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Systematic Review / Meta-analysis

Comparison of outcomes and safety of laparoscopic and robotic-assisted cyst excision and hepaticojejunostomy for choledochal cysts: A systematic review and meta-analysis

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ABSTRACT

Objectives: Minimally invasive cyst excision and Roux-en-Y hepaticojejunostomies include laparoscopic and robotic-assisted operations. The current systematic review and meta-analysis compared the efficacy between the 2 groups.
Methods: A systematic search of PubMed, Web of Science, Embase, Wiley, Cochrane Library and Clinical Trials was performed from May 1995 to December 2021. The primary outcome was postoperative complications, and the secondary outcomes were operative details and postoperative outcomes.
Results: The meta-analysis enrolled 6 reports including 484 patients (307 in the laparoscopic group and 177 in the robotic-assisted group). The laparoscopic group was associated with lower expenses (MD = −3851.60$, 95% CI = −4031.84 to −3671.36$, P < 0.00001). No significant difference was found in short-term complications (RR = 1.55, 95% CI = 0.74 to 3.23, P = 0.24), long-term complications (RR = 1.40, 95% CI = 0.63 to 3.10, P = 0.41), total complications (RR = 1.53, 95% CI = 0.59 to 3.94, P = 0.38), operative time (MD = −28.75 min, 95% CI = −77.13 to 19.64 min, P = 0.24), blood loss (MD = 2.28 ml, 95% CI = −13.51 to 18.06 ml, P = 0.78) or hospital stays (MD = 0.89 days, 95% CI = −0.13 to 1.91 days, P = 0.09). In subgroup analysis, the laparoscopic operation had shorter operative time (MD = −4.45 min, P = 0.009), and less blood loss (MD = −63.18 ml, P = 0.01) in adult patients.
Conclusions: Laparoscopic and robotic-assisted cyst excision and Roux-en-Y hepaticojejunostomy have comparable postoperative outcomes.

1. Introduction

Delayed management of choledochal cyst (CDC) can result in perforation, hepatic fibrosis or cholangiocarcinoma [1,2]. Operation is the only effective method to avoid these complications. The standard procedure is cyst excision and Roux-en-Y hepaticojejunostomy. Recently, the surgical procedure has developed from laparotomy to minimally invasive operation. Since Farello first reported the experience of laparoscopic operation for CDC in 1995 [3], laparoscopic management had increased rapidly for decades. In 2006, Woo reported the first case of robotic-assisted type I cyst excision and Roux-en-Y hepaticojejunostomy [4]. Subsequently, some reports on robotic-assisted operation had been published [5–16]. However, the evidence comparing the postoperative outcomes between laparoscopic operation (LA) and robotic-assisted operation (RA) is limited. The aim of this systematic review and meta-analysis was to compare the outcomes and safety between LA and RA for choledochal cysts.

2. Methods & materials

The current study was established in accordance with the PRISMA 2020 statement [17] and STROCSS 2021 criteria [18]. We registered the

Abbreviations: CDC, choledochal cyst; LA, laparoscopic; RA, robotic-assisted; NOS, the Newcastle-Ottawa Quality Assessment Scale; RR, Relative risk; MD, mean difference.

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study on INPLASY, of which the registration number was INPLASY2021120024. This meta-analysis was evaluated as high quality review in line with the AMSTAR 2 [19].

2.1. Search strategy

A systematic search of PubMed, Web of Science, Embase, Wiley, Cochrane Library and Clinical Trials databases was conducted independently by two independent teammates (YT and CSY). The search terms used were "laparoscopic" AND "robotic" AND "choledochal cyst", as well as all related MeSH terms. Reference lists from related articles were also scanned to broaden the search.

2.2. Eligibility criteria

Inclusion criteria of current study were: (1) the study was established between May 1995 to December 2021; (2) the study reported the minimally invasive operation comparing the laparoscopic (LA) and robotic-assisted (RA) cyst excision and Roux-en-Y hepaticojejunostomy; (3) the study reported at least one of the outcome results: postoperative complications, operative time, blood loss, hospital stays and expenses; and (4) the study was reported in English only.

The exclusion criteria were as follows: (1) review articles; (2) conference abstracts; (3) case reports (<5 cases); (4) the study included only one surgical method; and (5) no comparative outcomes in the study.

2.3. Study outcomes

The primary outcomes were postoperative complications, for which would significantly decrease the life quality of patients. We assessed all the complications reported by the included articles, including short-term complications, long-term complications, and total postoperative complications. In addition, secondary outcomes were operational details (operative time and blood loss), and postoperative outcomes (hospital stays and expenses).

2.4. Quality assessment

Two independent teammates (YT, CSY) assessed the articles according to the Newcastle-Ottawa Quality Assessment Scale (NOS) for cohort studies [20]. The NOS score for cohort studies focuses on three categories: selection, comparability and outcome. The maximum stars of NOS score are 9 stars. An article assessed ≥6 stars was considered to be of high quality and adopted in our study.

2.5. Data extraction

Two independent teammates (YT, CSY) extracted the following information in the 2 groups: name of first author, year of publication, study type, mean age with deviations, gender, number of populations, and main outcomes, including postoperative complications, operative time, blood loss, hospital stays and expenses. Patients were divided into two subgroups (pediatric group and adult group) according to their mean age at surgery.

2.6. Statistical analysis

Statistical analysis was conducted by Review Manager version 5.4. Relative risk (RR) was applied for dichotomous variables, and mean difference (MD) was applied for continuous variables. Some study outcomes were reported as medians with ranges or mid-quartiles with ranges. According to the methods introduced by Wan [21] and Hozo [22], those data were converted to means with deviations. The I^2 statistic was used to test the degrees of heterogeneity. And I^2 greater than 50% was considered to indicate high heterogeneity and then a random-effects model was applied to pool the results. However, an I^2 less than 50% was considered to indicate low heterogeneity, and then a fixed-effects model was used. To assess the risk of bias, the "Risk of bias" assessment tool was applied to the included records. A P value < 0.05 was considered to be statistically significant.

3. Results

3.1. Characteristics of included studies

The study flow was shown in Fig. 1. A total of 222 records were identified through the article search. After removing duplications, 158 records were excluded by reviewing the articles and abstracts. Furthermore, 2 records were excluded after assessing full-text articles for eligibility, and 1 record was excluded for its NOS score ≤5 stars. Finally, 6 retrospective cohort studies with 484 patients (307 in the LA group and 177 in the RA group) were enrolled in our study [11–16].

The baseline characteristics of the 6 records were listed in Table 1. All 6 articles were published in or after 2018. Patients of 3 records [11,13,15] were children, while that of the other 3 records [12,14,16] were adults. The NOS scores were ranged from 6 to 8 stars, reflecting the quality of cohort studies. The gender, age at surgery, weight, cyst type, diameter and BMI were comparable in each group.

The methodological quality was summarized in Fig. 2. The operative team in each report was mentioned as the same one to perform both the laparoscopic and robotic-assisted surgery. None of these 6 records described that the operational selection was a randomized sequence (selection bias). In addition, allocation concealment was not introduced adequately (selection bias). For those natures that the authors were also surgical teammates, it seemed impossible to conduct blinding of participants and personnel (performance bias), and blinding of outcome assessment (detection bias). After careful assessment of Koga's report [13], a brief description of follow-up durations could not be observed, and it was rated as unclear of bias. In Lee's report, some postoperative complications were not introduced clearly, and it was also rated as unclear of bias (attrition bias). Furthermore, there was not deliberate selection of target patients to report in order to obtain the positive or negative results in 6 records. Consequently, the selective reporting (reporting bias) and others (other bias) were rated as having a low risk of bias.

3.2. Primary outcomes: postoperative complications

3.2.1. Short-term complications

All 6 studies [11–16] contributed data, including 484 CDC patients (307 in the LA group and 177 in the RA group, Table 2). Heterogeneity was not significant ($I^2 = 37\%$, $P = 0.16$, Fig. 3); therefore, a fixed-effects model was applied. Meta-analysis showed no significant difference between the 2 groups (RR = 1.55, 95% CI = 0.74 to 3.23, $P = 0.24$). A total of 25 patients in the LA group (8.1%) and 8 patients in the RA group (4.5%) were diagnosed with short-term complications. The most common short-term complications were bile leakage in both the LA group (n = 14, 4.6%) and RA group (n = 6, 75.0%). Additionally, 11 patients in the LA group had developed bleeding (n = 4, 1.3%), intestinal obstruction (n = 2, 0.7%), wound infection (n = 2, 0.7%), acute pancreatitis (n = 1, 0.3%), fluid collection (n = 1, 0.3%) and vein thrombus (n = 1, 0.3%). The other 2 patients in the RA group suffered bleeding (n = 1, 12.5%) and umbilical herniation (n = 1, 12.5%). Subgroup analysis demonstrated no significant difference in pediatric (RR = 2.66, $P = 0.17$) and adult groups (RR = 1.23, $P = 0.65$).

3.2.2. Long-term complications

All 6 studies [11–16] contributed data, including 484 CDC patients (307 in the LA group and 177 in the RA group, Table 2). Heterogeneity was not significant ($I^2 = 0\%$, $P = 0.65$, Fig. (3), and a fixed-effects model was consequently used. There was no significant difference between the 2 groups (RR = 1.40, 95% CI = 0.63 to 3.10, $P = 0.41$) according to the

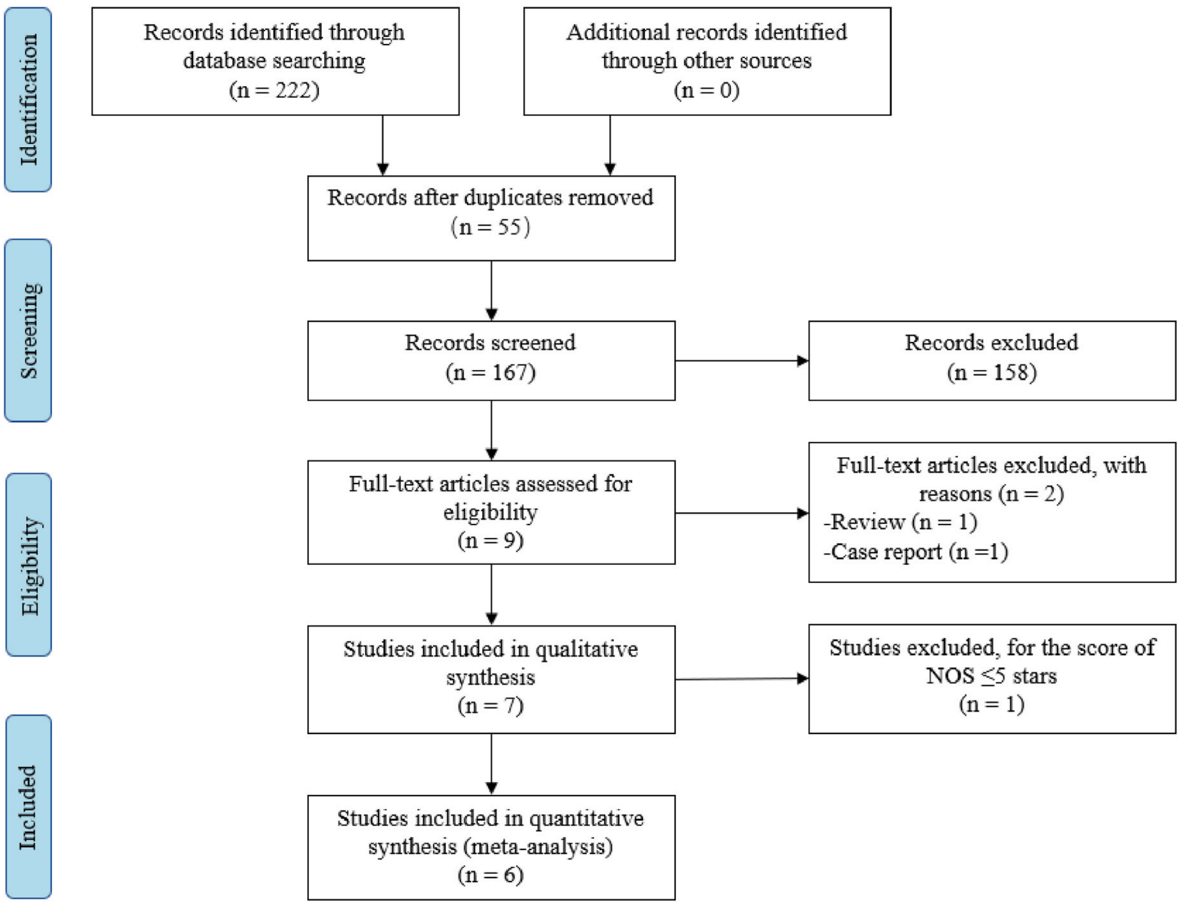

Fig. 1. The study flow.

Table 1
Characteristics of 6 records enrolled in the meta-analysis.

Name, year	Study type	Level of evidence		Number of patients	Gender	Age at surgery (months, years)	Follow-up (months)	NOS scores	Weight (kg)	Cyst type	Diameter (cm)	BMI (kg/m^2)
Chi [11], 2021	R	III	LA	70	22/48	36.21 ± 32.80 m	31.5 (13.8–42)	8	NR	65 I, 5 Ⅳ	NR	NR
			RA	70	22/48	34.00 ± 27.71 m	24 (14–39)		NR	65 I, 5 Ⅳ	NR	NR
Han [12], 2018	R	III	LA	34	7/27	37.5 ± 11.60y	5–100	8	NR	22 I, 12 Ⅳ	5.23	
			RA	22	0/22	35.3 ± 11.05y			NR	16 I, 6 Ⅳ	5.04	
Koga [13], 2019	R	III	LA	27	NR	5.2 ± 3.8 (0.7–13.8) y	NR	6	18.7 ± 8.2 (9.9–35.6)	NR	NR	15.9 ± 1.2
			RA	10	NR	5.6 ± 3.4 (1.8–11.2) y	NR		18.5 ± 11.6 (9.0–29.7)	NR	NR	15.6 ± 2.6
Lee [14], 2018	R	III	LA	49	6/43	36.57 ± 10.84y	Every 12-18	8	NR	33 I, 16 Ⅳ	NR	21.38 ± 2.98
			RA	18	0/18	36.17 ± 13.33y			NR	14 I, 4 Ⅳ	NR	20.94 ± 2.10
Xie [15], 2020	R	III	LA	104	25/79	28.00 (8.75–53.00) m	36	8	13.06 ± 6.06	90 I, 14 Ⅳ	3.78 ± 2.39	
			RA	41	10/31	48.00 (30.50–77.50) m	20		18.74 ± 11.44	33 I, 8 Ⅳ	3.18 ± 1.65	
Yoon [16], 2021	R	III	LA	23	3/20	34.3 ± 11.2y	Every 6	7	NR	22 I, 1 II	9.8 ± 1.9	23.0 ± 3.0
			RA	16	3/13	37.0 ± 10.7y			NR	16I	11.5 ± 4.3	21.4 ± 2.4

R: retrospective; LA: laparoscopic operation; RA: robotic-assisted operation; NR: not reported; BMI: body mass index.

meta-analysis. A total of 21 patients in the LA group (6.8%) and 8 patients in the RA group (4.5%) were diagnosed. Anastomotic strictures were the most common long-term complication in the 2 groups (8/307, 2.6% vs. 3/177, 1.7%). Additionally, patients in the LA group had cholelithiasis (n = 7, 2.3%), residual cysts (n = 2, 0.7%) and intestinal obstructions (n = 2, 0.7%). In Lee's report [14], another 2 patients

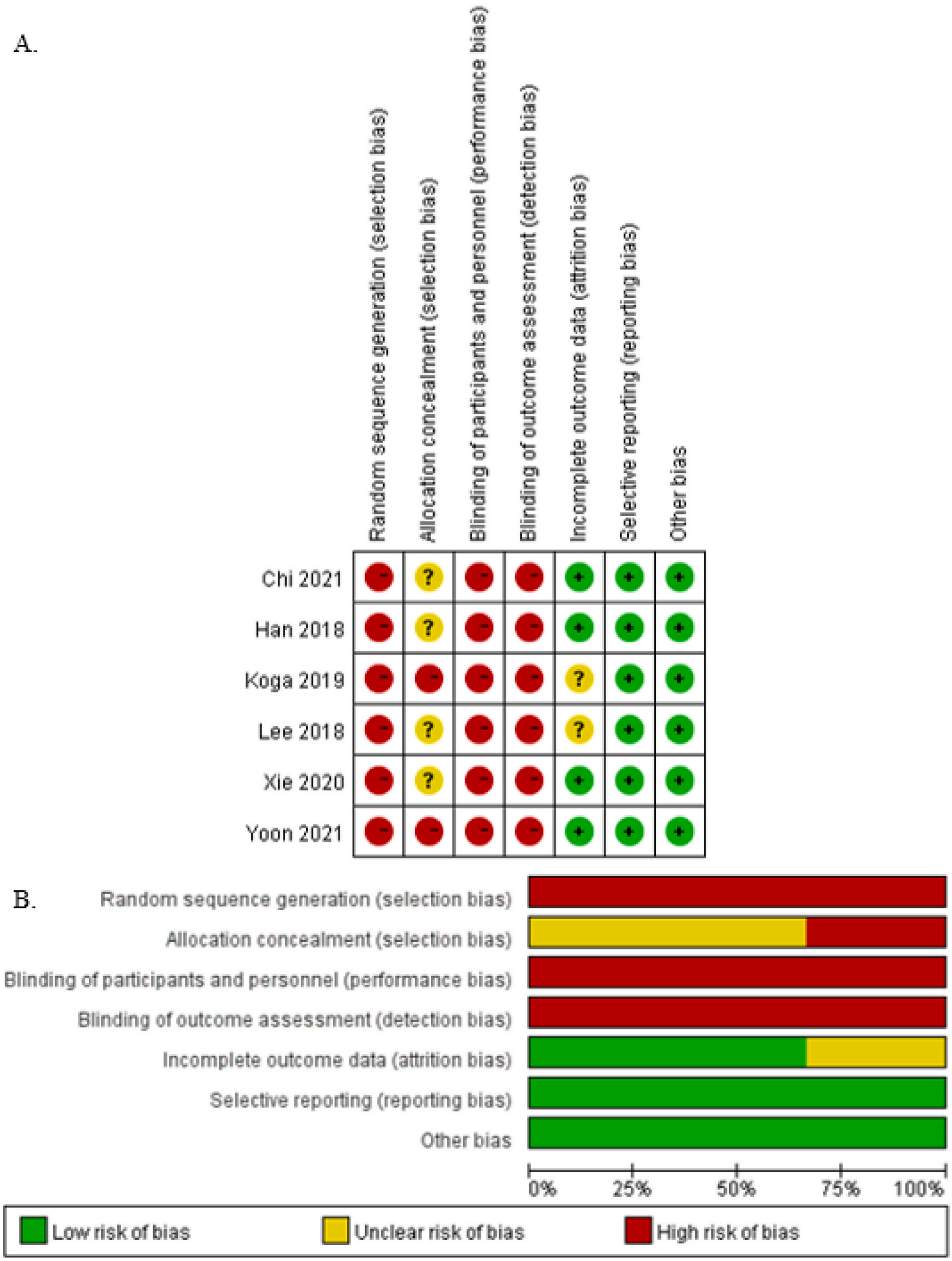

Fig. 2. Methodological quality assessment of the included records: (A) risk of bias summary; (B) risk of bias graph.

developed long-term complications, which were introduced vaguely. Other patients in the RA group had cholangitis (n = 2, 25.0%), intestinal obstructions (n = 2, 25.0%) and delayed fluid collection (n = 1, 12.5%). No statistical difference was noticed in both pediatric group (RR = 2.63, $P = 0.21$) and adult group (RR = 1.01, $P = 0.98$).

3.2.3. *Total complications*

All 6 studies [11–16] contributed data, including 484 CDC patients (307 in the LA group and 177 in the RA group, Table 2). Heterogeneity was significant ($I^2 = 57\%$, $P = 0.04$, Fig. (3), and a random-effects model was consequently adopted. Meta-analysis showed no significant difference between the 2 groups (RR = 1.53, 95% CI = 0.59 to 3.94, $P = 0.38$). A total of 46 patients in the LA group (15.0%) and 16 patients in the RA

Table 2
Complications, operational details and postoperative outcomes of 6 records enrolled in the meta-analysis.

Name, year		Number of patients	Postoperative complications			Operative time (minutes)	Blood loss	Hospital stays (days)	Expenses
			Short-term	Long-term	Total				
Chi [11], 2021	LA	70	4	3	7	172.00 (157.25–186.75)	23.24 ± 4.93 ml	7.91 ± 1.47	NR
	RA	70	0	1	1	229.50 (198.00–251.00)	6.81 ± 2 ml	6.94 ± 1.21	NR
Han [12], 2018	LA	34	4	3	7	236.2 ± 62.9	NR	7 ± 3.5	NR
	RA	22	2	1	3	258.5 ± 52.9	NR	7 ± 3	NR
Koga [13], 2019	LA	27	1	0	1	618 ± 96	0.91 ± 0.5 ml/kg	11 ± 2.4	NR
	RA	10	0	0	0	654 ± 144	0.70 ± 0.32 ml/kg	7.4 ± 1	NR
Lee [14], 2018	LA	49	11	7	18	181.31 ± 43.06	108.71 ± 15.53 ml	7.33 ± 2.96	NR
	RA	18	0	2	2	247.94 ± 54.14	172.78 ± 117.46 ml	6.22 ± 1.06	NR
Xie [15], 2020	LA	104	3	6	9	212.79 ± 34.94	21.73 ± 11.44 ml	7.56 ± 1.08	35,430 ± 1847 ¥
	RA	41	1	1	2	180.61 ± 14.07	21.34 ± 9.42 ml	7.55 ± 1.00	62,320 ± 3798 ¥
Yoon [16], 2021	LA	23	2	2	4	333.6 ± 60.9	128.3 ± 159.1 ml	11.4 ± 6.3	6568 ± 1047$
	RA	16	5	3	8	362.9 ± 86.6	156.9 ± 214.7 ml	14.7 ± 5.6	7331 ± 720$

LA: laparoscopic operation; RA: robotic-assisted operation; NR: not reported.

group (9.0%) were diagnosed with total complications. Besides, the outcomes of two operative methods were comparable in pediatric group (RR = 2.53, $P = 0.11$), as well as in adult group (RR = 1.14, $P = 0.86$).

3.3. Secondary outcomes: operative details

3.3.1. Operative time

All 6 studies [11–16] contributed data, including 484 CDC patients (307 in the LA group and 177 in the RA group, Table 2). Heterogeneity was significant between studies ($I^2 = 99\%$, $P < 0.00001$, Fig. (4), and a random-effects model was applied subsequently. Reviewing the enrolled articles, five studies [11–14,16] reported less operative time in the LA group. However, meta-analysis showed no significant difference between the 2 groups (MD = −28.75 min, 95% CI = −77.13 to 19.64 min, $P = 0.24$). In Koga's report [13], the mean operative time was 618 min and 654 min in the 2 groups, which were significantly longer than the other 5 reports. Subgroup analysis showed that the operative time of the 2 groups was similar in pediatric patients (MD = −17.27 min, $P = 0.65$). But in adult patients, the LA group had significant shorter operative time than that in RA group (MD = −4.45 min, $P = 0.009$).

3.3.2. Blood loss

Four studies [11,14–16] contributed data, including 391 CDC patients (246 in the LA group and 145 in the RA group, Table 2). Heterogeneity was also significant between studies ($I^2 = 96\%$, $P < 0.00001$, Fig. 4). Thus, a random-effects model was applied. Meta-analysis showed no significant difference between the 2 groups (MD = 2.28 ml, 95% CI = −13.51 to 18.06 ml, $P = 0.78$). There was no statistical difference between the 2 groups in pediatric patients (MD = 8.50 ml, $P = 0.29$). However, adult patients demonstrated significantly lower blood loss (MD = −63.18 ml, $P = 0.01$) in favor of laparoscopic management.

3.4. Secondary outcomes: postoperative outcomes

3.4.1. Hospital stays

All 6 studies [11–16] contributed data, including 484 CDC patients (307 in the LA group and 177 in the RA group, Table 2). The analysis of the pool showed statistically significant heterogeneity ($I^2 = 89\%$, $P < 0.00001$, Fig. (5), and a random-effect model was consequently adopted. Yoon's article reported that the mean hospital stay in the LA group was shorter than that in the RA group, and Han's article reported the comparable hospital stays in the 2 groups. The other 4 articles reported longer hospital stays in the LA group. To compare the pool, the mean difference stated no significant difference between the LA and RA groups (MD = 0.89 days, 95% CI = −0.13 to 1.91 days, $P = 0.09$). According to subgroup studies, the LA group had little longer hospital stays in pediatric patients (MD = 1.41 days, $P = 0.05$), but there was no significant difference. Nevertheless, the hospital stays were similar in the 2 groups in adult patients (MD = −0.00 days, $P = 1.00$).

3.4.2. Expenses

Two articles contributed data, including 184 CDC patients (127 in the LA group and 57 in the RA group, Table 2). To further assess the results, the expenses were converted to dollars, based on the exchange rate of December 2021 (1 ¥ = 0.157$). Heterogeneity was high ($I^2 = 99\%$, $P < 0.00001$, Fig. 5) and then a random-effect model was adopted. Due to its larger numbers, the forest plot could not show the whole results. It was obvious that the expenses of robotic-assisted operation were much higher than those of the laparoscopic operation, especially in Xie's report [15]. Pooled mean difference (MD = −3851.60$, 95% CI = −4031.84 to −3671.36$, $P < 0.00001$) indicated significantly higher costs in the RA group.

4. Discussion

With the developing demand in cosmetics, the magnified operational view, less surgical trauma and promoted postoperative recovery, the minimally invasive operation is becoming predominant in choledochal cysts. The first experience of laparoscopic surgery was reported by Farello in 1995 [3]. For decades, many studies had proven the safety and effectiveness of laparoscopic operation for CDCs. Woo [4] reported the first robotic-assisted operation for choledochal cyst in 2006. Since then, some centers had reported their experience with robotic-assisted approaches. However, no meta-analysis has compared the postoperative outcomes between the laparoscopic and robotic-assisted cyst excision and Roux-en-Y hepaticojejunostomy. The aim of our systematic review and meta-analysis was to compare the outcomes and safety between the 2 approaches.

The current meta-analysis, enrolling 6 retrospective cohort studies, included 484 CDC patients. Overall, the results suggested the comparable postoperative complications (primary outcomes), operative time, blood loss, and hospital stays (secondary outcomes). Moreover, the expenses of the RA group were far more expensive than those of the LA group. Subgroup analysis demonstrated the LA group had significant shorter operative time, and less blood loss in adult patients. Laparoscopic operations allowed rapidly changes of operational instruments and positions, which were limited in RA group once the dock was finished. This enables laparoscopic operations to reduce operative time. Otherwise, the outcomes were comparable between 2 groups in

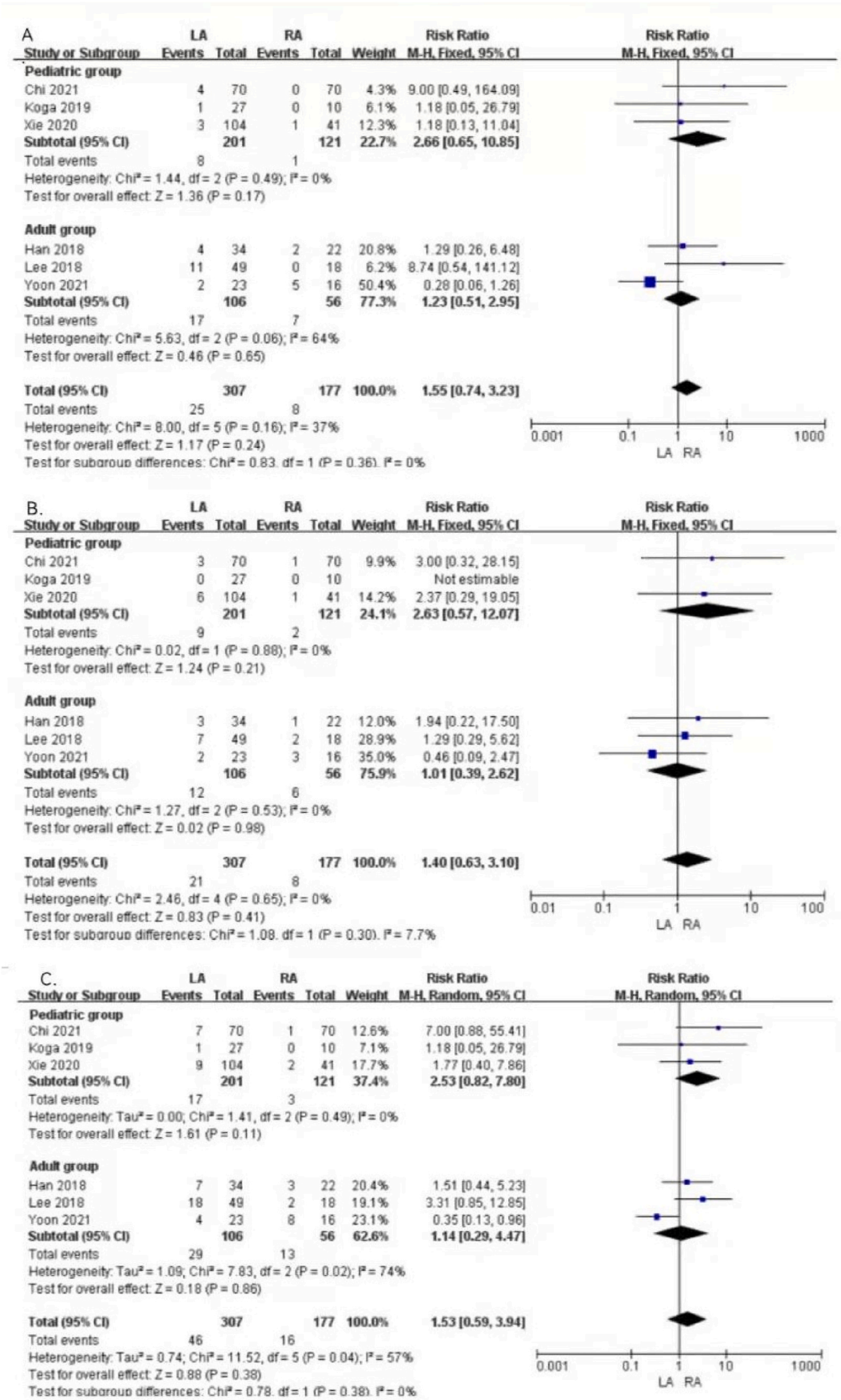

Fig. 3. Comparison of postoperative complications between the LA and RA groups. (A) Short-term complications; (B) long-term complications; (C) total complications.

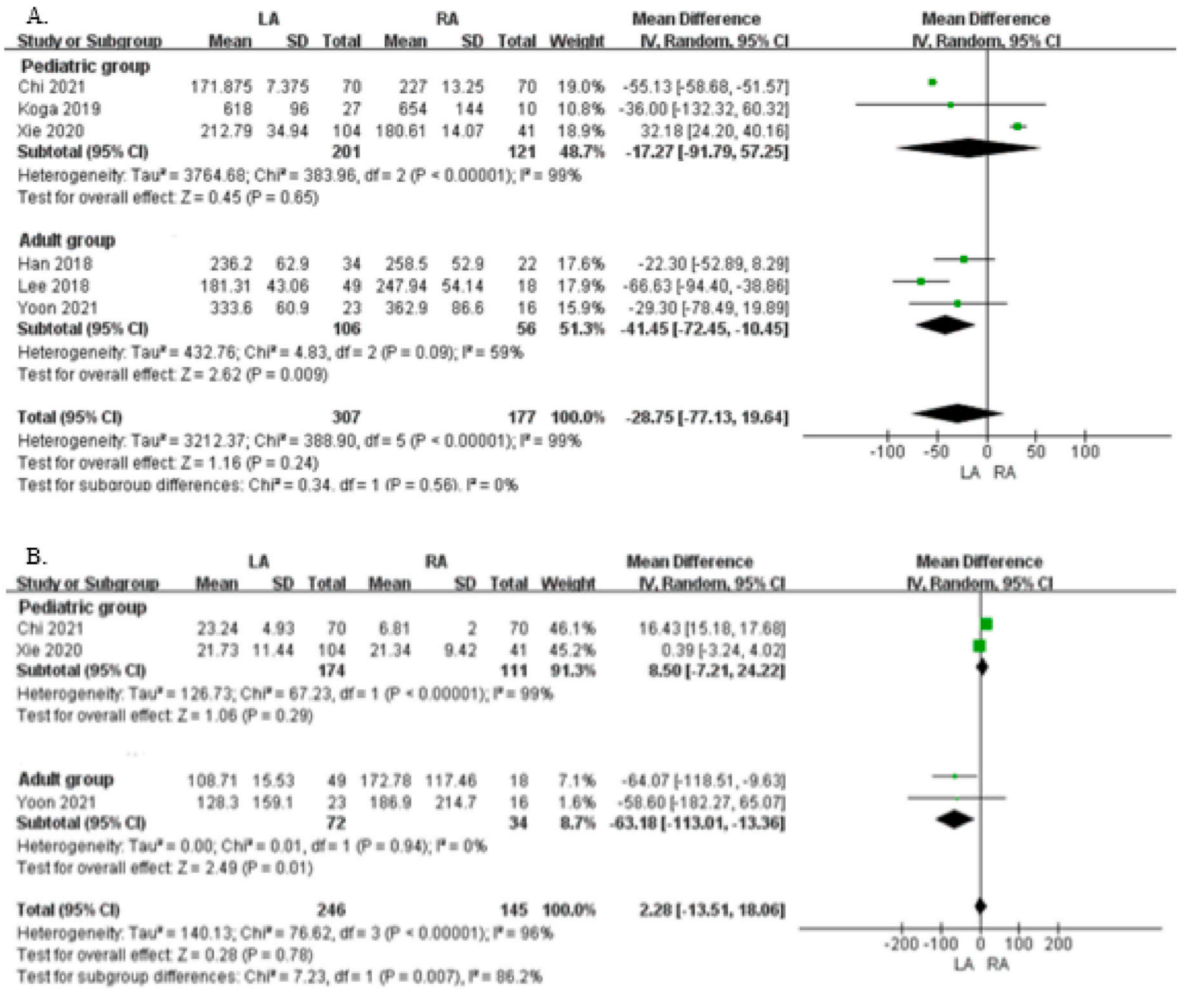

Fig. 4. Comparison of operational details between the LA and RA groups. (A) operative time; (B) blood loss.

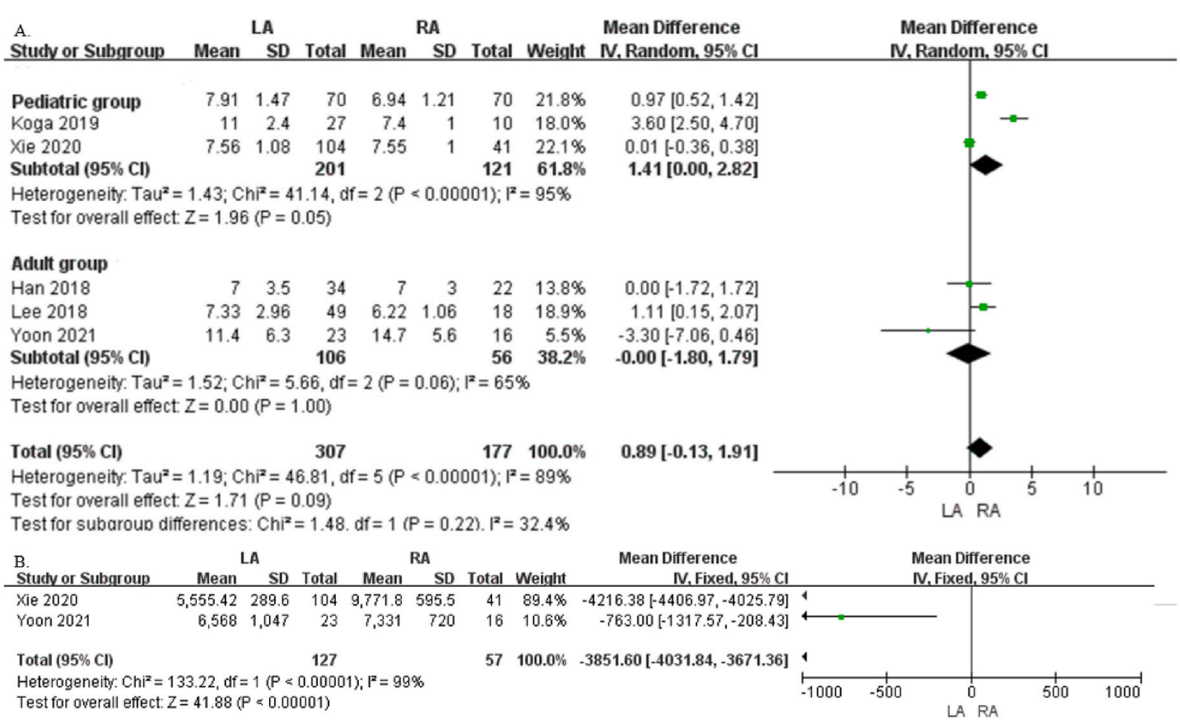

Fig. 5. Comparison of postoperative outcomes between the LA and RA groups. (A) hospital stays; (B) expenses.

pediatric patients, despite the small abdominal area making it hard to perform robotic-assisted surgery with enough inter-port distances to make flexible working space in children.

Contributed to the development of surgical instruments and surgical experiences, the predominance of laparoscopy has emerged in many countries for decades. Without the restriction of age or weight, laparoscopy could be applied in complicated CDC patients, such as newborns [23], perforated CDCs [24], two-stage CDCs [25], giant choledochal cysts [26] or redo-hepaticojejunostomy patients [27]. The completion of the learning curve for laparoscopic management is 35–37 cases [28,29]. Previous reported the much better intra- and post-operative outcomes of laparoscopic operation when compared to open surgery [30]. With the rigid surgical arms, laparoscopic operation is accompanied by a reduction in the abdomen and the fulcrum effect. However, the removable trocars and changeable arms allow laparoscopy with more operational strategies to facilitate the cyst disconnection and the Roux-loop formation. Many centers [13,14,16] have used laparoscopy to excise the choledochal cysts, and then performed robotic-assisted operations for anastomosis.

In 1987, the robot was first applied in the surgical field [31]. Recently, robotic-assisted operation was performed for CDCs. The robotic platform could provide the instruments with wrists, and bring out the high freedom to operate. In addition, the functions of tremor filtering and motion scaling could increase the dexterity and enable the operator to maneuver precise motion, such as suturing and knotting. The learning curve for robotic-assisted cyst excision and Roux-en-Y hepaticojejunostomy is 14 cases in pediatric patients [32]. However, the constraints of space and energy devices limit the patients' age and weight in robotic applications. Koga [13] felt that robotic-assisted operation was not suitable for children, although most CDC patients were diagnosed in their first ten years [33]. However, Dawrant [34] reported his experience with robotic-assisted operation in children less than 10 kg and found ergonomic advantages. Lack of force feedback is one of the worrisome points for robotic-assisted operation and this could further affect the precise dissection of the adjacent organs or adhesive tissues, especially in those inexperienced hands. Besides, total expenses were much higher in the RA group, which increases the economic burden on patients. The problem of surgical costs would influence the choice of operational management, especially in those countries where the robotic-assisted operation is not included the medical insurance system.

In general, laparoscopic and robotic-assisted cyst excision and hepaticojejunostomy are both safe operational maneuvers and have its own specialty. Robotic-assisted operation came latter and was developed based on laparoscopy also. Certainly, with the progress of minimally invasive surgical technology, more appropriate studies are required for choledochal cyst patient populations.

There are some limitations in our meta-analysis. First, the enrolled records were all retrospective cohort studies and lacked of randomized controlled studies, and that are inevitably subject to selection bias. Second, the operational teams were also report authors, therefore the performance bias and detection bias were very high. Third, only 6 records were analyzed, resulting in the potential risk of publication bias. Besides, the heterogeneities in some postoperative outcomes were too high. Additionally, further long-term follow-up is warranted.

5. Conclusion

Laparoscopic cyst excision and Roux-en-Y hepaticojejunostomy is as safe and effective as robotic-assisted operations due to their comparable postoperative complications, operative time, blood loss and hospital stays.

Conflict of interest

The authors declare no conflicts of interest.

Funding

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Ethics

Consent forms were obtained from the parents before the operation. This retrospective cohort study was approved by the Ethnical Committee of Capital Institute of Pediatrics.

Provenance and peer review

Not commissioned, externally peer-reviewed.

Ethical approval

Consent forms were obtained from the parents before the operation. This retrospective cohort study was approved by the Ethnical Committee of Capital Institute of Pediatrics.

Sources of funding

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Registration of research studies

1. Name of the registry: INPLASY.
2. Unique Identifying number or registration ID: INPLASY2021120024.
3. Hyperlink to your specific registration (must be publicly accessible and will be checked): https://doi.org/10.37766/inplasy2021.12.0024.

Guarantor

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CRediT authorship contribution statement

Tong Yin: project registration, systematic search, quality assessment, data extraction, Formal analysis, article writing. **Suyun Chen:** systematic search, quality assessment, data extraction, Formal analysis. **Qianqing Li:** Formal analysis, article editing. **Ting Huang:** Formal analysis. **Long Li:** article reviewing. **Mei Diao:** article reviewing, Funding acquisition.

Declaration of competing interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amsu.2022.103412.

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