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Single-incision versus conventional multiport laparoscopic cholecystectomy: a current meta-analysis of randomized controlled trials

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Abstract

Background We performed this study to compare the safety and feasibility of single-incision laparoscopic cholecystectomy (SILC) with conventional multiple-port laparoscopic cholecystectomy (MPLC).

Methods We searched PubMed, Embase, Web of Science, the Cochrane Controlled Register of Trials (CENTRAL), and ClinicalTrials.gov for randomized controlled trials comparing SILC versus MPLC. We evaluated the pooled outcomes for complications, pain scores, and surgery-related events. This study was performed in accordance with PRISMA guidelines.

Results A total of 48 randomized controlled trials involving 2838 patients in the SILC group and 2956 patients in the MPLC group were included in this study. Our results showed that SILC was associated with a higher incidence of incisional hernia (relative risk = 2.51; 95% confidence interval = 1.23–5.12; $p = 0.01$) and longer operation time (mean difference = 15.27 min; 95% confidence interval = 9.67–20.87; $p < 0.00001$). There were no significant differences between SILC and MPLC regarding bile duct injury, bile leakage, wound infection, conversion to open surgery, retained common bile duct stones, total complication rate, and estimated blood loss. No difference was observed in postoperative pain assessed by a visual analogue scale between the two groups at four time points (6 h, 8 h, 12 h, and 24 h postprocedure).

Conclusions Based on the current evidence, SILC did not result in better outcomes compared with MPLC and both were equivalent regarding complications. Considering the additional surgical technology and longer operation time, SILC should be chosen with careful consideration.

Keywords Laparoscopic cholecystectomy · Single-incision · Conventional · Meta-analysis · Systematic review

Laparoscopic cholecystectomy is the gold-standard surgical procedure for treating benign gallbladder diseases and was first reported in 1985 [1]. In conventional laparoscopic cholecystectomy, three or four ports are used. However, increasing patients demand for less invasive and cosmetic, the first single-incision laparoscopic cholecystectomy was reported in 1997 [2] and multiple studies using the technique have since been published. Recently, more literature became available for the feasibility of SILC [3, 4]. Some studies suggested that single-incision laparoscopic cholecystectomy (SILC) might be associated with less postoperative pain, better aesthetic results, and shorter recovery time [5–8]. Recently studies and meta-analysis showed that SILC is a safe procedure with postoperative outcome similar to that of standard LC [8–10]. However, SILC is still not in widespread use because of its longer operation time, greater technical difficulty, and a possible significant increase in complication rates [8, 11–13]. Several studies have compared SILC and multiport laparoscopic cholecystectomy (MPLC); however, definitive conclusions from these comparisons remain controversial. Meta-analyses have also been performed to compare SILC with MPLC regarding related events [9, 14–16], but findings are inconsistent. More recent studies evaluated only the technical considerations of SILC [14, 17, 18]. Therefore, a study is needed to evaluate recent randomized controlled trials (RCTs). To evaluate the safety and feasibility of SILC versus MPLC, we performed

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a meta-analysis to compare SILC with conventional MPLC (three- or four-port) using recently-published RCTs.

Methods

Inclusion and exclusion criteria

The search criteria included all studies comparing SILC and MPLC published in English with full texts. We included recent studies published by the same authors or agency. We excluded articles with insufficient data on outcome measures (study enrolled only 1 treatment method; data could not be used for statistical analysis and reported less one of the outcomes) and any studies evaluating miniport laparoscopic cholecystectomy (any trocar < 5 mm in size).

Search strategy

We searched PubMed, Embase, Web of Science, the Cochrane Controlled Register of Trials (CENTRAL) and ClinicalTrials.gov up to 1 May 2019. MPLC was defined as conventional laparoscopic cholecystectomy using three or four ports. English search terms included, but were not limited to, the following: "single incision," "single port," "single access," "multiport," "standard," "conventional," and "laparoscopic cholecystectomy". The references of articles identified after the initial search were also manually reviewed.

Outcome measures

The outcomes measures included bile duct injury (BDI), bile leakage, wound infection, incisional hernia, conversion to open cholecystectomy, total complication rate, operating time, estimated blood loss volume, and postoperative pain score assessed by a visual analogue scale at four time points (4 h, 6 h, 8 h, 12 h, and 24 h postprocedure).

Data extraction

Two reviewers independently extracted the original data from the literature to ensure homogeneity of the extracted data. The standardized selection form included the first author, year of publication, country in which the study was performed, and general data. Conflicts in data abstraction were resolved by consensus and by referring to the original article. Extracted data were entered into a pregenerated standard Microsoft Excel file (Microsoft Corporation, Redmond, WA, USA).

IRB approval and informed consent were not needed for this study.

Risk of bias assessment

We used the Cochrane Collaboration Handbook [19] to evaluate the quality of included studies. Disagreement, if any, was resolved by discussion.

Statistical analysis

All statistical analyses were performed using Review Manager (RevMan) version 5.3 software (Cochrane Informatics and Knowledge Management Department, London, UK). Summary outcomes are described as proportions and 95% confidence intervals (CI) for categorical data and weighted mean difference ± standard deviation for continuous data. Publication bias was evaluated using the χ^2 test and funnel plots. Heterogeneity among studies was evaluated using the χ^2 test. A two-tailed p value of < 0.05 was considered statistically significant. We also assessed the potential for publication bias through a visual inspection of funnel plot asymmetry. This meta-analysis was performed according to the PRISMA statement guidelines.

Results

Study selection and characteristics of the trials

Using the search strategy, the initial research yielded 1049 studies; 201 studies were identified after eliminating duplicates. Another 595 studies were excluded after reviewing the titles and abstracts. Finally, 48 RCTs were included in this meta-analysis [3, 4, 7, 10, 14, 18, 20–61]. A total of 5654 included patients were divided into an SILC group of 2769 patients and an MPLC group of 2885 patients. The sample size in the studies ranged from 33 to 600 patients and involved 19 countries. A detailed flowchart of the selection process following the PRISMA template is shown in Fig. 1. The characteristics of the included studies are shown in Table 1.

Methodological quality and risk of bias

The methodological quality of the included studies was evaluated by two reviewers using the Cochrane Collaboration tool for assessing the risk of bias. An overall summary of the methodological quality of the included studies is shown in Fig. 2.

Outcome measures

BDI

The incidence of BDI was reported in 25 studies. BDI was identified in 6/1563 patients in the SILC group and 5/1665

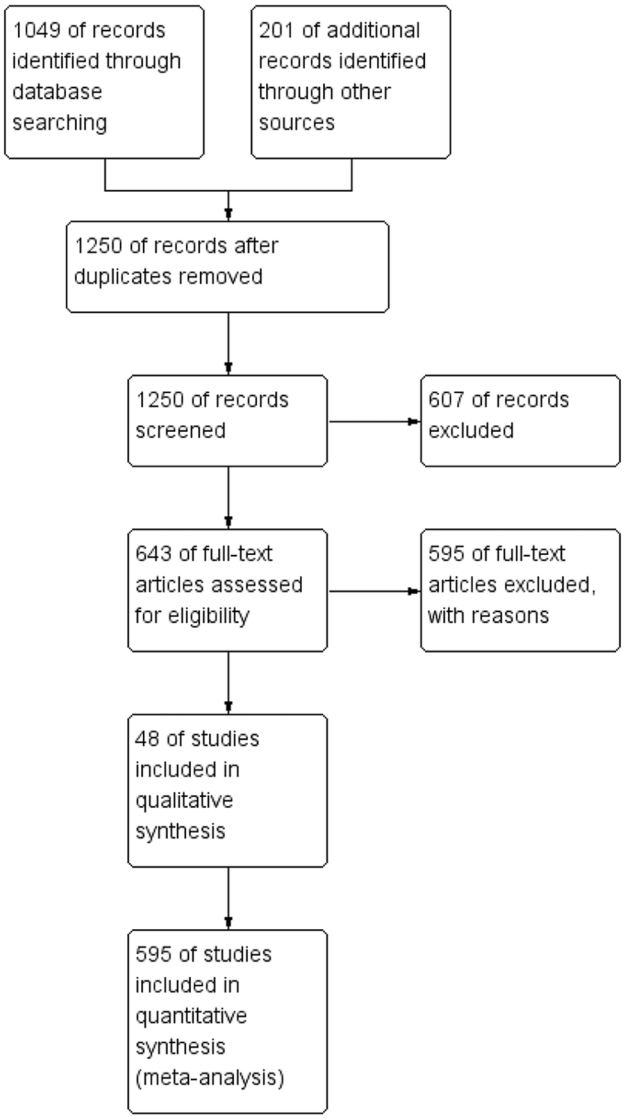

Fig. 1 Flow diagram of the published articles evaluated for inclusion in this meta-analysis

patients in the MPLC group. The risk ratio of BDI in SILC versus MPLC was 1.15 (95% CI 0.42–3.19, $p=0.78$) (Fig. 3).

Bile leakage

Bile leakage was identified in 20 studies. The incidence of bile leakage tended to be higher in the SILC group (13/1407 patients) than in the MPLC group (10/1284 patients), although the difference was not statistically significant (relative risk (RR): 1.08; 95% CI 0.5–2.31; $p=0.85$) (Fig. 4).

Wound infection

Twenty-four studies reported wound infection and we found no significant difference between the two groups (RR: 1.05; 95% CI 0.67–1.66; $p=0.82$) (Fig. 5).

Incisional hernia

Incisional hernia was reported in 35 studies and occurred in 29/2208 patients in the SILC group and in 7/2304 patients in the MPLC group. The pooled data for the meta-analysis showed that SILC may be associated with higher incisional hernia rates compared with MPLC (RR: 2.51; 95% CI 1.23–5.12; $p=0.01$) (Fig. 6A). A subgroup analysis showed no significant difference in the incidence of postoperative hernia in the single-incision subgroup (RR: 0.65; 95% CI 0.03–16.44; $p=0.79$) (Fig. 6B) and that SILC was associated with a higher incidence of incisional hernia compared with MPLC in the single-port subgroup (RR: 2.97; 95% CI 1.46–6.03 $p=0.003$) (Fig. 6C).

Conversion to open cholecystectomy

Twenty studies reported conversion to open cholecystectomy and we found no significant difference between SILC and MPLC (RR: 0.94; 95% CI 0.47–1.88; $p=0.85$; Fig. 7).

Retained common bile duct stones

Twelve studies reported retained common bile duct stones and we found no significant difference between the two groups using a fixed-effects model (RR: 1.23; 95% CI 0.45–3.39; $p=0.69$) (Fig. 8).

Total complications

We found no significant difference in total complication rates between the two groups (RR: 1.50; 95% CI 0.58–3.87; $p=0.41$) (Fig. 9).

Operation time

Operation time was reported in 27 studies. Compared with MPLC, SILC had a longer operation time and the difference was significant compared with MPLC (mean difference: 15.27 min; 95% CI 9.67–20.87; $p<0.00001$) (Fig. 10).

Estimated blood loss

Eleven trials reported estimated blood loss volumes. The pooled results showed that there was no significant difference between the SILC group and the MPLC group (mean difference: 1.35 ml; 95% CI −0.02–2.71; $p=0.05$) (Fig. 11).

Table 1 the characteristic of included studies

First of author	Year	Country	Sample		Gender			
			SILC	MPLC	SILC (M/F)		MPLC (M/F)	
Aprea	2011	Italy	25	25	12	13	6	19
Arezzo	2016	Italy	297	303	NA	NA	NA	NA
Bingener	2015	USA	55	55	10	45	11	44
Borle	2014	India	30	30	10	20	7	23
Brown	2013	USA	40	39	11	29	7	32
Bucher	2011	Switzerland	75	75	NA	NA	NA	NA
Cao	2011	China	57	51	23	34	22	29
Chang	2014	Singapore	51	50	19	31	20	30
Deveci	2013	Turkey	50	50	5	45	7	43
Ellatif	2013	Egypt	125	125	30	95	37	88
Goel	2016	India	30	30	4	26	7	23
Guo	2015	China	138	414	33	105	104	310
Hajong	2016	India	32	32	4	28	4	28
He	2015	China	200	100	91	108	52	48
Ito	2018	Japan	58	53	24	34	23	30
Jørgensen	2014	Denmark	60	60	NA	NA	NA	NA
Justo-Janeiro	2013	Mexico	18	19	2	16	6	13
Khorgami	2013	Iran	30	60	8	22	19	41
Koirala	2019	Nepal	100	100	20	80	21	79
Kumar	2019	India	50	74	40	10	53	21
Lai	2011	China	24	27	8	16	11	16
Lirici	2011	Italy	20	20	6	14	6	14
Luna	2012	Brazil	20	20	NA	NA	NA	NA
Lurje	2015	Switzerland	48	48	15	33	19	29
Ma	2011	Portland	21	22	NA	NA	NA	NA
Madureira	2013	Brazil	28	29	NA	NA	NA	NA
Marks	2013	USA	119	81	28	91	24	57
Noguera	2013	Spain	40	20	7	33	3	17
Omar	2017	Egypt	89	98	34	55	41	58
Ostlie	2013	USA	30	30	6	24	6	24
Pan	2013	China	49	53	23	26	22	31
Partelli	2015	Italy	30	29	8	22	14	15
Qu	2019	China	49	42	20	29	21	21
Raši ´c	2010	Croatia	48	50	22	26	18	32
Rizwi	2014	Lahore	100	100	41	59	43	57
Sasaki	2012	Japan	27	27	14	13	14	13
Sinan	2012	Turkey	17	17	4	13	8	9
Solomon	2012	USA	22	11	NA	NA	NA	NA
Sulu	2015	Turkey	30	30	9	21	12	18
Telciler	2014	Turkey	20	20	5	15	6	14
Tsimoyiannis	2010	Greece	20	20	5	15	1	19
Tyagi	2016	*India*	75	75	NA	NA	NA	NA
Vilallonga	2012	Turkey	69	71	30	39	35	36
Ye	2015	China	100	100	NA	NA	NA	NA
Yilmaz	2013	Turkey	43	40	9	34	13	27
Zapf	2013	USA	49	51	7	42	17	34
Zhao	2016	China	100	50	37	63	14	36
Zheng	2012	China	30	30	13	17	16	14

SILC single-incision laparoscopic cholecystectomy, *MPLC* multiport laparoscopic cholecystectomy, *NA* not available, *M* male, *F* female

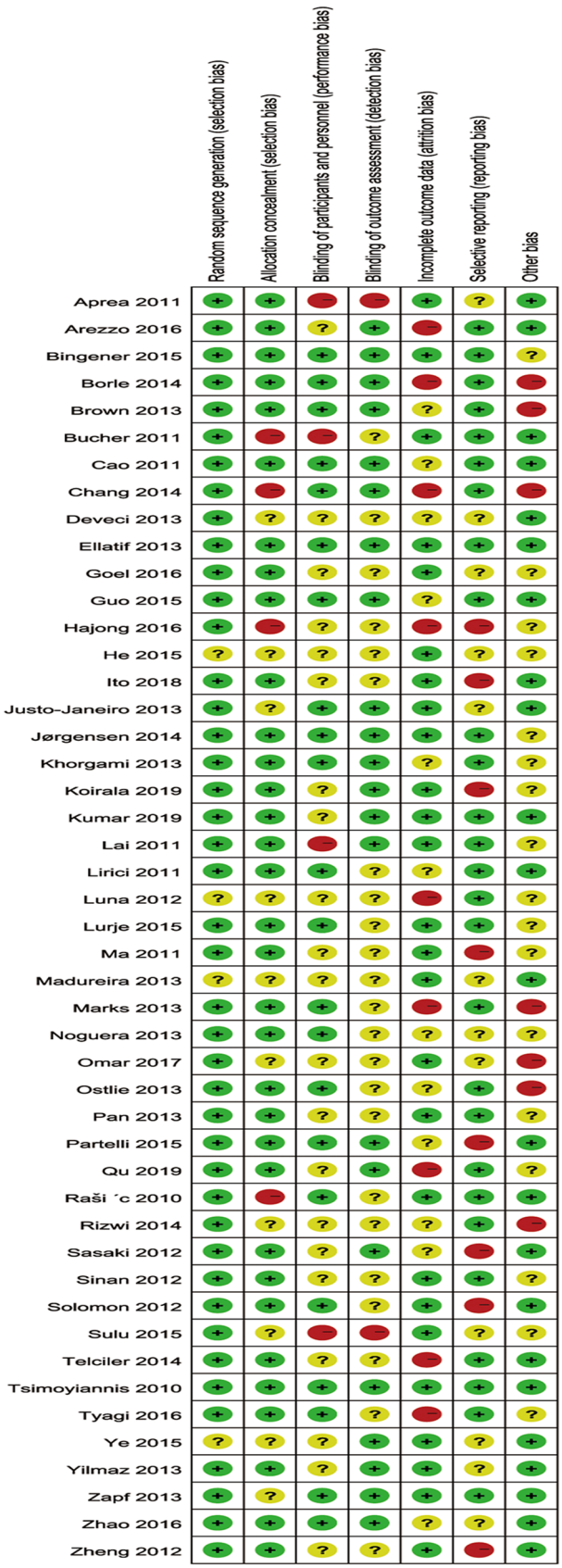

Fig. 2 Consensus risk of the bias assessment of the included studies. Green, low risk; yellow, unclear; red, high risk (Color figure online)

Postoperative pain assessed using a visual analogue scale (VAS)

Postoperative pain was estimated at four time points after laparoscopic cholecystectomy (6 h, 8 h, 12 h, and 24 h) using a VAS. SILC appeared to provide no better pain score than for MPLC in each of the four time subgroups ($p = 0.50$, $p = 0.44$, $p = 0.54$ and $p = 0.66$, respectively; Fig. 12).

Publication bias

Most graphical funnel plots of the parameters were symmetrical and Egger's test revealed no significant publication bias.

Discussion

This current meta-analysis of RCTs showed that SILC was associated with a higher incidence of incisional hernia and longer operation time. There was no significant difference between SILC and MPLC groups regarding BDI, bile leakage, wound infection, conversion to open cholecystectomy, or total complication rates. No difference was observed in postoperative pain assessed by VAS between the two groups 6 h, 8 h, 12 h, and 24 h postprocedure.

Laparoscopic cholecystectomy has become the gold-standard procedure for benign gallbladder disease. In conventional laparoscopic cholecystectomy, three or four ports are usually used. Previous studies have demonstrated that conventional laparoscopic cholecystectomy is safe and feasible for cholecystectomy [62]; however, to reduce postoperative pain and improve cosmetic results, SILC was introduced in 1997 [2]. Today, SILC and MPLC are the main approaches for laparoscopic cholecystectomy [63–66]. RCTs and meta-analyses have compared SILC with MPLC, but results are controversial.

The results of our review showed that SILC may be associated with a higher incidence of incisional hernia, as reported in several previous studies [15, 41, 67]. The size of the SILC incision is larger than that for MPLC, which may lead to a higher incidence of incisional hernia. Additionally, incision-related events, namely wound infection, seroma, and hematoma, may be associated with postoperative incisional hernia. Interestingly, many studies, including ours, showed no difference in the incidence of postoperative wound infections between the two groups, which indicates that in SILC, wound infection is not the only factor influencing postoperative incisional hernia rates. Some studies focusing on this topic have claimed that a larger fascial defect may increase the risk of incisional hernia [41, 68, 69]. The approach used in SILC includes a single skin incision or a specific port. Our subgroup analysis showed no significant difference in

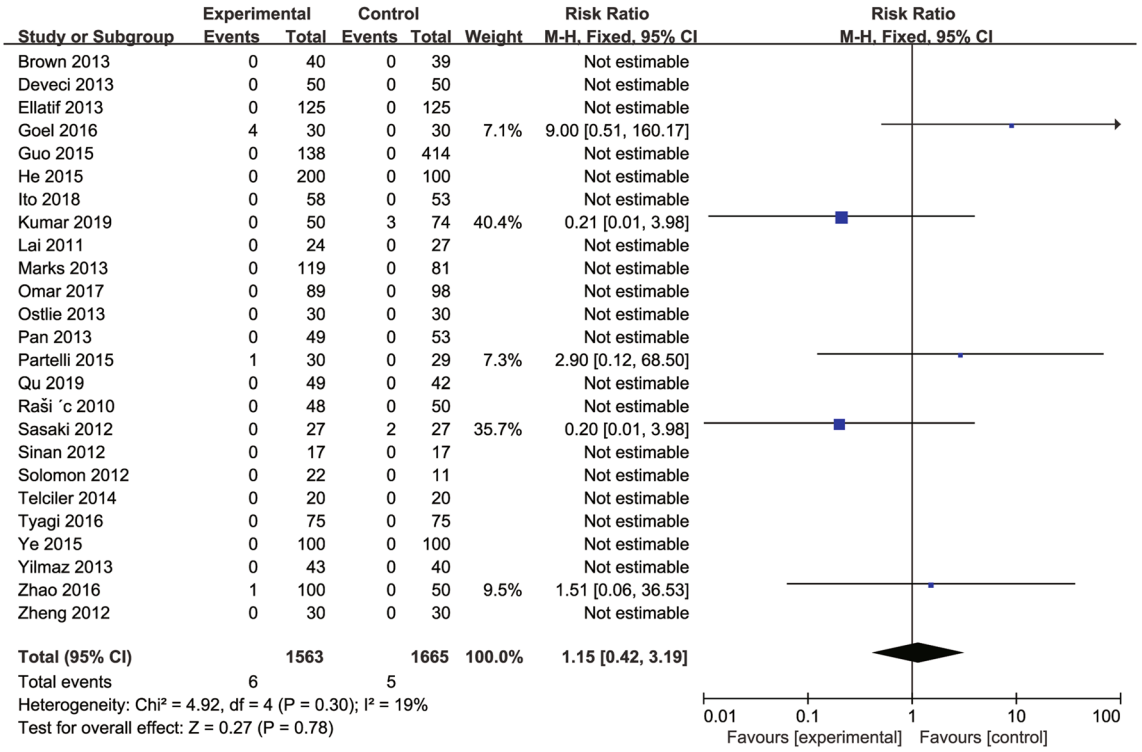

Fig. 3 Forest plot of the meta-analysis comparing SILC and MPLC regarding the incidence of BDI

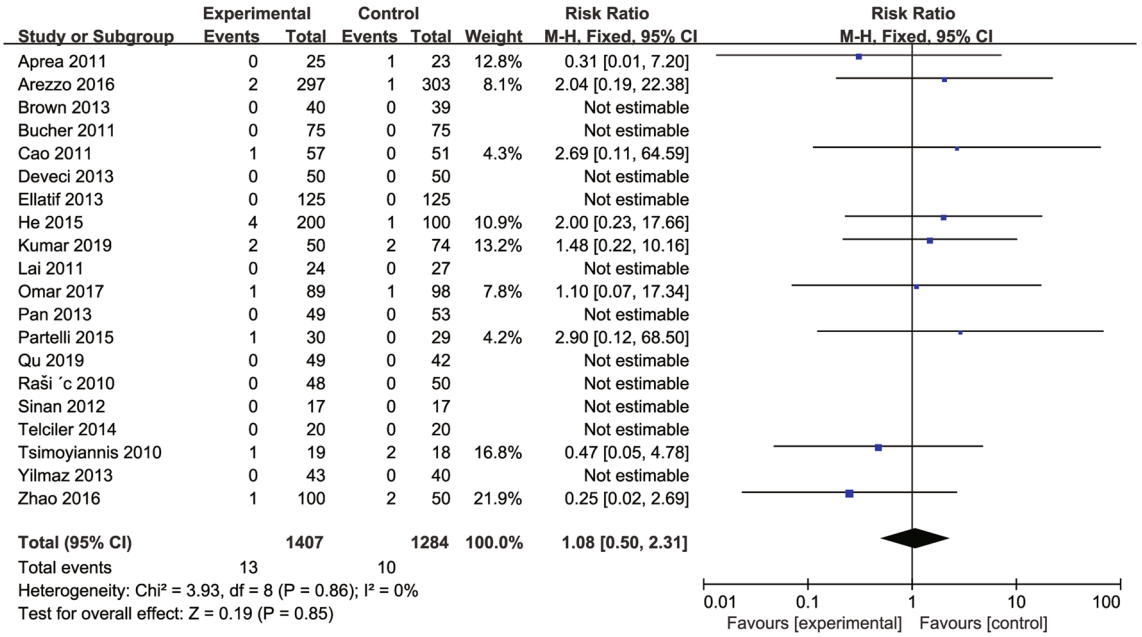

Fig. 4 Forest plot of the meta-analysis comparing SILC and MPLC regarding the incidence of bile leakage

the incidence of postoperative incisional hernias in the single skin incision subgroup. However, SILC was associated with higher incisional hernia rates compared with MPLC in the single-port subgroup. A study performed by Chuang et al. published in 2016 demonstrated that multiple trocars through a single skin incision may decrease the incidence of hernia [70]. The studies included in the meta-analysis could not provide complete data in terms of port size and the SILS

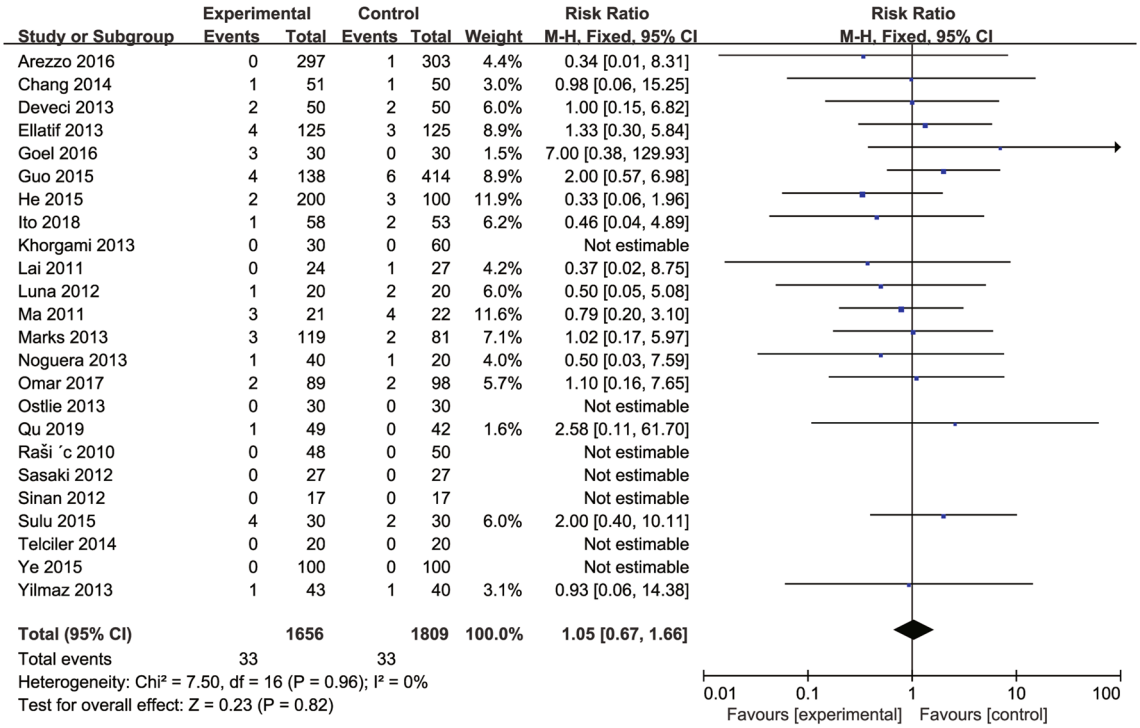

Fig. 5 Forest plot of the meta-analysis comparing SILC and MPLC regarding the incidence of wound infection

ports used in the included studies were different. However, whether SILC increases the incidence of postoperative incisional hernia remains inconclusive. Many factors may affect the incidence of hernia [35, 71, 72]. Most studies included in this meta-analysis provided the data of BMI which showed no difference between two groups. Interestingly, in the study by Marks et al. [41], there was a difference in BMI between the two groups, and there was a difference in the incidence of postoperative hernias between the two groups. However, multivariate analysis showed that BMI was not associated with postoperative hernia. A short follow-up time may underestimate the incidence of incisional hernia, which may occur years after the procedure. The follow-up time in our included studies ranged from 1 to 17 months, which was short, when assessing the occurrence of incisional hernia. Large-scale trials with > 30 months' follow-up demonstrated no difference between the two groups [73]; however, higher numbers of high-quality studies with longer follow-ups are required.

Postoperative pain is a main point of comparison between SILC and MPLC. In contrast to some previous meta-analyses [15, 67], our current study showed no significant difference between SILC and MPLC; findings for this comparison are controversial. Two studies performed by Bucher et al. [25] and Tsimoyianni et al. [47] showed that SILC has an advantage over MPLC regarding pain; however, findings for postoperative pain in recent studies differ considerably. The incision length, use of different anesthetics, pneumoperitoneal pressure, patients' psychological factors and the methods used to assess pain could contribute to heterogeneity in our included studies [15]. Regarding aesthetic results, assessment time points and methods differed in the included studies, although most reports documented better aesthetic results after SILC [25, 74, 75]. Arezzo et al. demonstrated that SILC was associated with better aesthetic results; however, results had high overall heterogeneity across the included studies. More high-quality RCTs focused on patients' postoperative pain and aesthetic results are needed.

SILC and MPLC had a similar rate of postoperative complication, namely, BDI, bile leakage and retained common bile duct stones. BDI is a major concern in laparoscopic cholecystectomy. In the current meta-analysis, we found no significant difference in the incidence of BDI and bile leakage, similar to findings in previous studies. Regarding retained common bile duct stones, we found no significant difference between SILC and MPLC; however, in some studies, routine cholangiography was performed during surgery [21, 76], so the rate of retained common bile duct stones differed in the included studies.

Consistent with previous studies, operation time was significantly longer for patients undergoing SILC, which involves an unnaturally ergonomic technique for surgeons. However, with continuous developments in SILC technology

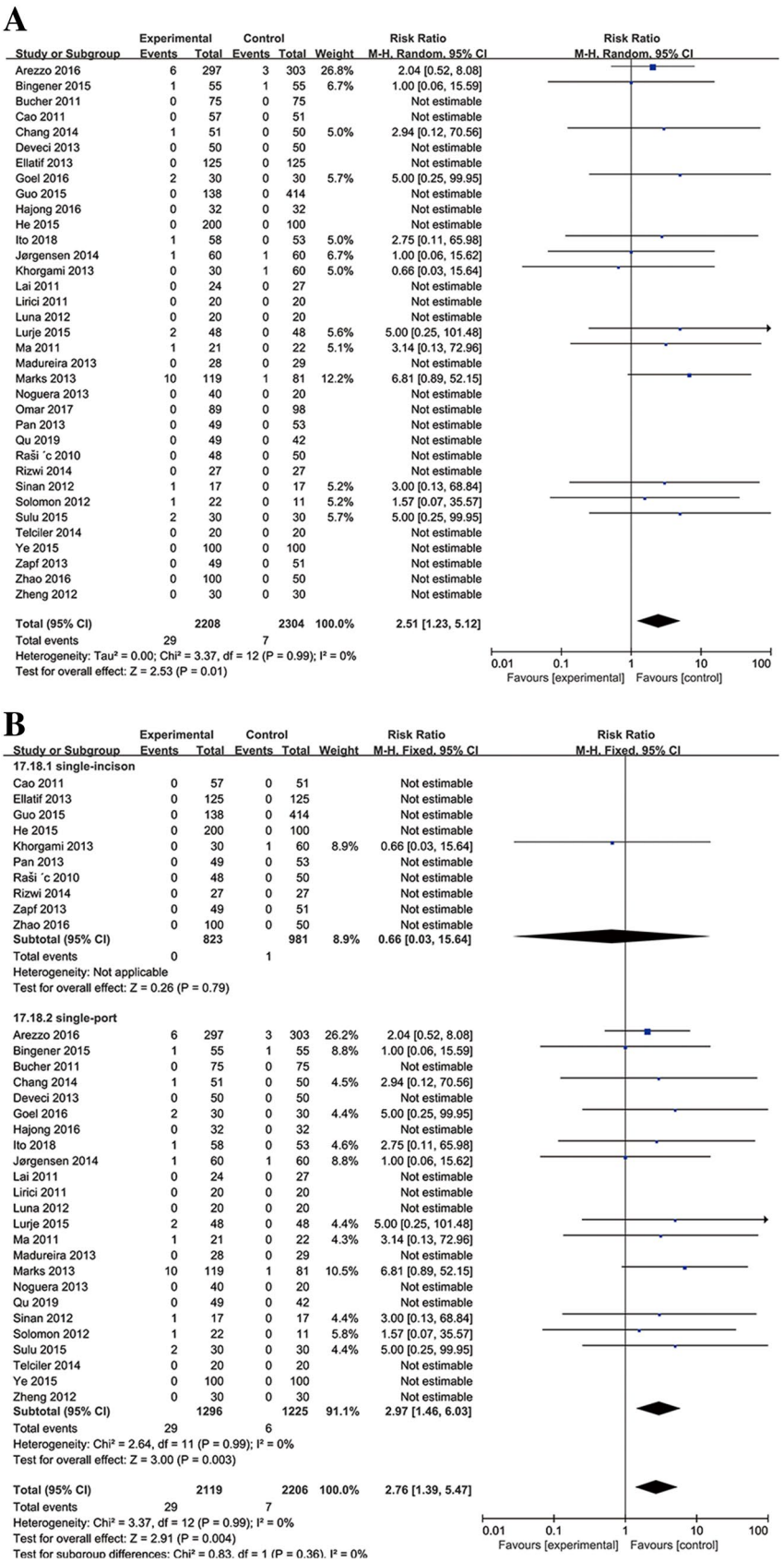

Fig. 6 Forest plot of the meta-analysis comparing SILC and MPLC regarding the incidence of incision hernia. **A** Total studies; **B** subgroup analyses

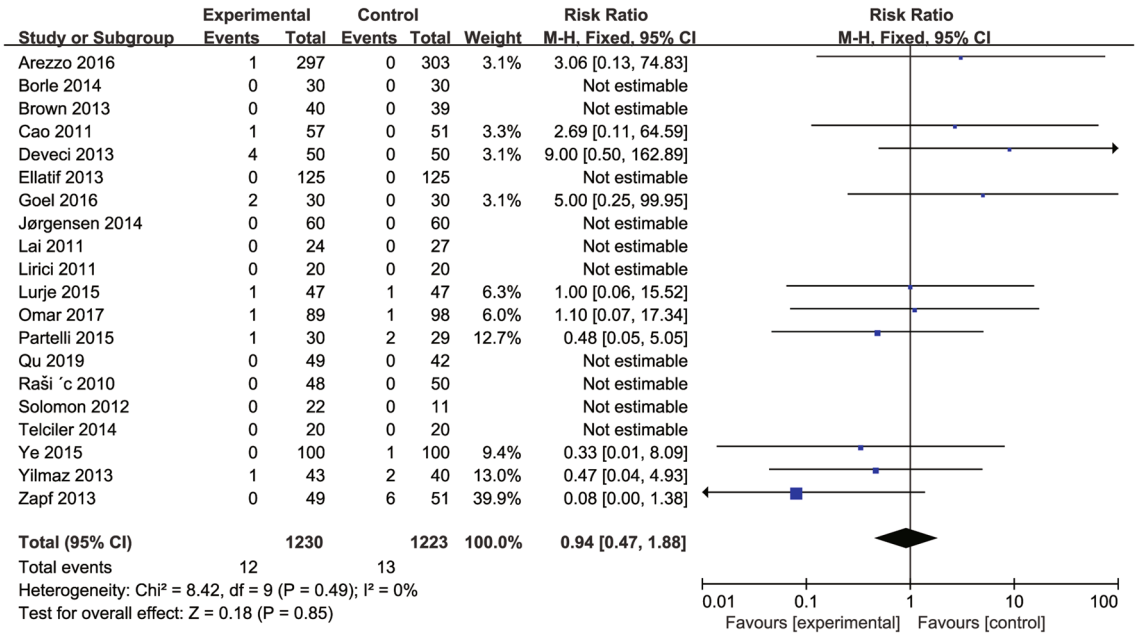

Fig. 7 Forest plot of the meta-analysis comparing SILC and MPLC regarding the incidence of conversion to open cholecystectomy

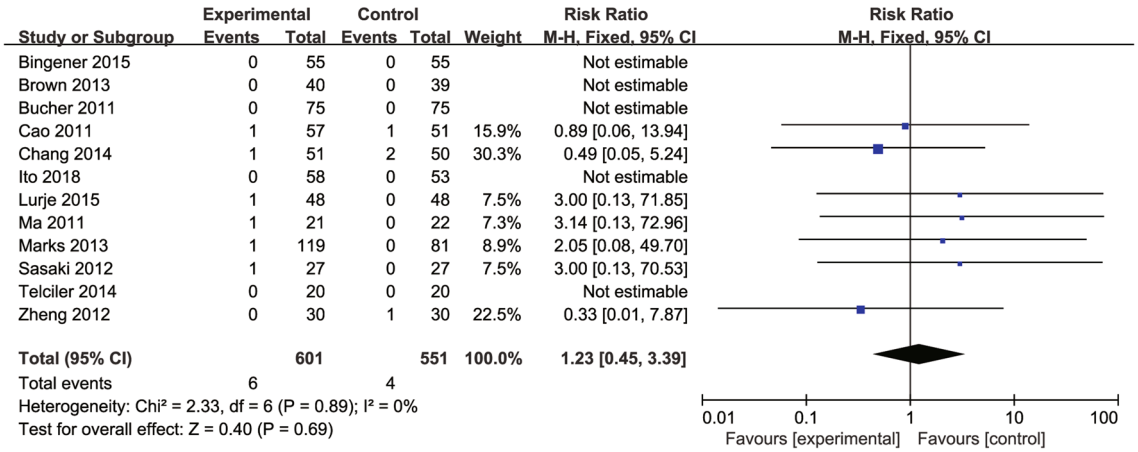

Fig. 8 Forest plot of the meta-analysis comparing SILC and MPLC regarding the retained common bile duct stones

and greater experience, this difference has gradually narrowed. A recent RCT performed by Umemura et al. showed no significant difference between SILC and MPLC regarding operation time [17]; however, the learning curves for SILC are longer than for MPLC and SILC requires more surgical experience.

Although our meta-analysis incorporated several of the latest RCTs, certain limitations must be mentioned. First, several trials in the present study had a high risk of bias and outcomes following SILC and MPLC may have been over- or underestimated. Second, the criteria describing intraoperative and postoperative complications were inconsistent. Third, we included studies published only in English. Considering these limitations, more large-scale, high-quality RCTs are required.

Conclusions

Based on the current evidence, SILC did not result in better outcomes compared with MPLC and both were equivalent regarding complications. Considering the additional surgical technology and longer operation time, SILC should be chosen with careful consideration.

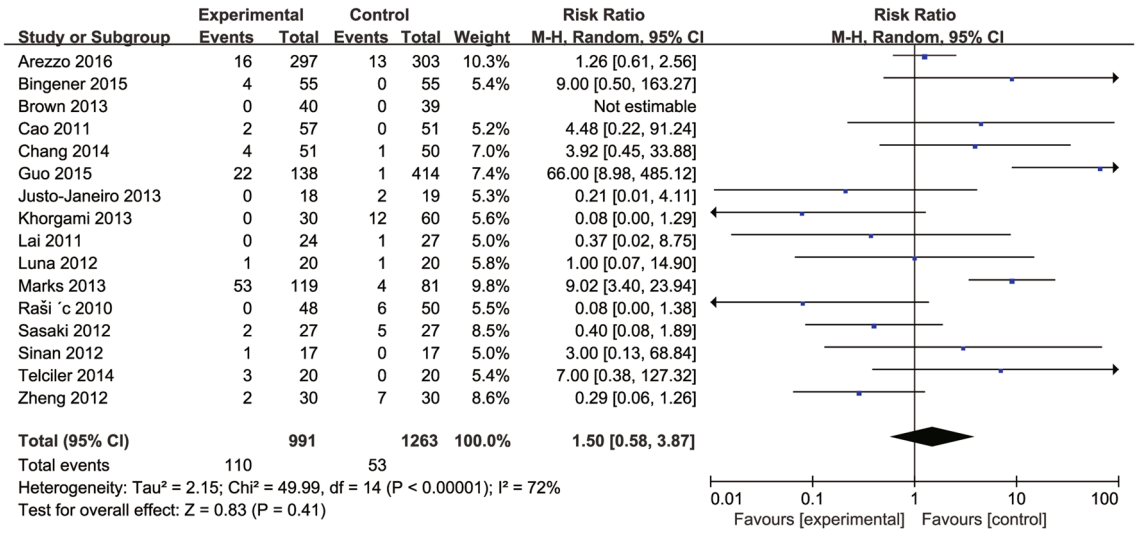

Fig. 9 Forest plot of the meta-analysis comparing SILC and MPLC regarding the total complication

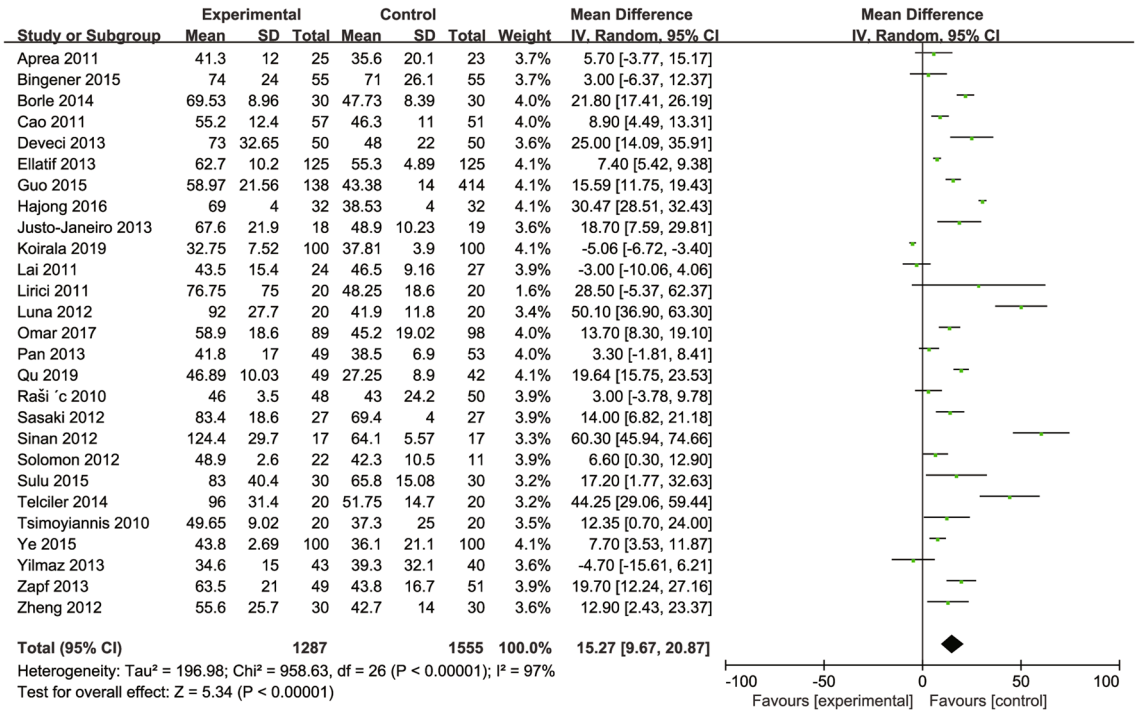

Fig. 10 Forest plot of the meta-analysis comparing SILC and MPLC regarding the operation time

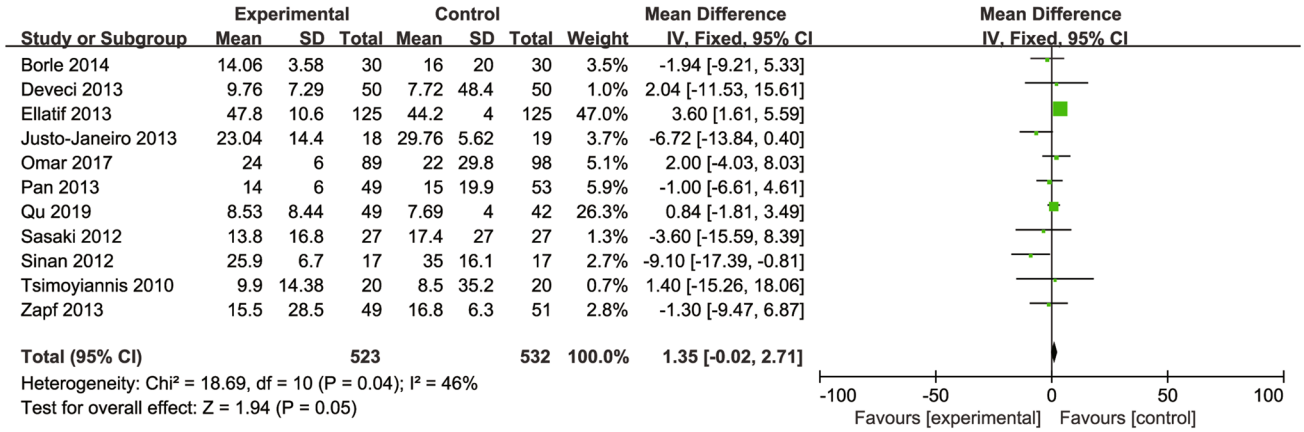

Fig. 11 Forest plot of the meta-analysis comparing SILC and MPLC regarding the estimated blood loss

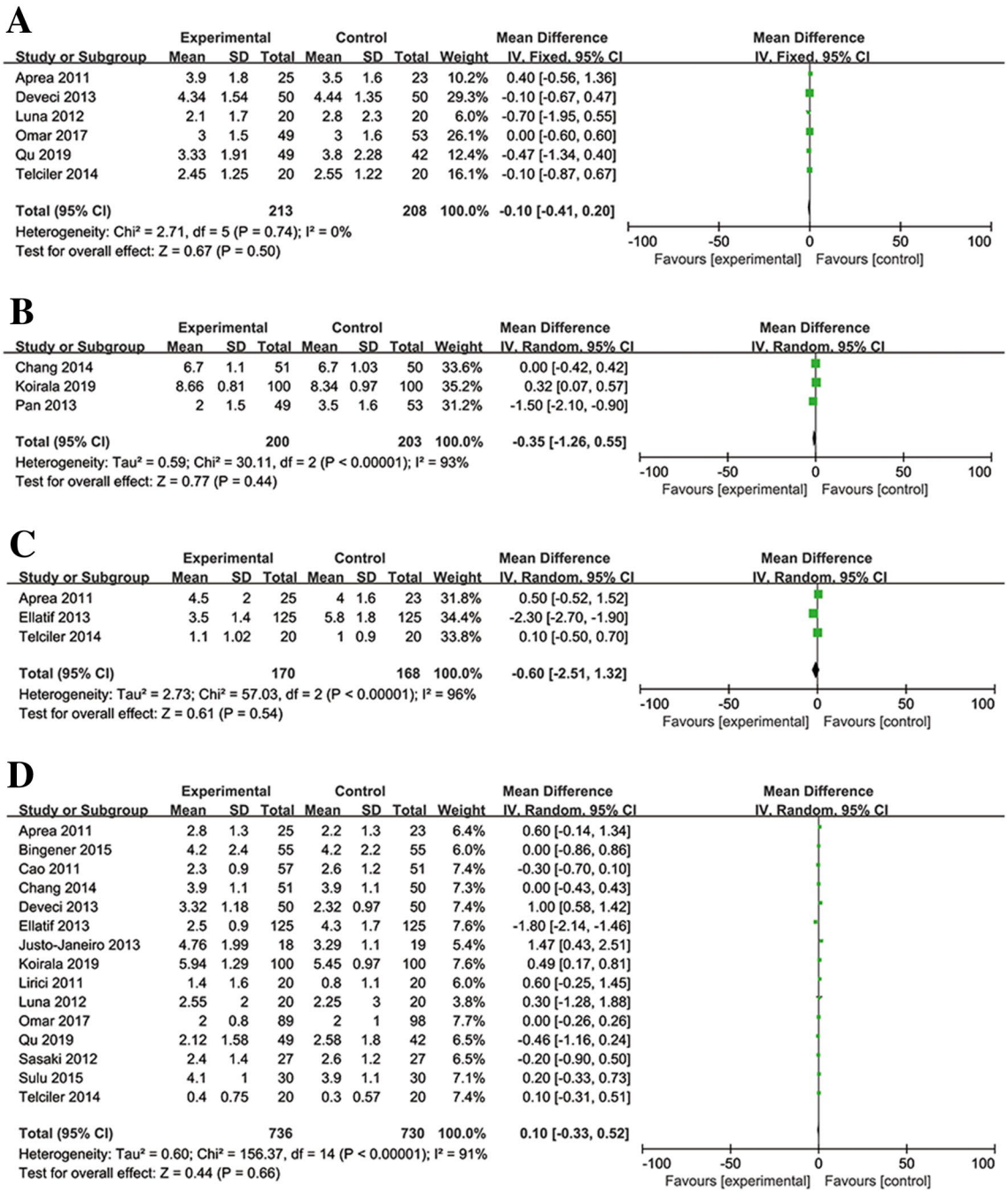

Fig. 12 Forest plot of the meta-analysis comparing SILC and MPLC regarding the VAS in four time subgroup. **A** VAS in 6 h; **B** VAS in 8 h **C** VAS in 12 h **D** VAS in 24 h

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Data availability All the data used in the study can be obtained from the original articles.

Compliance with ethical standards

Disclosures Yunxiao Lyu, Yunxiao Cheng, Bin Wang, Sicong Zhao, and Liang Chen have no conflicts of interest or financial ties to disclose.

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