



# Efficacy of robot-assisted hepaticojejunostomy and laparoscopic-assisted hepaticojejunostomy in pediatric congenital choledochal dilatation: a system review and meta-analysis

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## Abstract

**Purpose** The efficacy of robot-assisted hepaticojejunostomy (RAHJ) and laparoscopic-assisted hepaticojejunostomy (LAHJ) in children with congenital choledochal dilatation has been a topic of much debate and controversy. The purpose of this study was to evaluate the role of RAHJ and LAHJ in pediatric congenital choledochal dilatation.

**Method** The review program has been prospectively registered (PROSPEROID: CRD42022306868). We searched the PubMed, Embase, Cochrane, CBM, VIP, Web of Science, CNKI databases, and Wanfang databases from March 2021. The Mantel–Haenszel method and a random-effects model were used to figure out the hazard ratio (95% CI).

**Results** Ten studies evaluated eight hundred and sixty-nine subjects (three hundred and thirty-two in the robotic group and five hundred and thirty-seven in the laparoscopic group), meeting all inclusion criteria. Compared with the laparoscopic group, robotic group demonstrated fewer postoperative complications [ $p=0.0009$ ; OR=0.34 (95% CI, 0.18–0.64);  $I^2=3\%$ ], shorter postoperative hospital stay [ $p<0.0001$ ; MD=−2.05 (95% CI, −2.40–1.70);  $I^2=0\%$ ], and less intraoperative bleeding [ $p=0.008$ ; MD=−10.80 (95% CI, −18.80–2.81);  $I^2=99\%$ ]. There was no significant difference in operative time between the two groups [ $p=0.10$ ; MD=24.53 (95% CI, −5.11–54.17);  $I^2=99\%$ ]. The same situation happened in short-term complication outcomes [ $p=0.06$ ; RR=0.45 (95% CI, 0.19–1.04);  $I^2=0\%$ ]. However, children in the RAHJ group had significantly lower levels of long-term complications [ $p=0.04$ ; OR=0.41 (95% CI, 0.17–0.96);  $I^2=0\%$ ]. Hospitalization costs were significantly higher in the RAHJ group [ $p<0.00001$ ; OR=27,113.86 (95% CI, 26,307.24–27,920.48);  $I^2=0\%$ ]. For overall complications, subgroup analysis of literature published after 2020 and of literature with high quality scores showed a significant decrease in the RAHJ group.

**Conclusion** In children with congenital choledochal dilatation, RAHJ is associated with reduced intraoperative bleeding, postoperative complications, and length of stay. Robotic surgery has a bright future in the treatment of pediatric common hepatic duct cysts and deserves to be promoted and popularized.

**Keywords** Robot-assisted hepaticojejunostomy · Laparoscopic-assisted hepaticojejunostomy · Congenital choledochal dilatation · Meta-analysis

## Introduction

Congenital choledochal dilatation is a congenital malformation involving both local dilatation of the extrahepatic bile duct, including the common bile duct, and pancreaticobiliary maljunction. However, cases associated with intrahepatic bile duct dilatation can be included in this entity [1]. Congenital choledochal dilatation are uncommon congenital anomalies of bile ducts with an incidence of 1 in 100,000–150,000 live births in the western population [2–4], but reported to be as high as 1 in 13,500 live births in the United States and 1 in 15,000 in Australia [5]. The

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incidence is higher in Asian population with an incidence of 1 in 1000 [6], of which about two-third cases are reported from Japan [7]. Holistic examination of the data regarding robotic congenital choledochal dilatation excision in children makes it clear that more research is needed to examine the utility of this approach. The most recent and larger studies do show acceptable complication rates, and robotic congenital choledochal dilatation excision does not appear inferior with regard to complications if performed by experienced surgeons. On the other hand, concerns regarding the long operative times may be reinforced if forthcoming data show similar trends; additionally, cost-effective information should be reported given known expense of robotic platforms [8].

The current investigation is an updated meta-analysis of postoperative complications and postoperative length of stay for RAHJ and LAHJ for pediatric congenital choledochal dilatation. More specifically, a systematic evaluation and meta-analysis was performed to determine the impact of RAHJ and LAHJ on postoperative complications and postoperative length of stay.

## Materials and methods

### Search strategy

The review protocol was prospectively registered (PROSPEROID: CRD42022306868). A systematic review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guideline [9]. The search was conducted in the major electronic databases of PubMed, Embase, Cochrane, CBM, VIP, Web of Science, CNKI databases, and Wanfang databases.

Giving an example, we search terms such as choledochal cyst, robotic surgery, and literature types, as well

as all related MeSH terms. The keyword of the search was recorded in the appendix section.

When several studies reported findings for the same patients, the most recent or most complete study was chosen.

### Inclusion criteria

Studies were included according to the following criteria. Case inclusion criteria: (1) congenital choledochal dilatation diagnosed by magnetic resonance cholangiopancreatography; (2) children undergoing da Vinci robotic surgery or conventional laparoscopic surgery (including intraoperative conversion to open surgery); (3) surgery time, intraoperative bleeding, postoperative complications, and hospital stay were recorded.

We excluded articles that included in the study those who presented with choledochal cyst-related acute abdomen necessitating emergency surgery. Studies were excluded if the type of article was a case report or a review. A small number of studies were conference literature, where the original article could not be found, and were also excluded. (Fig. 1).

### Definitions

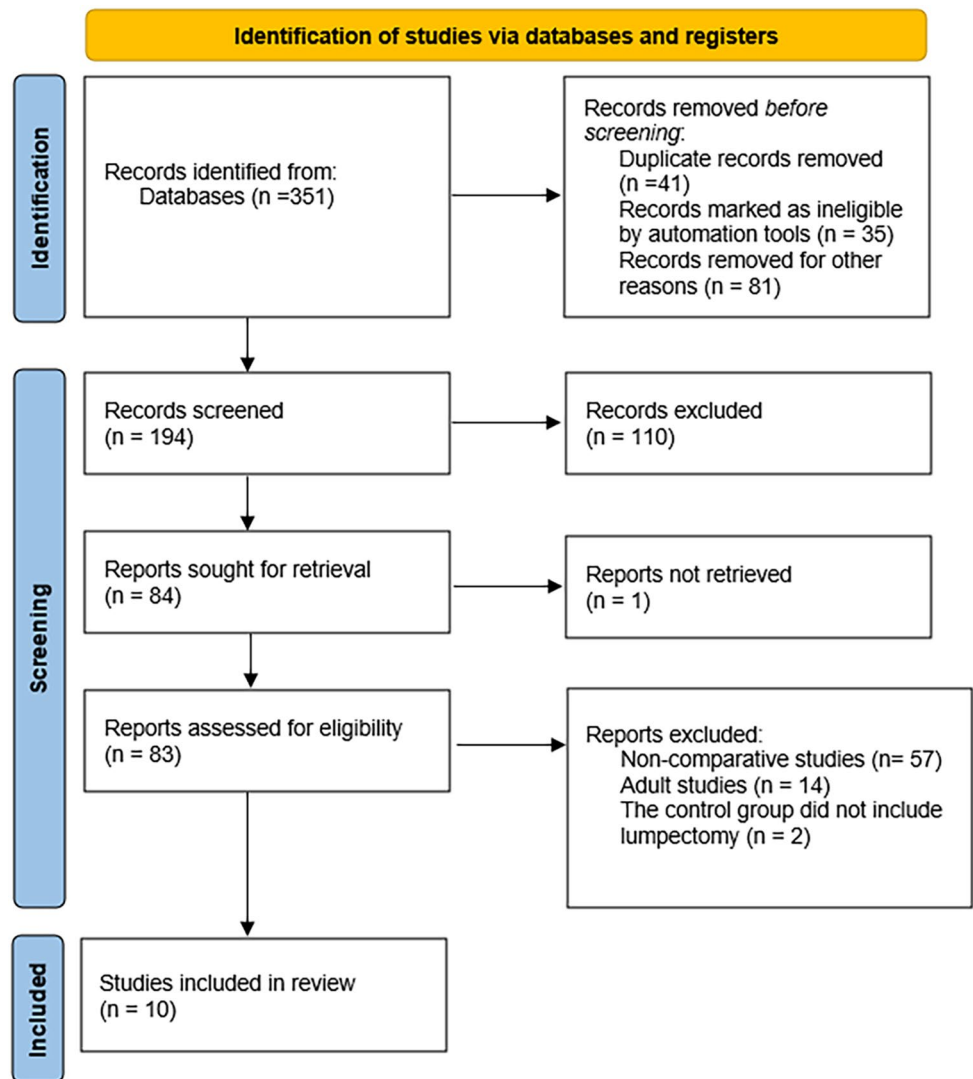
In this post, we focus on patients who underwent RAHJ and LAHJ. “RAHJ” stands for robot-assisted hepatic tunnel-jejunostomy and “LAHJ” stands for laparoscopic hepatic tunnel-jejunostomy.

### Data extraction

We reviewed all titles and abstracts to determine eligibility and retrieve articles. The following information was

**Table 1** Summary of all incorporated literature

References	Country	Typing	Sample size	Group number	No. of complication
Cai et al. [12]	China	I:44	44	RAHJ:25 LAHJ:19	RAHJ:2 LAHJ:1
Cai et al. [14]	China	II:5	5	RAHJ:1 LAHJ:4	No complications
S.Q.Chi et al. [19]	China	Ia:111 Ib:3 Ic:46 IVa:8 IVb:2	170	RAHJ:85 LAHJ: 85	RAHJ:4 LAHJ:12
Dong et al. [20]	China	I:87 Others:16	103	RAHJ:21 LAHJ:82	RAHJ:1 LAHJ:5
Xiao et al. [15]	China	V:2	2	RAHJ:1 LAHJ:1	No complications
Xie et al. [13]	China	I:341 II:1 IV:59	401 (172)	RAHJ:54 LAHJ:118 OS:229	OS:7 LAHJ:9 RAHJ:2
Chi et al. [19]	China	Ia: 87 Ib: 3 Ic: 40 IVa: 8 IVb: 2	140	RAHJ:70 LAHJ:70	RAHJ:3 LAHJ:21
Koga et al. [11]	Japan	NA	37	RAHJ:10 LAHJ:27	LAHJ:1
Lin et al. [22]	China	Ia:29 Ib:3 Ic:11 IVa:7 IVb:1	51	RAHJ:24 LAHJ:27	RAHJ:2 LAHJ:23
Xie et al. [18]	China	I: 312 II: 1 IV: 58	371 (145)	RAHJ:41 LAHJ:104 OS: 226	RAHJ:2 LAHJ:9 OS: 7

**Fig. 1** Schematic diagram of the literature selection process

extracted according to a fixed protocol: study design, geographical location, stage, sample size, group number, and number of complications (Table 1).

### Validity assessment

The quality of included studies was assessed independently by the Newcastle–Ottawa Quality Assessment Scale. The scale comprises three factors: patient selection, comparability of the study groups, and assessment of outcome. A score of 1 was awarded for each item if the standard was completely met, a score of 0.5 was awarded if the standard was partially met, and a score of 0 was awarded if it was not met or if it was unclear whether it was met. The total score for each study was then calculated, a score of  $> 6$  indicated a high-quality study, a score of  $\geq 3$  and  $\leq 6$  indicated a median-quality study, while a score of  $\geq 0$  and  $\leq 2$  indicated a low-quality study [10].

None of the ten included studies stated that operational selection was randomized (selection bias). The type of topic of our study dictates that confidentiality of participants and personnel is not possible (performance bias). The same happens with the confidentiality of the assessment of the results (test bias). After careful assessment of reports of Koga et al. [11], Cai et al. [12], Xie et al. [13], a brief description of follow-up durations could not be observed, and it was rated as unclear of bias. In reports of Cai et al. [14], Xiao et al. [15], some postoperative complications were not introduced clearly, and it was also rated as unclear of bias (attrition bias). These cases are summarized in Fig. 2.

### Statistical analysis

Statistical analysis was conducted by Review Manager version 5.4. The significance of pooled OR/MD was assessed by Z test, and a  $P$  value  $< 0.05$  was considered significant.

	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personnel (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Cai 2021	⊖	⊖	⊖	⊖	⊕	⊕	?
Cai 2022	⊖	⊖	⊖	⊖	⊕	⊕	?
Chi 2021	⊖	⊖	⊖	⊖	⊕	⊕	?
Dong 2021	⊖	⊖	⊕	⊖	⊕	⊕	?
Koga 2019	⊖	⊖	⊖	⊖	⊕	⊕	?
Lin 2022	⊖	⊖	⊖	⊖	⊕	⊕	?
S. Q. Chi 2021	⊖	⊖	⊖	⊖	⊕	⊕	?
Xiao 2019	⊖	⊖	⊖	⊖	⊕	⊕	?
Xie 2020	⊕	⊖	⊖	⊖	⊕	⊕	?
Xie 2021	⊖	⊖	⊖	⊖	⊕	⊕	?

Fig. 2 Risk of bias statistics for the included literature

Statistical heterogeneity between studies was assessed by  $I^2$  and Q statistics. The  $I^2$  statistic was used to test for heterogeneity. More than 50% of  $I^2$  was considered to be highly heterogeneous and the results were aggregated using random-effects models. However,  $I^2 < 50%$  is considered to be low heterogeneous, so fixed-effect models can be used, and subgroup analysis was used to explore potential causes of heterogeneity [16]. To assess the risk of publication bias, funnel plots were used to assess publication bias [17].  $P$  values  $< 0.05$  were considered significant for heterogeneity.

Table 2 Literature quality score

References	Selection	Comparability	Outcome	Total
Cai et al. [12]	3.5	0	1.5	5
Cai et al. [14]	3.5	1	2.5	7
S.Q.Chi et al. [19]	3.5	0	1.5	5
Dong et al.[20]	3.5	1	2.5	7
Xiao et al.[15]	3	0	2	5
Xie et al.[13]	3	1	2	6
Chi et al. [19]	3.5	2	2.5	8
Koga et al.[11]	3.5	2	2.5	8
Lin et al.[22]	3.5	2	2.5	8
Xie et al.[18]	3.5	1	2.5	7

## Results

Ten studies evaluated eight hundred and sixty-nine subjects (five hundred and thirty-seven in the laparoscopic group and three hundred and thirty-two in the robotic group). Sample sizes ranged from 2 to 172 (Table 1). The literatures were published in 2019 or later. Validity scores could be obtained in Table 2. Six articles were of high quality, four articles were of moderate quality, and low-quality articles were not being continued research. Xie et al. [13, 18] additionally documented surgical conditions, complications, and post-operative length of stay in open surgery patients.

## Results of the meta-analysis

Robotic surgery showed a trend toward reduced intraoperative bleeding and shorter postoperative hospital stay. There was no obvious distinction in operative time between the two groups. Robotic surgery group significantly improved the postoperative complication profile of patients. Children in the RAHJ group had significantly lower levels of long-term complications. However, short-term complication outcomes did not change obviously. RAHJ group was proved to be more expensive, as expected. For overall complications, subgroup analysis of literature published after 2020 and of literature with high quality scores showed a significant decrease in the RAHJ group.

## Intraoperative bleeding

Six studies provided data including seven hundred and eighty-one patients with congenital choledochal dilatation (two hundred and ninety-five in the RAHJ group and four hundred and eighty-six in the LAHJ group). Heterogeneity between studies was also significant ( $I^2 = 99%$ ,  $P < 0.00001$ ). Therefore, a random-effects model was

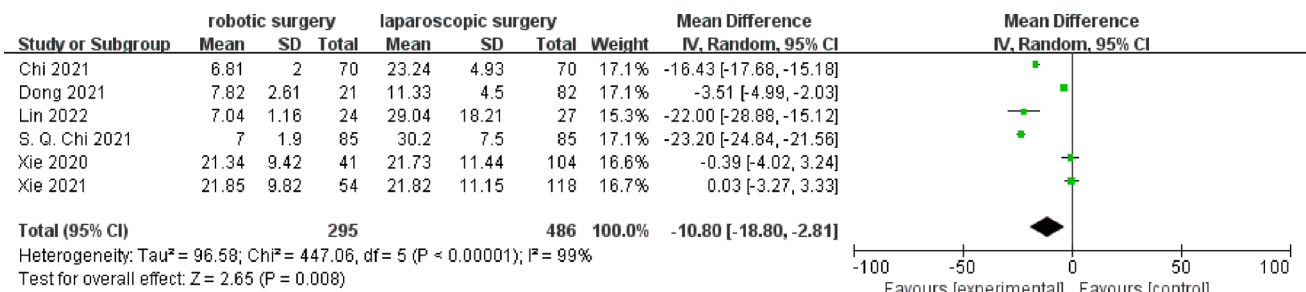


Fig. 3 Forest plot on intraoperative bleeding volume SD standard deviation

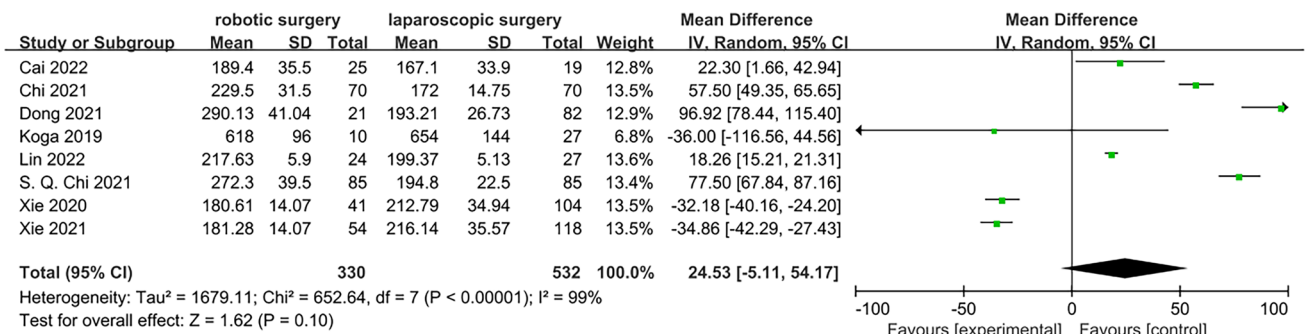


Fig. 4 Forest chart about the time of surgery SD standard deviation

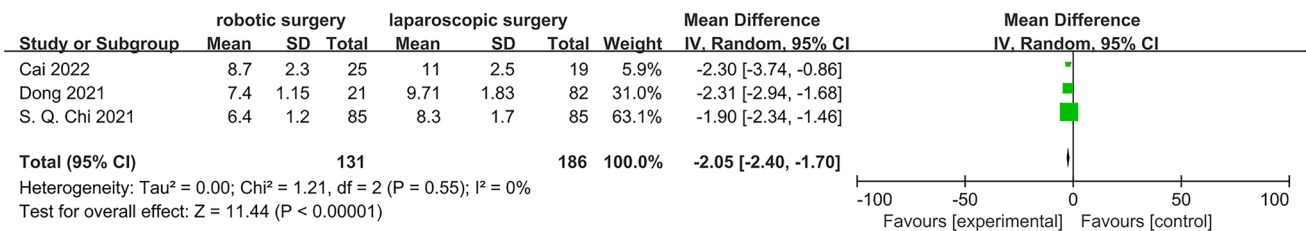


Fig. 5 Forest chart on postoperative hospital stay SD standard deviation

applied. Of the six studies included in the review, five studies reported less intraoperative bleeding in the RAHJ group. There was less intraoperative bleeding in the RAHJ group [ $p=0.008$ ; MD = - 10.80 (95% CI, - 18.80–2.81);  $I^2=99%$ ] (Fig. 3).

### Time to surgery

Eight studies [12, 13, 18–23] provided data including eight hundred and sixty-two patients with congenital choledochal dilatation (three hundred and thirty in the RAHJ group and five hundred and thirty-two in the LAHJ group). Heterogeneity between studies was significant [ $I^2=99%$ ,  $P<0.00001$ ],

and a random-effects model was subsequently applied. Of the included articles reviewed, five studies by Cai et al. [12], Chi et al. [19, 23], Dong et al. [20], and Lin et al. [22] reported less operative time in the LAHJ group. However, no obvious distinction happened on this indicators [ $p=0.10$ ; MD = 24.53 (95% CI, - 5.11–54.17);  $I^2=99%$ ] (Fig. 4).

### Postoperative hospital stay

In the current meta-analysis, a total of 457 cases were included in the 4 studies to study the issue of postoperative length of stay, and after sensitivity analysis, the article by Chi et al. was finally removed. A total of 3 articles were



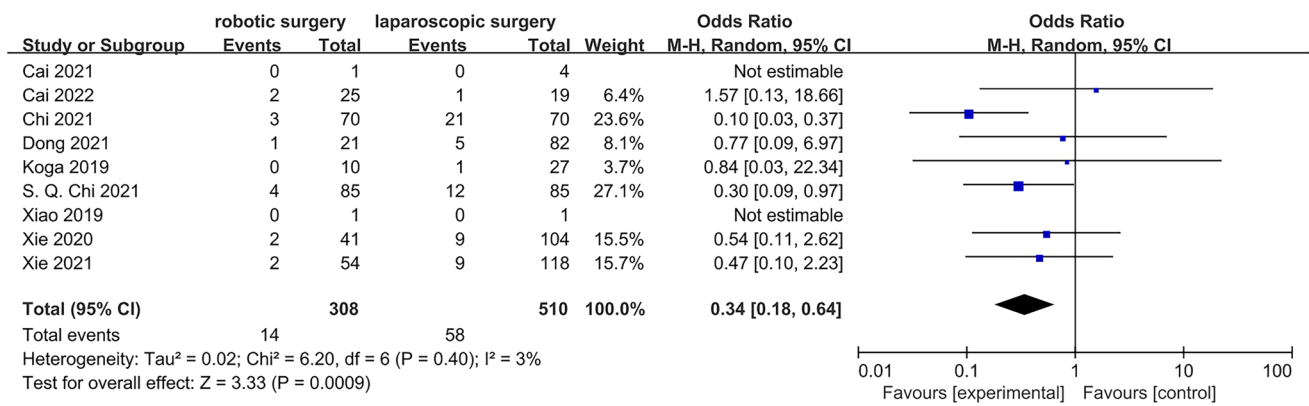


Fig. 6 Forest chart on total postoperative complications

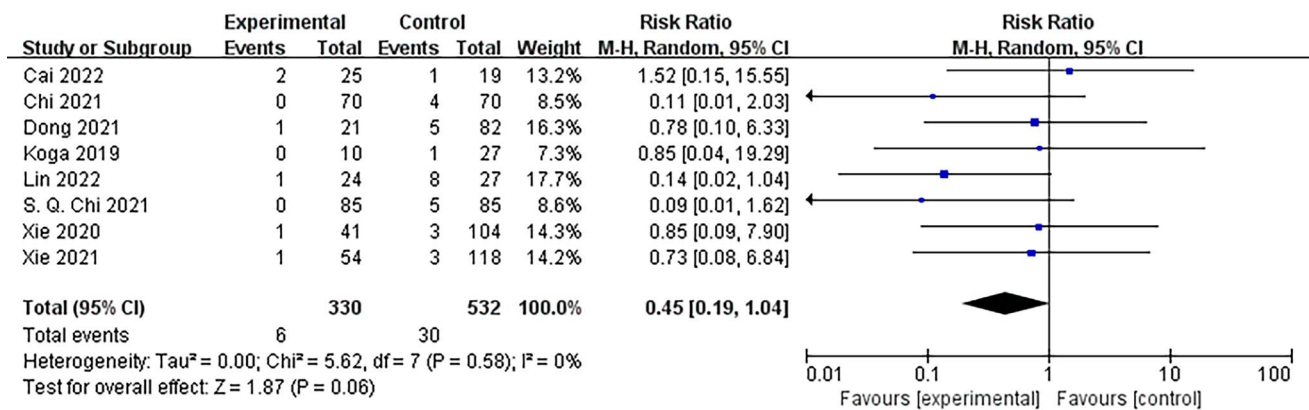


Fig. 7 Forest chart on short-term postoperative complications

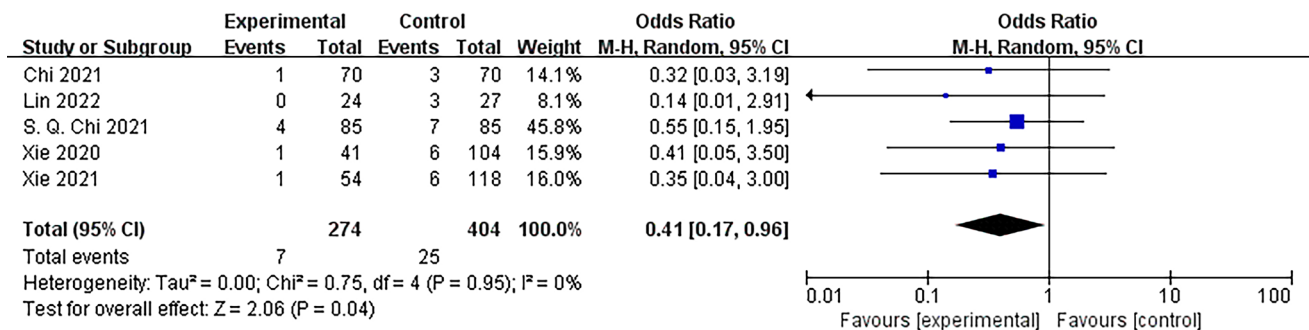


Fig. 8 Forest chart on long-term postoperative complications

finally included, including 131 cases in the RAHJ group and 186 cases in the LAHJ group. All of which showed a significantly lower postoperative length of stay in the RAHJ group compared to the LAHJ group [ $I^2 = 0\%$ ,  $P = 0.55$ ]. RAHJ group was able to significantly reduce the postoperative hospital stay [ $p < 0.00001$ ; MD = - 2.05 (95% CI, -2.40–1.70);  $I^2 = 0\%$ ] (Fig. 5).

## Postoperative complications

### Total complications

A total of 818 cases were included in the final 9 papers, 308 in the RAHJ group and 510 in the LAHJ group [ $I^2 = 3\%$ ,  $P = 0.40$ ]. RAHJ was associated with a reduction

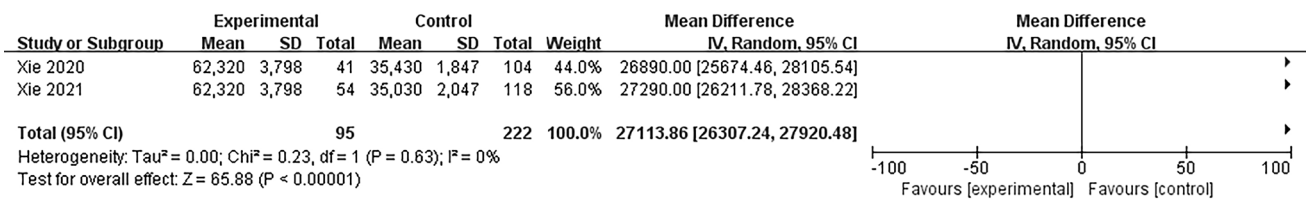


Fig. 9 Forest chart on costs during hospitalization SD standard deviation

in complications, possibly because of the reduced bleeding and operative time in the surgery [ $p = 0.0009$ ; MD = 0.34 (95% CI, 0.18–0.64);  $I^2 = 3%$ ] (Fig. 6).

**Short-term complications**

Short-term complications were defined as those that occurred within 30 days after surgery. Short-term complications were documented in 8 of the 10 publications, with a cumulative total of 862 cases included (330 in the RAHJ group and 532 in the LAHJ group). The overall heterogeneity was low [ $I^2 = 0%$ ,  $P = 0.58$ ]. The two surgical procedures did not produce obvious changes in this metric [ $p = 0.06$ ; RR = 0.45 (95% CI, 0.19–1.04);  $I^2 = 0%$ ] (Fig. 7).

**Long-term complications**

Long-term complications were defined as those that occurred more than 30 days after surgery. Long-term complications were documented in 5 of the 10 publications, with a cumulative total of 678 cases included (274 in the RAHJ group and 404 in the LAHJ group). The overall heterogeneity was low [ $I^2 = 0%$ ,  $P = 0.95$ ]. RAHJ group had significantly lower levels of long-term complications [ $p = 0.04$ ; OR = 0.41 (95% CI, 0.17–0.96);  $I^2 = 0%$ ] (Fig. 8).

**Hospitalization costs**

The cost of robotic surgery is undoubtedly higher than that of laparoscopic surgery. To discuss the difference in the total cost of the two treatment modalities when accounting for postoperative hospitalization costs, a further analysis was performed. Among them, the cost data recorded in the Cai et al. [12] article were recorded with interquartile spacing and were skewed [RAHJ: 11,250 (10,950 ~ 12,900) \$, LAHJ: 4800 (4050 ~ 5400) \$], so they are only statistically described here and not included in the combined analysis. The overall heterogeneity was low [ $I^2 = 0%$ ,  $P = 0.63$ ]. As expected, RAHJ group showed an expensive price [ $p < 0.00001$ ; OR = 27,113.86 (95% CI, 26,307.24–27,920.48);  $I^2 = 0%$ ] (Fig. 9).

**Subgroup analysis**

We performed subgroup analysis of total complications, short-term complications, and long-term complications of cases according to the year of publication (<2020, >2020) and quality score (high or medium; Table 3). Of the literature reporting long-term complications, the number of publications before 2020 was only one and could not be included in the combined analysis. There were no significant differences

**Table 3** Summary of subgroup analysis results TC total complications SC short-term complications LC long-term complications

Subgroups	TC: RAHJ vs. LAHJ	SC: RAHJ vs. LAHJ	LC: RAHJ vs. LAHJ
Years	OR = 0.59 [0.14, 2.44] $I^2 = 0%$ $P = 0.46$	RR = 0.85 [0.14, 5.21] $I^2 = 0%$ $P = 0.86$	–
< 2020	OR = 0.32 [0.14, 0.74] $I^2 = 26%$ $P = 0.008$	RR = 0.43 [0.15, 1.22] $I^2 = 4%$ $P = 0.11$	OR = 0.28 [0.07, 1.13] $I^2 = 0%$ $P = 0.07$
> 2020			
Quality	OR = 0.42 [0.18, 1.02] $I^2 = 0%$ $P = 0.06$	RR = 0.56 [0.12, 2.71] $I^2 = 20%$ $P = 0.47$	OR = 0.49 [0.16, 1.46] $I^2 = 0%$ $P = 0.20$
Moderate	OR = 0.31 [0.10, 0.95] $I^2 = 30%$ $P = 0.04$	RR = 0.39 [0.13, 1.11] $I^2 = 0%$ $P = 0.08$	OR = 0.30 [0.07, 1.20] $I^2 = 0%$ $P = 0.09$
High			

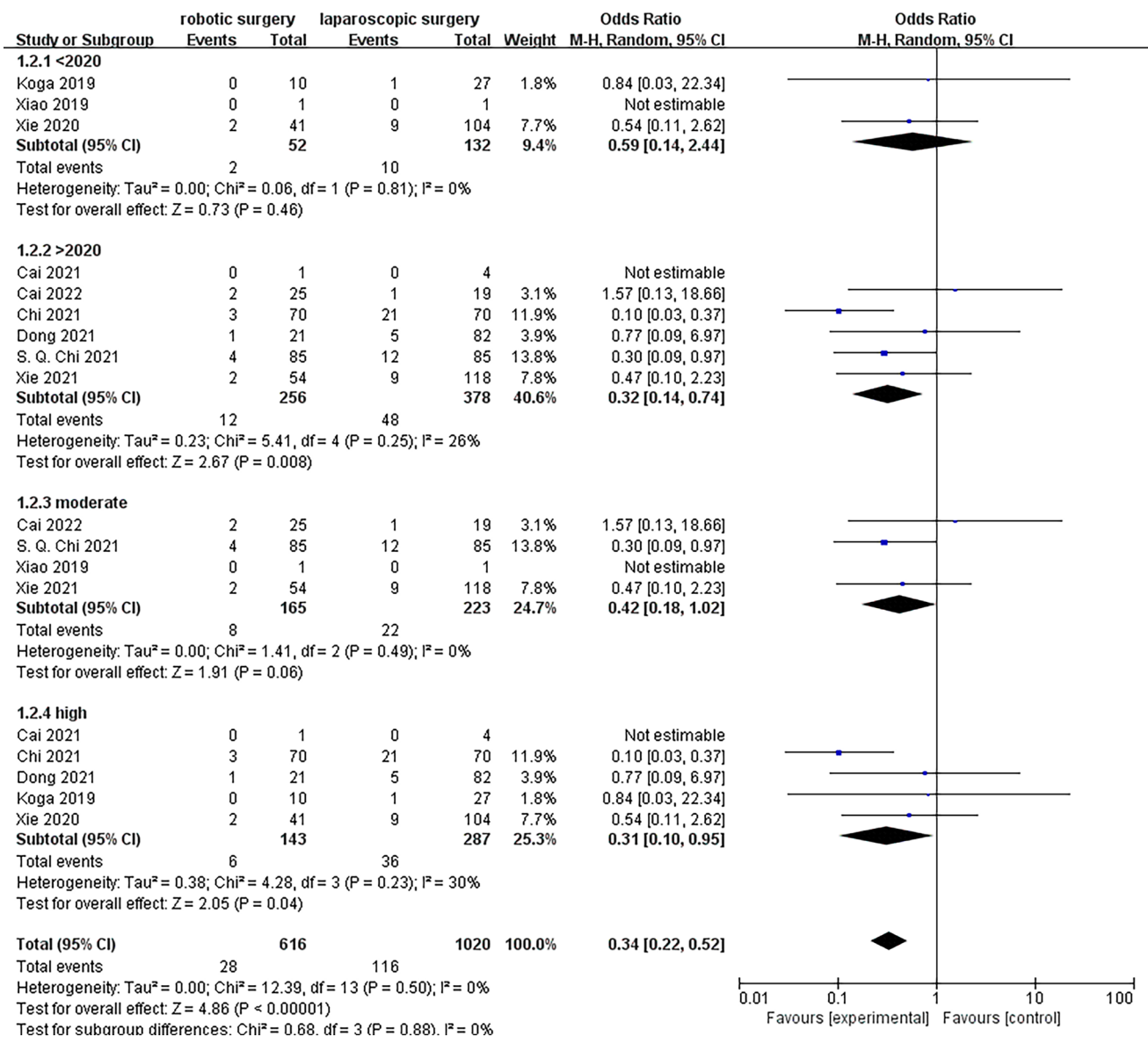


Fig. 10 Forest plot on subgroup analysis of postoperative complications

in levels in each subgroup, whether for long-term or short-term complications. For overall complications, subgroup analysis of literature published after 2020 and of literature with high quality scores showed a significant decrease in the RAHJ group, while subgroup analysis of literature published before 2020 and of literature with moderate quality scores showed no obvious distinction (Fig. 10).

**Publication bias**

In the funnel plots comparing postoperative complications (Supplementary Fig. 1), postoperative length of stay (Supplementary Fig. 2), intraoperative bleeding (Supplementary

Fig. 3), and operative time (Supplementary Fig. 4) between the RAHJ and LAHJ groups, studies grouped at the top of the plot suggest that larger studies with larger numbers of patients are more likely to be included. The lack of studies at the bottom of the graph suggests that publications with smaller sample sizes are rare.

**Discussion**

Robotic surgical system has been utilized in the treatment of choledochal cysts since 2006. Its advantages include three-dimensional visualization through a stereo endoscope, tremor reduction, motion scaling, and the additional degrees



of freedom compared to the standard laparoscopic instruments. However, at present, it is not widely accepted yet because of the size of current robotic hardware in relation to child's body size, the loss of hepatic feedback, special training requirement, and expensive hardware and maintenance of the robotic system. With the technical improvement, the refined robotic system will provide an optimal alternative to achieve the advanced goal of minimal invasive surgery, scarlessness, minimal surgical trauma, and steep learning curve [24]. More recent studies have shown improved outcomes compared to the early era of robotic choledochal dilatation excision [8]. The purpose of this study was to evaluate the role of robot-assisted and laparoscopic-assisted surgery in the management of children with congenital choledochal dilatation.

### **Intraoperative bleeding, time to surgery, and postoperative hospital stay**

The meta-analysis by Yin et al. in terms of intraoperative bleeding included 4 studies including 391 patients with choledochal dilatation (145 in the RAHJ group and 246 in the LAHJ group), where overall there was no significant difference in intraoperative bleeding between the RAHJ and LAHJ groups, subgroup analysis showed no significant difference between the two groups in pediatric patients, while adult patients showed lower bleeding [25]. Compared to the meta-analysis by Yin et al., this paper focuses on pediatric patients themselves rather than all age groups, includes a newer and more complete literature, and draws conclusions with improved reliability.

In Koga's report, the mean operative times in the two groups were 618 and 654 min, significantly longer than in the other seven groups. Similar to the meta-analysis on intraoperative bleeding, the heterogeneity of this part of the meta-analysis was very high. The clinical value of the conclusions drawn from it was low. The meta-analysis by Yin et al. in terms of surgery time included 6 studies including 484 patients with choledochal dilatation (177 in the RAHJ group and 307 in the LAHJ group), where overall there was no significant difference in surgery time between the RAHJ and LAHJ groups, subgroup analysis showed no significant difference between the 2 groups in pediatric patients, while adult patients showed significant shorter operative time [25]. This is consistent with the conclusion reached in this paper.

It is worth noting that patients' postoperative medications differed in different studies, which to some extent affects the accuracy of the conclusions on postoperative length of stay. The meta-analysis by Yin et al. on length of stay included 6 studies including 484 patients with biliary dilatation (177 in the RAHJ group and 307 in the LAHJ group), in which overall there was no significant difference in length of stay between the RAHJ and LAHJ groups, and subgroup analysis

showed no significant differences between the 2 groups in pediatric and adult patients [25]. This is inconsistent with the conclusion reached in this paper. This may be related to the small number of pediatric patient cases included in this literature.

## **Postoperative complications**

### **Total complications**

In the present analysis, ten reports described intraoperative and postoperative complications. Unexpectedly, Cai et al. [12, 14], Dong et al. [20], Xiao et al. [15], Xie et al. [13, 18], Chi et al. [19], Kim et al. [26], and Lin et al. [22] reported that complications were not related to the extent of resection. After sensitivity analysis, the article by Lin et al. was excluded.

### **Short-term complications**

A total of 6 (1.8%) patients in the RAHJ group were identified as having short-term complications, compared to a total of 30 (5.6%) in the LAHJ group. In the report by Cai et al. [12], there were one case of umbilical incision infection with abscess formation and one case of postoperative intra-abdominal bleeding in the RAHJ group with one case of bile leakage in the LAHJ group. In the report by Chi et al. [19], no short-term complications happened in the RAHJ group. Meanwhile, one child had anastomotic bleeding, one child had wound infection, two kids had bile leakage in the LAHJ group. In the report by Dong et al. [20], one kid who underwent RAHJ had pneumoperitoneum and number of the same indicator is three in the LAHJ group. Apart from this, there is one kid with incision infection and one kid with pancreatic fistula separately in the LAHJ group. In the report by Koga et al. [11], there were no short-term complications in the RAHJ group and anastomotic leakage complicated one LAHJ case. In the report by Lin et al. [22], there was one child who had upper respiratory infection in the RAHJ group. In the LAHJ group, one child had anastomotic bleeding accompanied by bile leakage. Three children had upper respiratory infection. Three children had wound infection. In the report by Chi et al. [23], there were two anastomotic bleeding cases, one wound infection case, and two bile leakage cases in LAHJ group while the number of cases in RAHJ group was zero. In the report by Xie et al. [18], one child with anastomotic bleeding received RAHJ while one child with anastomotic bleeding and two children with bile leakage received LAHJ. In the report by Xie et al. [13], there were one child with gallbladder bleeding in the RAHJ group and one child with gallbladder bleeding, two children with bile leakage in the LAHJ group.

The most common short-term complication in the RAHJ group was anastomotic bleeding ( $n=3$ , 50.0%), and the most common complication in the LAHJ group was wound infection ( $n=8$ , 26.7%). In addition, four patients in the RAHJ group had umbilical incision infection with abscess ( $n=1$ , 16.7%), intra-abdominal bleeding ( $n=1$ , 16.7%), upper respiratory tract infection ( $n=1$ , 16.7%), and peritoneal effusion ( $n=1$ , 16.7%). Twenty-two patients in the LAHJ group had biliary fistula ( $n=11$ , 36.7%), anastomotic bleeding ( $n=6$ , 20.0%), peritoneal effusion ( $n=1$ , 3.3%), pancreatic fistula ( $n=1$ , 3.3%), anastomotic fistula ( $n=1$ , 3.3%), and upper respiratory tract infection ( $n=3$ , 10.0%). In the report by Yin et al. [25], no significant differences in short-term complications were shown between RAHJ-treated and LAHJ-treated patients. The results of the subgroup analysis remained the same for the pediatric group as well as the adult group.

### Long-term complications

A total of 7 (2.6%) patients in the RAHJ group were identified as having short-term complications, compared to a total of 25 (6.2%) in the LAHJ group. In the report by Chi et al. [19], one child had cholangitis in the RAHJ group and the number of hepaticojejunostomy stricture, residual cyst, distal lithiasis was one separately in the LAHJ group. The median values of the follow-up time in the RAHJ group and the LAHJ group were 24 and 31.5 months. In the report by Lin et al. [22], one child developed stenosis of hepatoenteric anastomosis and two children developed cholangitis in LAHJ group while there were no long-term complications cases in the RAHJ group. In the RAHJ group, the average following time was  $13.38 \pm 2.02$  months. In the LAHJ group, the average following time was  $14.04 \pm 3.18$  months. In the report by Chi et al. [23], there were one child with stenosis of hepatoenteric anastomosis, two children with cholangitis, and one child with distal lithiasis in the RAHJ group. Meanwhile, two children had stenosis of hepatoenteric anastomosis, one child developed cholangitis, one child developed residual cyst, and three children developed distal lithiasis in the LAHJ group. The median values of the follow-up time in the RAHJ group and the LAHJ group were 34 and 36 months. In the report by Xie et al. [18], one child developed intestinal obstruction in the RAHJ group. In the LAHJ group, there were one child with intestinal obstruction, one child with biliary stones, one child with residual cyst, and three children with stricture of hepaticojejunostomy. The median follow-up time in the RAHJ group and the LAHJ group were, respectively, 20 months and 36 months. In the report by Xie et al. [13], there was one child with intestinal obstruction in the RAHJ group. However, there were three children with stricture of hepaticojejunostomy, one child with intestinal obstruction, one child with biliary stones,

and one child with residual cyst in the LAHJ group. The follow-up time was not mentioned.

The most common complication in the RAHJ group was cholangitis ( $n=3$ , 42.9%), and the most common complication in the LAHJ group was anastomotic stricture ( $n=10$ , 40.0%). Other long-term complications in the RAHJ group included anastomotic strictures ( $n=1$ , 14.3%), distal stones ( $n=1$ , 14.3%), and intestinal obstruction ( $n=2$ , 28.6%). Other long-term complications in the LAHJ group included residual abscesses ( $n=4$ , 16.0%), distal stones ( $n=4$ , 16.0%), cholangitis ( $n=3$ , 12.0%), gallstones ( $n=2$ , 8.0%), and intestinal obstruction ( $n=2$ , 8.0%). In the report by Yin et al. [25], there was no significant difference in the long term between the RAHJ and LAHJ groups in terms of the level of complications, and the same was true for the results of the pediatric and adult groups in the subgroup analysis.

### Secondary surgery and hospitalization costs and follow-up time

Among the ten publications, only the report of Xie et al. [18] clearly documented the secondary surgery, one case in the RAHJ group and five cases in the LAHJ group. In RAHJ group, one patient with bleeding at the hepaticojejunostomy received a reoperation with laparotomy. In LAHJ group, one patient with bleeding at the hepaticojejunostomy received an exploratory laparotomy, one patient with biliary stone received choledochojejunostomy and lithotomy, three patients with stricture of the hepaticojejunostomy received a reoperation of choledochojejunostomy.

The analysis result of hospitalization costs is also in line with expectations. However, only two Chinese studies were included in this price comparison. Koga et al. [11] reported that the Japanese national health insurance system does not cover the use of robotic surgery, resulting in an average procedure cost of approximately \$15,000. There are few statistical studies related to congenital choledochal dilatation abroad, and the cost issue lacks supporting literature. Therefore, the conclusions are limited for foreign children.

Seven articles mentioned the issue of follow-up time. Among them, the mean of the follow-up time exceeded 24 months in both the RAHJ and LAHJ groups as reported by S. Q. Chi et al. [23], Chi et al. [19], and Lin et al. [22].

### Subgroup analysis

We believe the outcome is due to the increasing popularity of the surgical da Vinci robot over time, as well as the increasing experience and proficiency of robotic surgical operators through continuous practice and training, which undoubtedly contributes to the improvement of robotic surgical outcomes. At the same time, articles with high quality scores imply less



Abstract])) OR (Common Bile Duct Cyst[Title/Abstract])) OR (Cyst, Common Bile Duct[Title/Abstract])) OR (Cysts, Common Bile Duct[Title/Abstract])) OR (Choledochal Cyst, Type III[Title/Abstract])) AND (((((((((((((((((((((((((Robotic Surgical Procedures[Title/Abstract])) OR (Procedure, Robotic Surgical[Title/Abstract])) OR (Procedures, Robotic Surgical[Title/Abstract])) OR (Robotic Surgical Procedure[Title/Abstract])) OR (Surgical Procedure, Robotic[Title/Abstract])) OR (Robot Surgery[Title/Abstract])) OR (Robot Surgeries[Title/Abstract])) OR (Surgery, Robot[Title/Abstract])) OR (Robot-Assisted Surgery[Title/Abstract])) OR (Robot Assisted Surgery[Title/Abstract])) OR (Robot-Assisted Surgeries[Title/Abstract])) OR (Surgery, Robot-Assisted[Title/Abstract])) OR (Robot-Enhanced Procedures[Title/Abstract])) OR (Procedure, Robot-Enhanced[Title/Abstract])) OR (Robot Enhanced Procedures[Title/Abstract])) OR (Robot-Enhanced Procedure[Title/Abstract])) OR (Surgical Procedures, Robotic[Title/Abstract])) OR (Robotic-Assisted Surgery[Title/Abstract])) OR (Robotic Assisted Surgery[Title/Abstract])) OR (Robotic-Assisted Surgeries[Title/Abstract])) OR (Surgery, Robotic-Assisted[Title/Abstract])) OR (Robot-Enhanced Surgery[Title/Abstract])) OR (Robot Enhanced Surgery[Title/Abstract])) OR (Robot-Enhanced Surgeries[Title/Abstract])) OR (Surgery, Robot-Enhanced[Title/Abstract])) OR (Robotic[Title/Abstract])) AND (((((((((((((((((((((((((Research Support, U.S. Government [Publication Type])) OR (Research Support, American Recovery and Reinvestment Act [Publication Type])) OR (Research Support, N.I.H., Extramural [Publication Type])) OR (Research Support, N.I.H., Intramural [Publication Type])) OR (Research Support, U.S. Gov't, P.H.S. [Publication Type])) OR (Research Support, U.S. Gov't, Non-P.H.S. [Publication Type])) OR (Research Support, Non-U.S. Gov't [Publication Type])) OR (Support, Non-U.S. Gov't[Publication Type])) OR (Support, Non-U.S. Govt[Publication Type])) OR (Support, Non U.S. Gov't[Publication Type])) OR (Support, Non U.S. Govt[Publication Type])) OR (Comparative Study[Publication Type])) OR (Comparative Studies[Publication Type])).

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**Data availability** The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author/s.

## Declarations

**Conflict of interest** The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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