* (14-16). A comprehensive table for the assessment of quality among the included trials is given in *Tables 1,2*.

Statistical analysis

Statistical analysis was performed using RevMan 5.4 (Review Manager 5.4, The Nordic Cochrane Centre, Copenhagen, Denmark) (23). For comparing the continuous variables, the standardised mean difference (cost comparison) or mean difference (operative time) and for comparing dichotomous variables, odds ratio (bile leakage, conversion rate and post operative complications) with a confidence interval (CI) of 95% were used under the random-effects model analysis (24,25). A forest plot was used to calculate the heterogeneity by computing the χ^2 test, with significance set at $P < 0.05$ as well as using the I^2 test with a maximum value of 30% identifying low heterogeneity (26). For the calculation of the standardised mean difference, the inverse-variance method was used under the random effect model (27) analysis. If no event happened in the treatment and the control group, 0.5 was added to the cell frequency in the sensitivity analysis, according to the method recommended by Deeks *et al.* (28). In the event of unavailable standard deviation, the guidelines provided by the Cochrane Collaboration were used for the risk of bias calculation (24). The criteria used

as per the guidelines assumed that variance was the same in both the groups since this might not be true in all the cases, and if this is the case then variance was estimated either from range or P value. The estimate of the difference between both techniques was pooled, depending upon the effect weights in results determined by each trial estimate variance. Graphical displays of the results were represented by using a forest plot. The square around the estimate represented the accuracy of estimation (sample size) while the horizontal line represented 95% CI.

Results

The initial database search generated 30 studies. After assessment of the studies for duplication, study type and inclusion criteria, 24 were excluded. Three RCTs and 3 comparative trials were included for comparing postoperative outcomes and 1 RCT and 3 comparative studies were included for cost comparison in the final meta-analysis (*Figure 1*).

Characteristics and demographics of included studies

Three RCTs and three comparative trials on 1,013 patients were included to study for postoperative outcomes and cost comparison in the meta-analysis and principles advised by the Cochrane Collaboration were used in this analysis. The PRISMA flow chart which was used in the selection of trial is given in *Figure 1*. The trials included were conducted in Switzerland (17,20), Taiwan (21,22), USA (18), and Italy (19). Primary demographic characteristics of the studies included are specified in *Table 3* and the protocol used in the treatment for each study is given in *Table 4*.

Methodological quality of included studies

The methodological quality of RCTs included and comparative trials are concise in *Tables 1,2*. The Mantel Haenszel model for random effects was used to calculate

Table 2 Quality of included comparative trials

Quality variables	Hagen, 2018 (20)	Li, 2017 (21)	Su, 2017 (22)
Inclusion criteria	1	1	1
Exclusion criteria	0	1	1
Demographics comparable?	1	1	1
Can the number of participating centres be determined	1	1	1
Can the number of surgeons who participated be determined	1	1	1
Can the reader determine where the authors are on the learning curve for the reported procedure	1	1	1
Are diagnostic criteria clearly stated for clinical outcomes if required	1	1	1
Is the surgical technique adequately described	1	1	1
Is there any way that they have tried to standardize the operative technique	1	1	1
Is there any way that they have tried to standardize perioperative care	1	1	1
Is the age and range given for patients in the laparoscopic group	1	1	1
Do authors address whether there is any missing data	0	1	1
Is the age and range given for patients in the robotic group	1	1	1
Were patients in each group treated along similar timelines	1	1	1
Did all the patients asked to enter the study take part	1	1	0
Dropout rates stated	0	0	0
Outcomes clearly defined?	1	1	1
Blind assessors	0	0	0
Standardised assessment tools?	1	0	1
Analysis by intention to treat	0	0	0
Score	15	16	16

the strength and weakness to any outlier from the included trials. The randomization in RCTs was done electronically (17,19), and the concealment was done using sealed envelopes (18,19). Single blinding (17), double blinding (19) and no blinding (18) were adopted in the included randomized trials. The quality of the included three retrospective comparison trials was analysed by using the principles of the Scottish Intercollegiate Guidelines Network and Dudgeon *et al.* (16), and all three included studies were found to have good quality (20-22).

Outcome of the primary variable

In postoperative outcome comparison, random effect model analysis was used, the duration of operation (mean difference: -10.23, 95% CI: -16.23 to -4.22, $Z=3.34$,

$P=0.0008$) was shorter in the LC cohort. Moderate heterogeneity was seen ($\text{Tau}^2=22.21$; $\text{Chi}^2=8.56$, $df=5$, $P=0.13$, $I^2=42\%$) between included RCTs (*Figure 2*). For the complication of bile leak (odds ratio: 3.34, 95% CI: 0.85 to 13.03, $Z=1.73$, $P=0.08$) without heterogeneity ($\text{Tau}^2=0.00$, $\text{Chi}^2=0.11$, $df=2$, $P=0.95$, $I^2=0\%$) (*Figure 3*) and postoperative complications (odds ratio: 1.49, 95% CI: 0.50 to 4.46, $Z=0.72$, $P=0.47$) with moderate heterogeneity ($\text{Tau}^2=0.82$; $\text{Chi}^2=8.96$, $df=4$, $P=0.06$, $I^2=55\%$) (*Figure 4*), both were statistically similar between RC and LC groups. When cost comparison random effect model was used again, LC was associated with the reduced cost (standardised mean difference: -7.42, 95% CI: -13.10 to -1.74, $Z=2.56$, $P=0.01$) compared to RC. However, there was noteworthy heterogeneity ($\text{Tau}^2=24.85$, $\text{Chi}^2=629.70$, $df=3$, $P<0.00001$, $I^2=100\%$) (*Figure 5*) among the studies included.

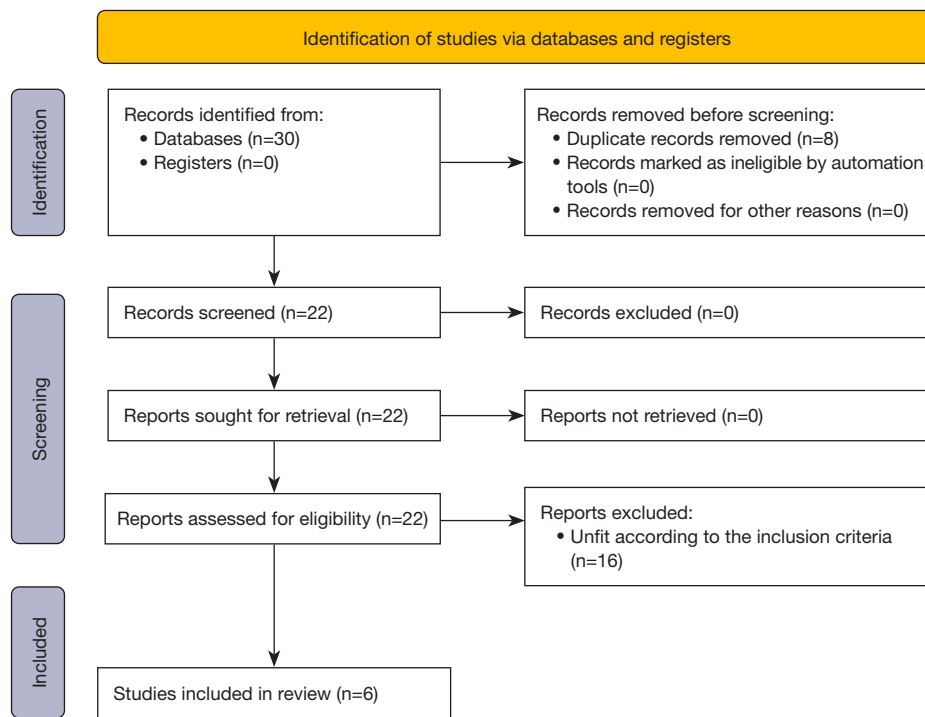


Figure 1 PRISMA flowchart showing literature search outcomes.

Table 3 Demographics of the included studies

Study	Surgery	Country/region	Type	Age (years)	Gender (men), percentage	Sample size
Grochola, 2019 (17)	Laparoscopic	Switzerland	RCT	51.5±11.5*	46.67	30
	Robotic			52.4±13.0*	33.33	30
Hagen, 2018 (20)	Laparoscopic	Switzerland	Retrospective study	47±14	27.27	99
	Robotic			47.4±12.6	27.27	99
Li, 2017 (21)	Laparoscopic	Taiwan	Retrospective study	51.44±14.11*	43.9	367
	Robotic			59.69±13.35*	48.3	78
Su, 2017 (22)	Laparoscopic	Taiwan	Retrospective study	50.94±13.79	36.51	63
	Robotic			53.64±15.54	35.29	51
Kudsi, 2017 (18)	Laparoscopic	USA	RCT	46.5±17.3	7	53
	Robotic			46.8±15.5	21	83
Pietrabissa, 2016 (19)	Laparoscopic	Italy	RCT	NR	NR	30
	Robotic			NR	NR	30

*, Bing AI was used to calculate mean ± SD from the available data. NR, not reported; RCT, randomised control trial; AI, artificial intelligence; SD, standard deviation.

Table 4 Treatment protocol among the included studies

Study	Laparoscopic technique	Robotic technique
Grochola, 2019 (17)	SILC—12 mm multiple lumen access device Diagnosis—cholecystolithiasis (96.67 %) and GB polyps (3.3%)	SSRC—multiple lumen single site port (one 8.5-mm port, two 4-mm ports and one 5-mm port) Diagnosis—cholecystolithiasis (96.67%) and GB polyps (3.3%)
Hagen, 2018 (20)	MPLC—one 12-mm periumbilical port (open technique), two 5-mm ports: right flank and the sub-xiphoidal area, one 12-mm port: left upper hemi-abdomen, cholangiogram used Diagnosis—cholecystolithiasis and acute cholecystitis	SSRC—detail not available; cholangiogram not used Diagnosis—cholecystolithiasis and acute cholecystitis
Li, 2017 (21)	MPLC—detail not available Diagnosis—GB stone (64%), GB stone with AC (24.8%) and GB polyp (11.2%)	SSRC—detail not available Diagnosis—GB stone (68%), GB stone with AC (21.8%) and GB polyp (10.3%)
Su, 2017 (22)	SILC—Lagiport system, including two 5-mm seals and two 12-mm seals Diagnosis—GB stones and GB polyps	SSRC—da Vinci single-site multichannel port Diagnosis—GB stones and GB polyps
Kudsi, 2017 (18)	MPLC—one umbilical port and three 5-mm ports (one in xiphoid and two in right upper quadrant) Diagnosis—chronic cholecystitis (26.4%), cholelithiasis (62.3%), others (13.2%)	SSRC—da Vinci single-site instrumentation and accessories Diagnosis—chronic cholecystitis (30.1%), cholelithiasis (53%), others (16.8%)
Pietrabissa, 2016 (19)	MPLC—one 12-mm umbilical port, three 5-mm ports at left subcoastal, right subcoastal and right iliac fossa Diagnosis—GB stone and GB polyp	SSRC—daVinci single site surgical system Diagnosis—GB stone and GB polyp

SILC, single incision laparoscopic cholecystectomy; SSRC, single site robotic cholecystectomy; GB, gall bladder; MPLC, multiport laparoscopic cholecystectomy; AC, acute cholecystitis.

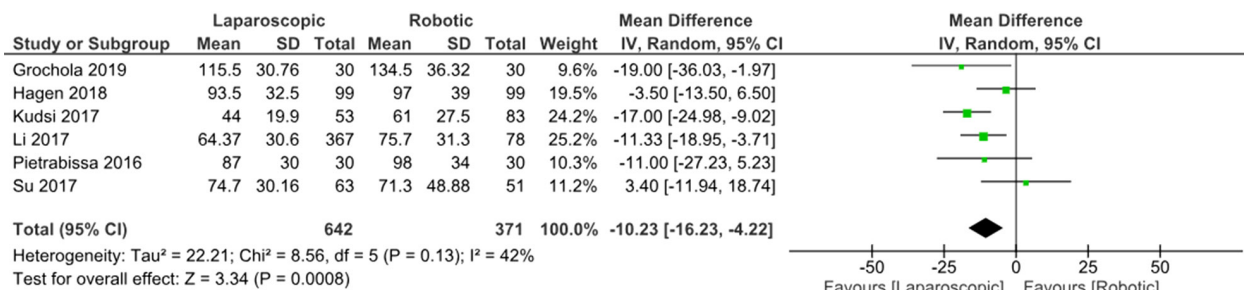


Figure 2 Forest plot showing the operative time in laparoscopic and robotic cholecystectomy. The outcome is presented as mean difference with 95% CI. IV, inverse variance; CI, confidence interval; SD, standard deviation.

Discussion

Key findings

Three RCTs and three comparative trials on 1,013 (642 patients in LC group and 371 patients in RC group) patients were used in post operative outcomes and four

comparative studies (1 RCT and 3 retrospective studies) on 817 patients undergoing RC versus LC were found suitable for cost comparison. RC failed to prove any clinical advantage over LC for postoperative outcomes including longer duration of operation; moreover, the LC seems to be more cost effective compared to RC in terms of procedural

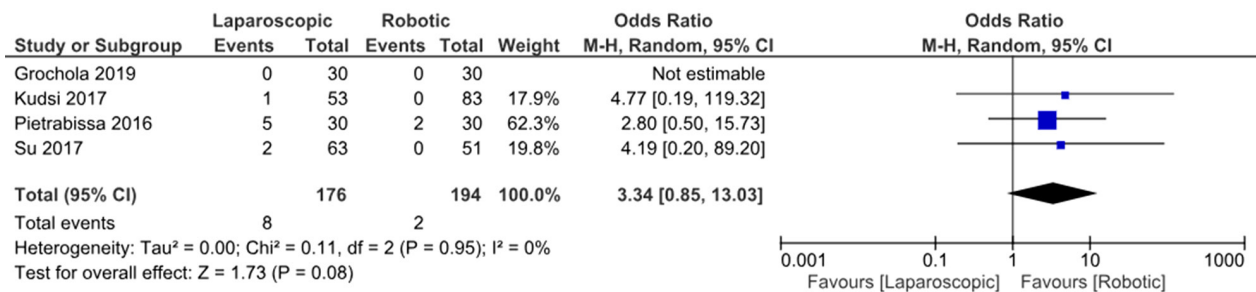


Figure 3 Forest plot showing the bile leak in laparoscopic and robotic cholecystectomy. The outcome is presented as odds ratio with 95% confidence interval. M-H, Mantel Haenszel; CI, confidence interval.

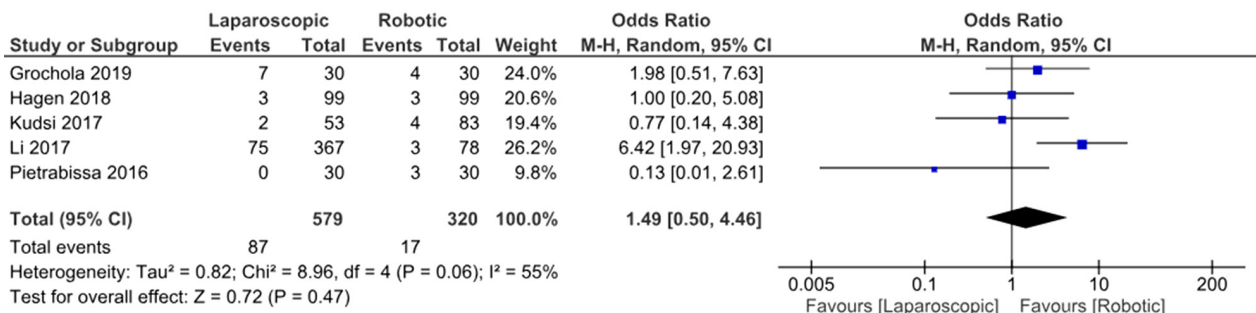


Figure 4 Forest plot showing the post operative complications in laparoscopic and robotic cholecystectomy. The outcome is presented as odds ratio with 95% confidence interval. M-H, Mantel Haenszel; CI, confidence interval.

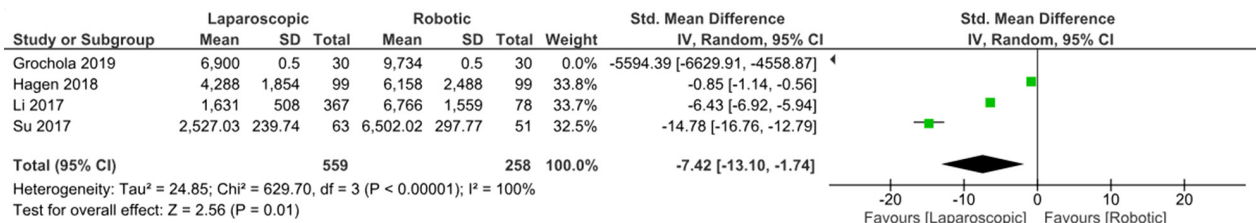


Figure 5 Forest plot showing the procedural cost in laparoscopic and robotic cholecystectomy. The outcome is presented as standardised mean difference with 95% CI. IV, inverse variance; CI, confidence interval; SD, standard deviation.

cost. These findings are insufficient to draw a stronger conclusion due to the paucity of RCTs and statistically significant heterogeneity among included studies; therefore, a major multicentre RCT is required to strengthen and validate the existing evidence.

Comparison with existing literature

Sun *et al.* did a meta-analysis comparing post operative outcome between SSRC and multiport laparoscopic

cholecystectomy (MPLC) (29). It concluded that SSRC is having higher risk of incisional hernia. Meta-analysis done by Han *et al.*, and Huang *et al.*, also conclude that RC has similar perioperative outcomes (30,31). Hoffman *et al.* have published a major comparative trial concluding that patient with robot-assisted cholecystectomy in New York State had a higher complication rate (32). We did a thorough literature review and there is no reported systematic review in comparing the cost effectiveness of SSRC vs. LC.

Strength and limitations

Two of the trials used (17,22) were in between single incision LC and SSRC, while rest (18-21) were between MPLC and SSRC. One of the RCTs used (18) had manual randomization that had no blinding and no reported intention-to-treat analysis was reported in this trial. Also, there was no reported blinding in one of the RCT (17). The aim of the systematic review was to provide a concise review comparing the cost as well as perioperative complication of this approach, and therefore some studies are comparing SSRC with MPLC and some with SILC.

The heterogeneity among the included trials was not there, and the RCTs used in the systematic review despite their shortcomings were of good strength.

Implications

The SSRC can be a viable replacement for conventional LC, but at present this is an expensive approach. Also, there is no added benefits of SSRC over MPLC as shown in this systematic review and by Sun *et al.* (29), moreover there is a higher risk of incisional hernia.

Conclusions

RC failed to prove any clinical advantage over LC for postoperative outcomes including longer duration of operation; moreover, LC was more cost effective. To further confirm the findings of the systematic review, a major multicentre RCT is needed. Also, it might be possible to perform the comparison of cost on a greater cohort of the patient and this might be imperative to confirm the cost-effectiveness of SSRC.

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Footnote

Reporting Checklist: The authors have completed the PRISMA checklist. Available at <https://tgh.amegroups.com/>

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Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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