



Clinical Research Paper

One-stage versus two-stage ERCP followed by laparoscopic cholecystectomy for the management of pediatric choledocholithiasis: A systematic review and meta-analysis



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ABSTRACT

Background: The optimal approach to managing pediatric choledocholithiasis remains a subject of ongoing debate. Both single-stage strategies, combining laparoscopic cholecystectomy (LC) with bile duct clearance via intraoperative ERCP and sphincterotomy, and two-stage approaches, typically involving preoperative ERCP followed by interval LC, are widely employed. While prior meta-analyses in predominantly adult populations suggest comparable safety profiles between these strategies, pediatric-specific data remain lacking in consensus.

Methods: We performed a systematic review and meta-analysis of studies comparing one-stage versus two-stage management of pediatric choledocholithiasis. Pubmed, Embase, and Cochrane Library were searched up to July 2025. Pooled estimates were calculated with risk ratios (RR) and mean differences (MD) using random-effects models in RevMan Web.

Results: We included three studies with 165 patients. One-stage management was associated with a significant reduction in anesthesia time compared with the two-stage approach (MD −25.23 min; 95 % CI −48.07 to −2.38; $p = 0.03$; $I^2 = 67\%$). No significant differences were observed for length of hospital stay (MD −0.71 days; 95 % CI −1.69 to 0.26; $p = 0.15$; $I^2 = 15\%$), overall complications (RR 0.77; 95 % CI 0.30 to 1.94; $p = 0.58$; $I^2 = 0\%$), or readmissions (RR 0.59; 95 % CI 0.12 to 3.05; $p = 0.53$; $I^2 = 22\%$). **Conclusions:** This systematic review and meta-analysis demonstrates that, in pediatric patients with choledocholithiasis, a single-stage approach—combining laparoscopic cholecystectomy and endoscopic retrograde cholangiopancreatography (ERCP) under the same anesthetic session—significantly reduces cumulative anesthesia exposure without increasing the risk of postoperative complications, hospital length of stay, or readmission rates. These findings support the safety, efficiency, and resource optimization potential of the one-stage strategy compared to the conventional two-stage pathway in the context of pediatric surgical care.

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Abbreviations: CBD, Common bile duct; CI, Confidence Interval; ERCP, Endoscopic Retrograde Cholangiopancreatography; IOC, Intraoperative Cholangiography; LC, Laparoscopic Cholecystectomy; LCBDE, Laparoscopic Common Bile Duct Exploration; MD, Mean difference; MRCP, Magnetic Resonance Cholangiopancreatography; NA, Not Available; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; REML, Restricted Maximum Likelihood; ROBINS-I, Risk of Bias in Non-randomized Studies of Interventions; RR, Risk Ratio; SI, One-Stage group; SII, Two-Stage group.

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1. Introduction

Choledocholithiasis in pediatric patients is a relatively uncommon condition; however, its incidence has been gradually increasing in recent years [1]. When not adequately treated, it may progress to complications such as cholangitis, pancreatitis, and biliary obstruction [2]. Traditionally, choledocholithiasis requires surgical intervention, with the most frequently used approach being laparoscopic cholecystectomy (LC) combined with endoscopic retrograde cholangiopancreatography (ERCP), performed either pre- or postoperatively [3].

The therapeutic plan can be conducted in two ways: in the two-stage approach, the patient initially undergoes ERCP for stone removal, followed by LC; in the single-stage approach, LC is combined with intraoperative ERCP [4]. In adults with choledocholithiasis, several studies have demonstrated the benefits of the single-stage strategy; however, the real impact of this approach in pediatric patients remains uncertain [3–5].

The traditional two-stage approach, involving ERCP followed by laparoscopic cholecystectomy in separate settings, has been widely adopted but exposes pediatric patients to repeated anesthesia and prolonged hospital stays [6]. Recent advances have introduced the one-stage strategy, in which laparoscopic cholecystectomy and ERCP are performed within the same anesthetic session. This technique aims to minimize perioperative risks, reduce overall complications, and improve recovery by consolidating procedures into a single intervention [6,7].

Although choledocholithiasis in pediatric patients remains relatively rare, recent systematic reviews and meta-analyses in adults strongly support the advantages of single-stage management, combining laparoscopic cholecystectomy (LC) with intraoperative ERCP, over the traditional two-stage approach [8].

Available studies comparing these techniques in children are limited and show controversial results. Although the two-stage approach remains the most widely used in clinical practice, it has not yet been established which strategy offers the best balance between safety and efficacy in pediatrics [9–11]. In view of ongoing clinical uncertainty and the lack of pediatric-focused synthesis, we conducted a systematic review and meta-analysis to evaluate the comparative effectiveness of single-stage versus two-stage approaches, combining laparoscopic cholecystectomy and endoscopic retrograde cholangiopancreatography (ERCP), in the management of choledocholithiasis in children. Our primary objective was to determine whether the single-stage strategy offers equivalent safety in terms of complication rates, while conferring the procedural advantage of accomplishing definitive treatment within a single anesthetic episode.

2. Methods

We conducted a systematic review and meta-analysis following the PRISMA guidelines. In July 2025, a comprehensive search was performed in PubMed, Embase, and Cochrane databases. The review was registered in PROSPERO under the number [CRD420251131603].

2.1. Eligibility criteria

Studies were included if they met the following criteria: (1) pediatric patients (≤ 18 years) diagnosed with common bile duct stone and choledocholithiasis; (2) single-stage management: concurrent laparoscopic cholecystectomy (LC) and endoscopic retrograde cholangiopancreatography (ERCP) performed in the same anesthesia setting as the intervention; (3) two-stage

management: ERCP followed by laparoscopic cholecystectomy (LC) performed in distinct procedures in the control group. Studies were excluded if they had the wrong study design, as such, compared different techniques like intraoperative cholangiography (IOC) or laparoscopic common bile duct exploration (LCBDE). If the study had the wrong population, or the publication type was also excluded.

Studies were excluded if they were case reports, review articles, editorials, letters, or conference abstracts without accessible full text. Additionally, studies with mixed adult and pediatric populations were excluded unless pediatric data could be clearly isolated, and studies not reporting relevant clinical outcomes were also excluded.

2.2. Search strategy and data extraction

The search strategy combined indexed terms (MeSH, Emtree) and keywords related to choledocholithiasis, single-stage, two-stage, and children. No language restrictions were applied. We used the following search strategy in the databases: Choledocholithiasis OR common bile duct stone OR common bile duct stones) AND (child OR pediatric OR children) AND (single-stage AND laparoscopic cholecystectomy AND endoscopic retrograde cholangiopancreatography) AND (two-stage AND laparoscopic cholecystectomy AND endoscopic retrograde cholangiopancreatography). The complete search strategy for each database is provided in [Supplementary Material \(Table 2\)](#).

The selection process was carried out independently by two reviewers (G.M.S. and P.E.O.F.) in two stages: first, by search strategy and study designs. The identified studies were imported into the Rayyan software, and duplicates were removed. Two independent reviewers (G.M.S. and P.E.O.F.) screened the titles and abstracts. Potentially eligible studies were assessed in full text, and disagreements were resolved by a third reviewer (W.F.O.A.). The selection process is detailed in the PRISMA flowchart ([Fig. 1](#)). Additionally, we manually examined the reference lists of full-text review articles to identify other eligible studies.

The predefined outcomes included successful common bile duct (CBD) stone clearance, symptom resolution (evaluated through clearly defined clinical criteria, standardized assessment tools, or patient-reported outcome measures), postoperative morbidity, conversion to alternative procedures, overall morbidity, anesthesia time, operative time, overall complications, intraoperative bleeding, length of hospital stay, and hospital readmission. Data extraction was performed using a standardized form, which encompassed general study characteristics (first author and year of publication), population demographics (age, sex, body mass index, and weight), as well as detailed information related to the outcomes of interest. Although multiple outcomes were predefined as relevant endpoints, limited reporting in the primary studies restricted the quantitative synthesis to four outcomes, reflecting variability in outcome availability across the literature.

2.3. Statistical analysis

The meta-analysis was conducted using RevMan Web (version 9.9.0) software. Effect measures were calculated using relative ratios (RR) and mean differences (MD), with a 95 % confidence interval (CI). A random-effects model was applied according to the heterogeneity of the studies, with REML estimator. Heterogeneity was assessed using Cochran's Q test and the I^2 statistic, classified as low (<25 %), moderate (25–50 %), or high (>50 %).

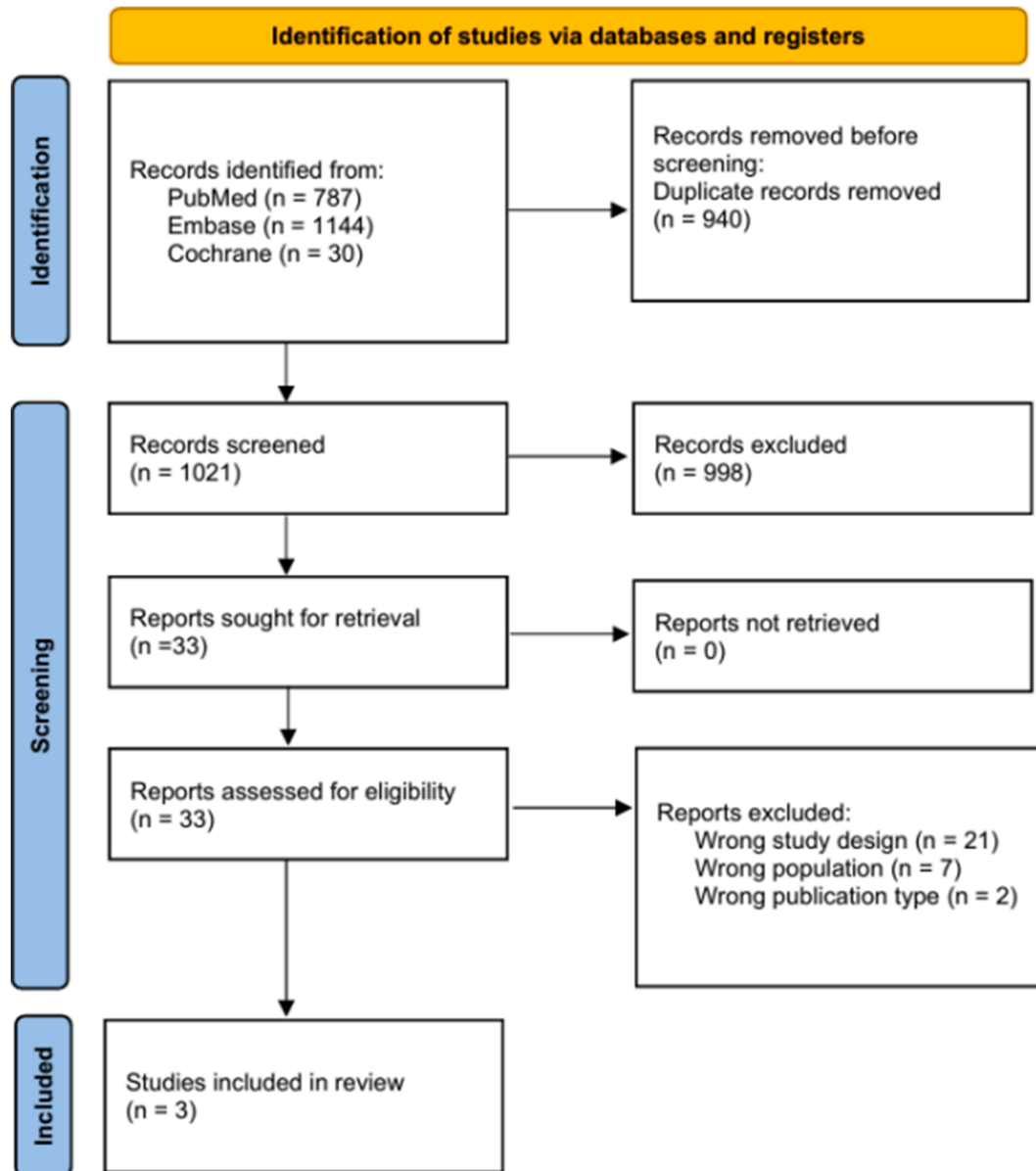


Fig. 1. The PRISMA 2020 flowchart for study screening and selection.

2.4. Risk of bias assessment

The risk of bias for non-randomized studies was assessed independently by two reviewers using the Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool, as recommended. The following seven domains were evaluated: (1) bias due to confounding, (2) bias in selection of participants into the study, (3) bias in classification of interventions, (4) bias due to deviations from intended interventions, (5) bias due to missing data, (6) bias in measurement of outcomes, and (7) bias in selection of the reported result. Each domain was judged as “low,” “moderate,” “serious,” or “critical,” and an overall risk of bias judgment was assigned to each study, following the ROBINS-I guidance. Disagreements were resolved through discussion, and consensus was reached for all judgments.

3. Results

3.1. Study selection and baseline characteristics of the included studies

The systematic search initially identified 1961 records. After the removal of 940 duplicates, 1021 unique studies were screened based on titles and abstracts. Of these, the vast majority were excluded for not meeting the predefined eligibility criteria, leaving a small subset for full-text review. Ultimately, three observational studies fulfilled all inclusion criteria and were incorporated into the present systematic review and meta-analysis. The detailed study selection process, including reasons for exclusion at each stage, is depicted in the PRISMA flow diagram (Fig. 1).

Table 1
Baseline characteristics of the included studies.

Author and Year	Patients SI/SII	Age (years) SI/SII	Weight (kg) SI/SII	CBD size (mm) SI/SII	Direct bilirubin (mg/dL) SI/SII	MRCP(n) SI/SII	Pancreatitis at presentation (n)SI/SII
Fishman et al. 2020	25/42	15.34 ± 2.67/ 14.47 ± 2.60	67.91 ± 18.47/ 67.89 ± 9.95	NA	3.19 ± 4.64/ 2.94 ± 4.32	NA	0/0
Gee et al. 2019	14/42	14.2 ± 3.9/ 14.2 ± 2.0	NA	7.46 ± 3.2/ 9.0 ± 3.0	2.8 ± 3.9/ 3.4 ± 6.5	0/6	NA
Santángelo et al. 2025	27/15	13 ± 1.56/ 15 ± 1.63	60.21 ± 14.87/ 65.54 ± 4.72	9.35 ± 3.91/ 11.09 ± 2.45	3.02 ± 2.98/ 2.9 ± 3.87	27/15	4/3

Footnotes: SI: one-stage group; SII: two-stage group; CBD: common bile duct; NA: not available; MRCP: magnetic resonance cholangiopancreatography.

Three observational studies were included, comprising a total of 165 pediatric patients with choledocholithiasis. Among them, 66 (40 %) underwent a one-stage approach combining laparoscopic cholecystectomy and ERCP, while the remainder were managed with a traditional two-stage strategy. Across studies, median ages ranged from 13 to 15 years, with a predominance of female patients, and baseline clinical and laboratory characteristics were generally comparable between groups. Fishman et al. (2020) was the only study to report on underlying hemolytic disease, which was present in 19 % of patients overall, 28 % in the one-stage group and 14 % in the two-stage group. The included studies were from 2019 to 2025. Additional characteristics of the included studies are summarized in Table 1.

3.2. Comparison of anesthesia time between one-stage and two-stage procedures

In this forest plot, each square represents the mean difference in anesthesia time between the one-stage and two-stage groups for an individual study, with the horizontal line indicating the 95 % confidence interval (CI). The size of each square reflects the weight that the study contributes to the overall analysis. The diamond at the bottom represents the pooled mean difference, with its center indicating the overall point estimate (MD = −25.23), and its width representing the 95 % CI (−48.07 to −2.38) (Fig. 2).

In this review, “anesthesia time” refers to the total duration of general anesthesia, measured in minutes. For studies employing a two-stage strategy, anesthesia time was calculated as the sum of anesthetic durations for ERCP and laparoscopic cholecystectomy. Concerning anesthesia time, the pooled analysis demonstrated a statistically significant reduction in the one-stage group compared with the two-stage group (MD −25.23, 95 % CI −48.07 to −2.38, $p = 0.03$). Moderate-to-high heterogeneity was observed ($I^2 = 67$ %; $p = 0.05$), suggesting that the variation among studies may not be entirely attributable to chance.

Leave-one-out sensitivity analyses were conducted to assess the robustness of the findings. The analysis revealed instability: the effect lost statistical significance when either Fishman et al. (2020) or Santángelo et al. (2025) were excluded, whereas exclusion of Gee et al. (2019) strengthened the association and eliminated heterogeneity (MD = −36.03; 95 % CI −50.76 to −21.30; $p < 0.0000$; $I^2 = 0$ %). These findings indicate that the observed effect is highly dependent on individual studies and should be interpreted with caution (Fig. 2A–C).

3.3. Length of hospital stay

The pooled analysis demonstrated no statistically significant difference between one-stage and two-stage procedures (MD = −0.71; 95 % CI −1.69 to 0.26; $p = 0.15$; $I^2 = 15$ %) (Fig. 3).

Leave-one-out sensitivity analysis for length of hospital stay revealed that the exclusion of individual studies influenced the

magnitude of the pooled effect but did not establish statistical robustness. Removing Fishman (2020) attenuated the estimated effect towards the null (MD = −0.22; 95 % CI −1.40 to 0.96; $p = 0.72$; $I^2 = 0$ %), whereas exclusion of Gee (2019) strengthened the association, reaching statistical significance in favor of one-stage procedures (MD = −1.23; 95 % CI −2.41 to −0.05; $p = 0.04$; $I^2 = 0$ %). Conversely, omitting Santángelo (2025) produced a modest reduction in the pooled mean difference (MD = −0.69; 95 % CI −1.85 to 0.47; $p = 0.24$; $I^2 = 39$ %) (Fig. 3A–C).

3.4. Overall complications related to procedure and anesthesia

There were no statistically significant differences in overall complications between one-stage and two-stage procedures (RR = 0.77; 95 % CI 0.30 to 1.94; $p = 0.58$; $I^2 = 0$ %) (Fig. 4).

The leave-one-out analysis for postoperative complications showed that the exclusion of any single study did not materially alter the overall conclusions. When Fishman (2020) was removed, the pooled risk ratio shifted slightly to 0.81 (95 % CI 0.31 to 2.15; $p = 0.68$; $I^2 = 0$ %), while excluding Gee (2019) increased the estimate to 0.99 (95 % CI 0.38 to 2.57; $p = 0.99$; $I^2 = 0$ %). The removal of Santángelo (2025) yielded a risk ratio of 1.17 (95 % CI 0.29 to 4.79; $p = 0.83$; $I^2 = 0$ %). In all scenarios, the results remained statistically non-significant (Fig. 4A–C).

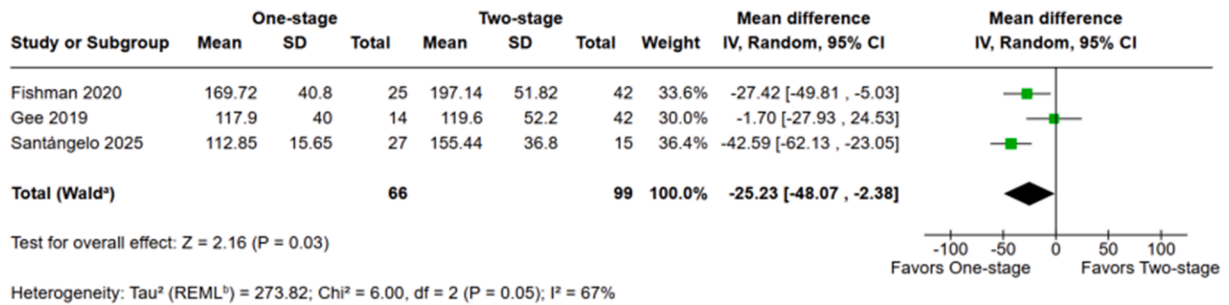
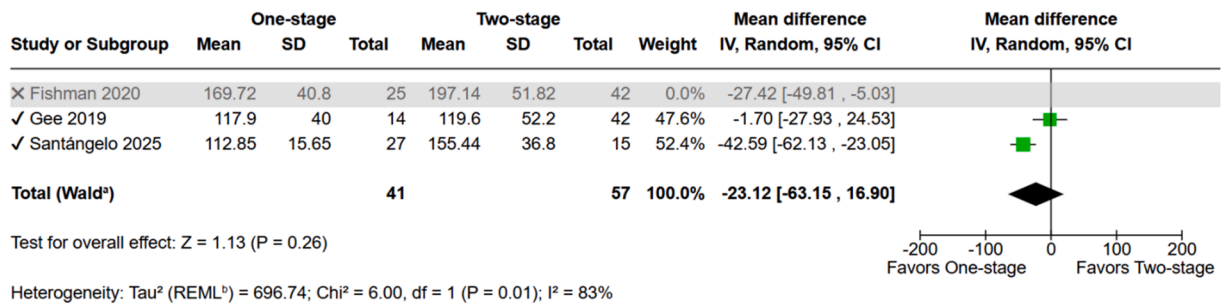
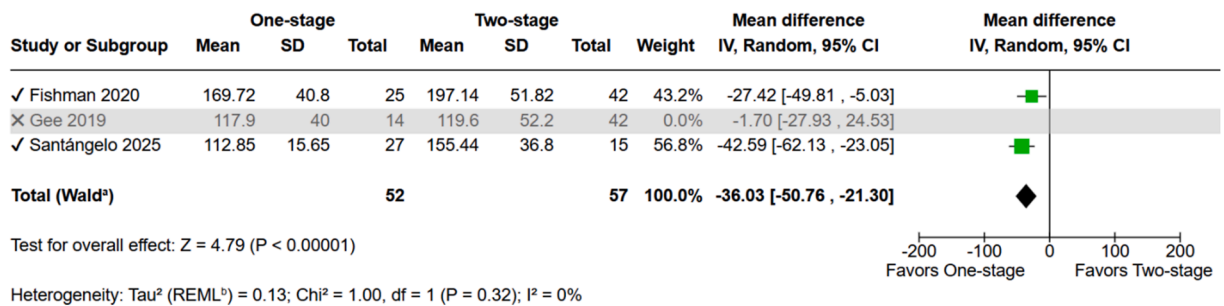
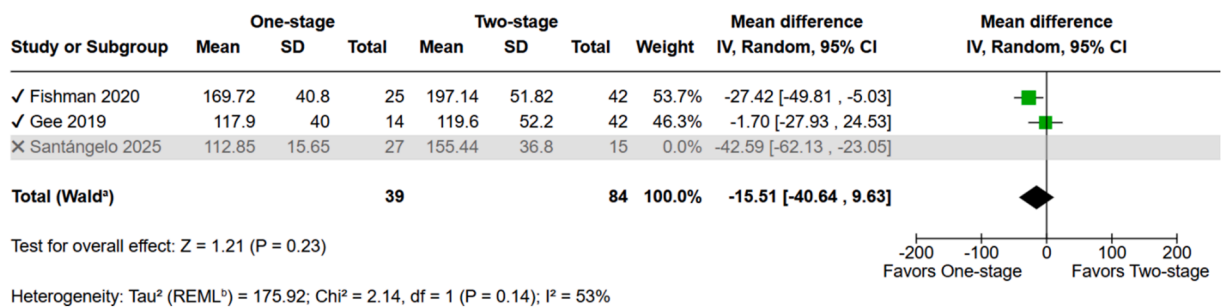
3.5. Readmission

The pooled analysis showed no statistically significant difference in event risk between one-stage and two-stage procedures (RR = 0.59; 95 % CI 0.12 to 3.05; $p = 0.53$; $I^2 = 22$ %) (Fig. 5).

The leave-one-out sensitivity analysis for readmissions showed that excluding any individual study did not alter the significance of the results (Fig. 5A–C).

3.6. Risk of bias

The risk of bias assessment indicated methodological limitations across the three included studies. Fishman et al. (2020) was judged at serious overall risk of bias, primarily due to confounding related to institutional practice patterns and the concentration of one-stage procedures in a limited number of centers, although classification of interventions and outcome measurement were considered reliable. Gee et al. (2019) also presented a serious overall risk of bias, largely attributable to residual confounding and the retrospective, single-center design with a small sample size, despite clearly defined interventions and objective outcome assessment. In contrast, Santángelo et al. (2025), who employed a prospective cohort design, were judged to have a moderate risk of bias. The main concern was confounding, since allocation to one- or two-stage management was based on the availability of surgeons and endoscopists rather than randomization; however, the study benefited from prospective data collection, minimal missing

**Footnotes**^aCI calculated by Wald-type method.^b Tau^2 calculated by Restricted Maximum-Likelihood method.**A****B****C****Fig. 2.** Forest plot for anesthesia time with leave one out sensitivity analysis.

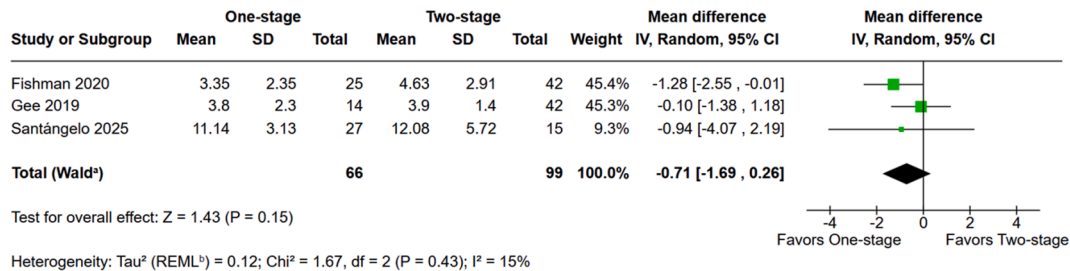
data, and standardized outcome measurement. The complete risk of bias assessment is provided in [Supplementary Material \(Table 3\)](#).

4. Discussion

This systematic review and meta-analysis included three observational studies with a total of 165 pediatric patients with

choledocholithiasis. Our analysis showed a significant reduction in anesthesia time with the one-stage approach compared to the two-stage strategy.

The successful outcomes and high efficacy demonstrated by the single-stage (SI) approach within this meta-analysis are intrinsically linked to meticulous preoperative patient selection, a critical factor that tempers the enthusiasm for its broad application outside of specialized centers. The included studies

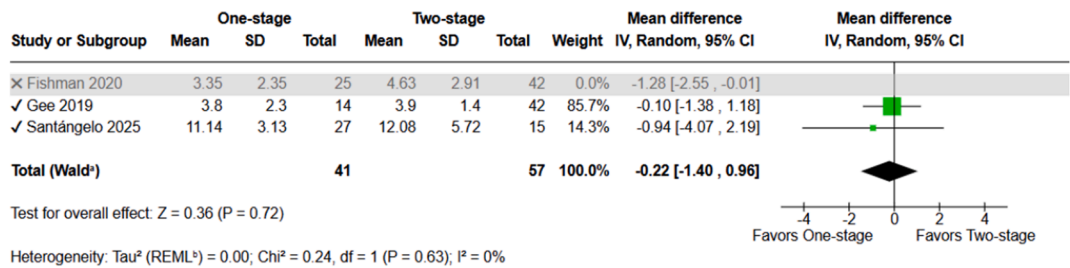


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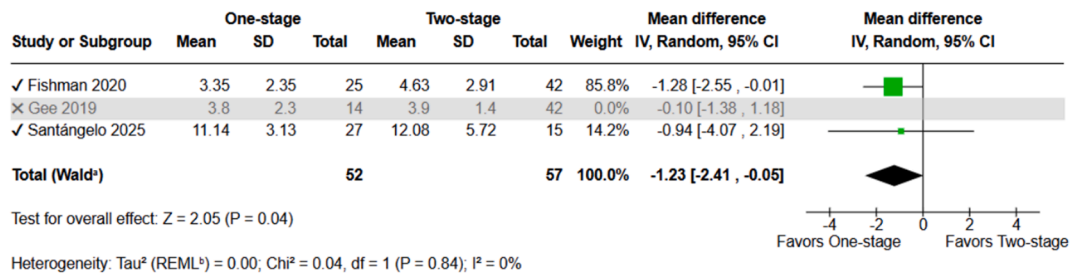
^aCI calculated by Wald-type method.

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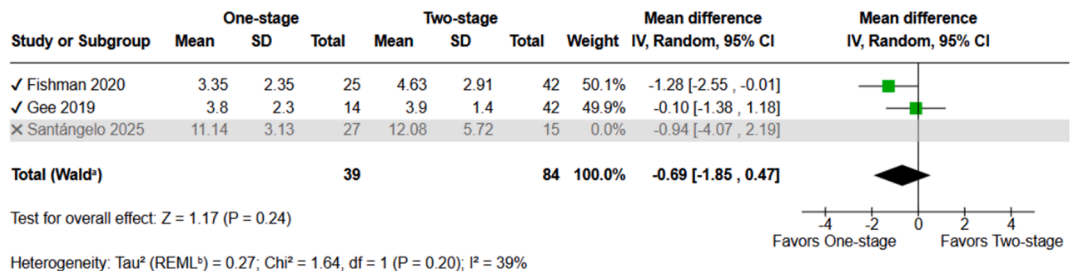
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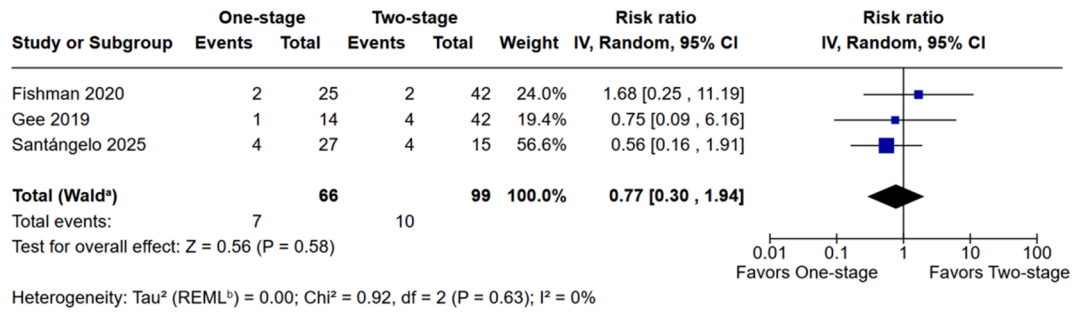
^aCI calculated by Wald-type method.

^bTau² calculated by Restricted Maximum-Likelihood method.

Fig. 3. Forest plot for length of hospital stay with leave one out sensitivity analysis.

relied on rigorous diagnostics, frequently utilizing Magnetic Resonance Cholangiopancreatography (MRCP) to preoperatively confirm choledocholithiasis before proceeding to the combined intervention [12,13]. This careful selection process minimizes the risk of unnecessary endoscopic procedures; for example, one study reported a high stone confirmation rate of 96 % at endoscopy in the combined group, which is well above the 50 % threshold suggested by the ASGE for assessing the need for ERCP [14]. Conversely, many centers performing the combined

approach do not routinely perform intraoperative cholangiography (IOC), in part because routine IOC has not been shown to reduce laparoscopic cholecystectomy complication rates in all pediatric patients [12,13]. Therefore, the ability of specialized centers to proceed directly to the combined SI intervention with high diagnostic confidence mitigates the uncertainty faced in settings that might rely solely on intraoperative imaging, further restricting the generalizability of these findings to high-resource environments.

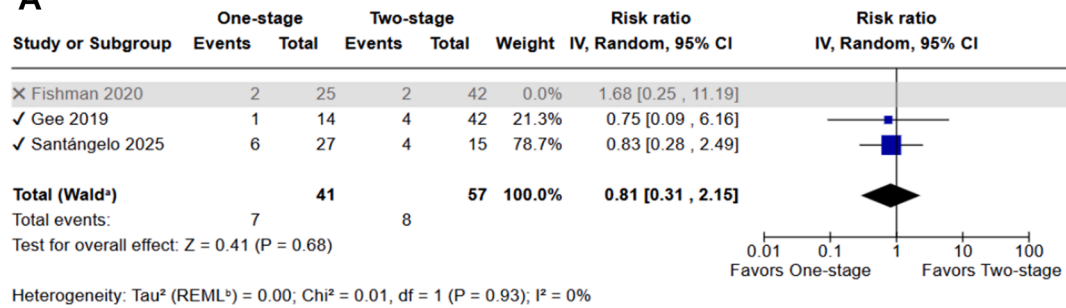


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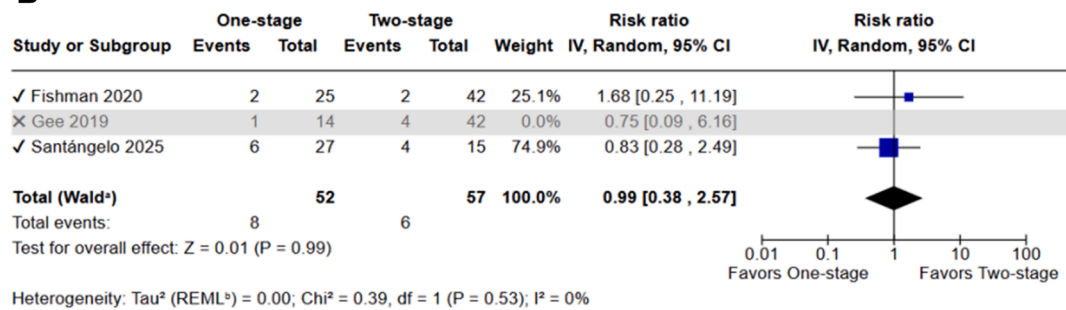
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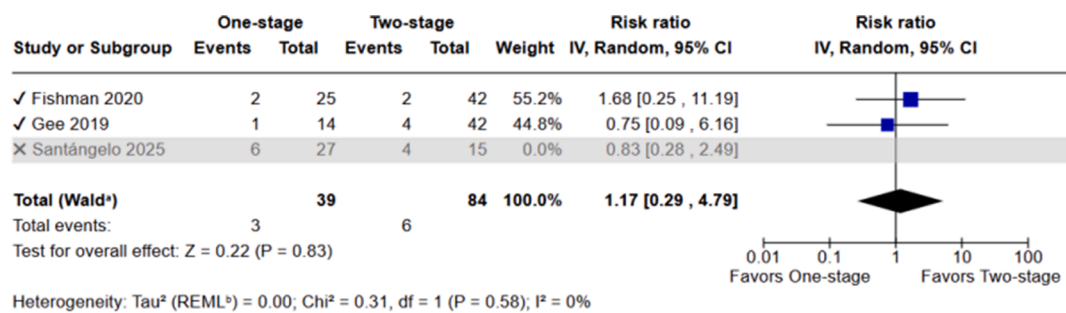
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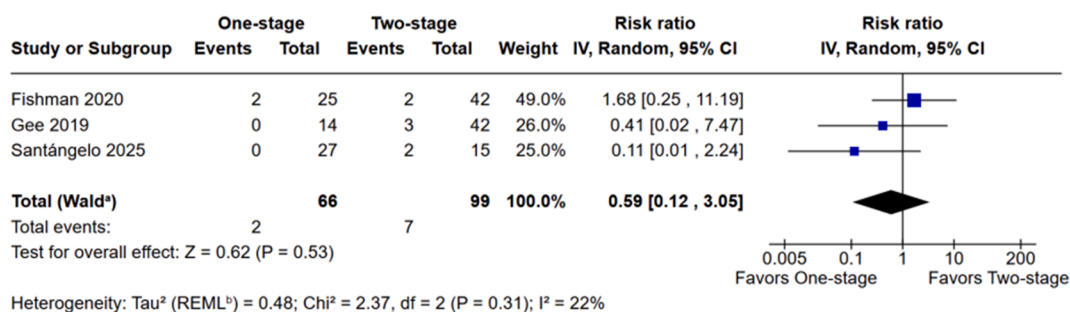
^bTau² calculated by Restricted Maximum-Likelihood method.

Fig. 4. Forest plot for complications related to surgery and anesthesia with leave one out sensitivity analysis.

4.1. Summary of results

Our analysis demonstrated a significant reduction in anesthesia time with the one-stage strategy compared to the two-stage

approach, a finding of particular importance in pediatrics, where prolonged anesthesia may increase respiratory and neurocognitive risks [15]. Although anesthesia time was consistently reported as the total duration of general anesthesia in minutes, there remains

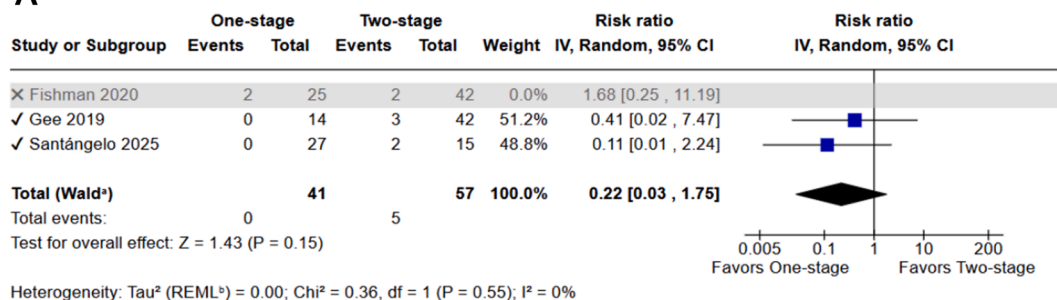


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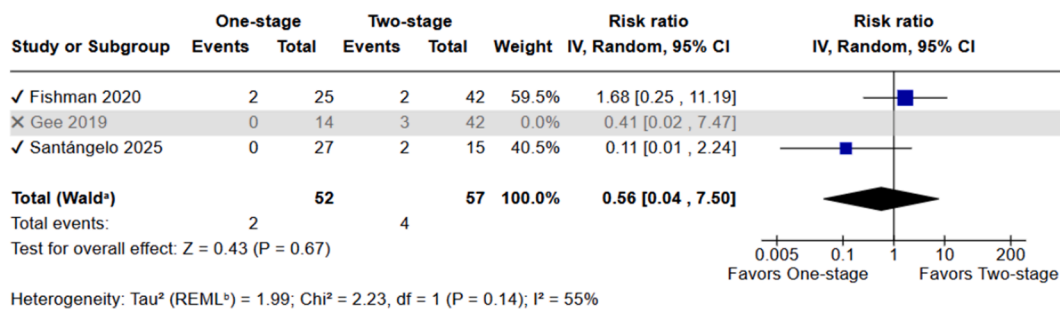
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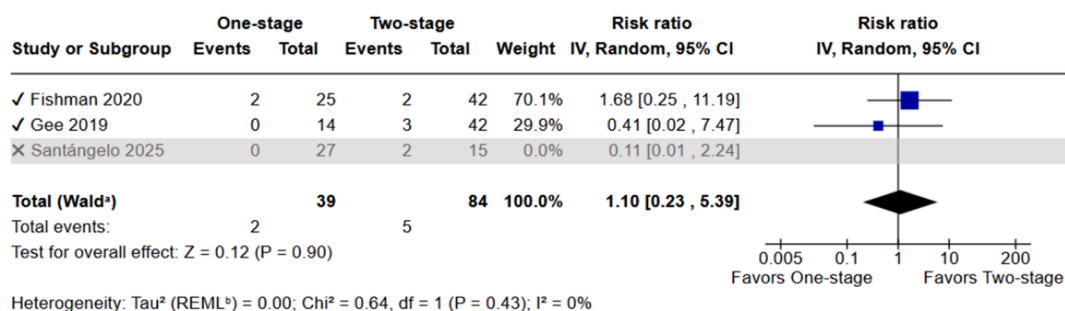
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^aCI calculated by Wald-type method.

^bTau² calculated by Restricted Maximum-Likelihood method.

Fig. 5. Forest plot for readmission with leave one out sensitivity analysis.

potential heterogeneity in how individual studies measured and recorded this variable. For example, while Fishman et al. (2020) and Gee et al. (2019) documented the overall anesthetic duration for each procedure, Santángelo (2025) calculated anesthesia time in the two-stage strategy as the sum of two separate anesthetic events. This variability should be considered when interpreting pooled results, as differences in measurement may contribute to residual heterogeneity across studies.

Length of hospital stay showed a non-significant trend toward reduction, although sensitivity analyses suggested that results were influenced by individual studies. Importantly, the one-stage approach did not increase complications, instead offering the potential benefits of reduced anesthetic exposure, fewer hospital encounters, and lower risk of interval adverse events.

Across individual studies, complications were generally comparable between groups. Fishman et al. (2020) reported no major adverse events, while Gee et al. (2019) observed minimal bleeding events and two delayed complications in the two-stage arm. Santángelo et al. (2025) described several hemorrhagic events and two treatment failures in the one-stage group, alongside surgical and interval complications in the two-stage group. Readmission rates were low overall, with no consistent difference between strategies, though interval problems such as cholangitis and cholecystitis appeared more often in two-stage care. Collectively, these findings suggest that a single-stage approach may improve perioperative safety without increasing complications, while potentially mitigating risks associated with delayed surgery.

A recurring signal favoring one-stage care is the reduction of interval problems that may arise between ERCP and delayed cholecystectomy [16,17]. In the dataset, two-stage care was associated with cholangitis (Gee et al., at five months postoperatively) and with cholecystitis/readmissions during the waiting period for LC (Santángelo et al.).

4.2. Comparison with world literature

Several recent studies have expanded the understanding of ERCP in pediatric populations. Keil et al. (2019) reported a large retrospective series of 856 procedures in 626 patients, showing high technical success with complication rates comparable to adults, while also emphasizing age-specific indications [18]. Similarly, Çirkin et al. (2024) described 65 ERCPs in Turkish children, noting choledocholithiasis and chronic pancreatitis as leading indications, a 92.3 % cannulation success rate, and moderate rates of post-procedure pancreatitis, highlighting the importance of specialized expertise [19].

A systematic review by Usatin et al. (2016), including 32 studies and 3566 procedures, estimated a pooled complication rate of 6 % and underscored the need for standardized reporting [20]. In a multicenter analysis, Lorio et al. (2023) observed a 95.5 % success rate across 716 ERCPs, with adverse events more frequent in younger children and in pancreatic interventions [21]. Troendle et al. (2022), through an international registry of 1124 procedures, found a 90.5 % success rate, higher in biliary than pancreatic indications, and identified post-ERCP pancreatitis as the most common complication [22]. Hosseini et al. (2023) demonstrated that ERCP achieves a high success rate (~95 %) with an overall adverse event rate of 7 %, most commonly post-ERCP pancreatitis (~4 %), supporting its safety and efficacy when performed by experienced teams [23].

More recent reports have refined the discussion of specific contexts: Wang et al. (2025) demonstrated excellent outcomes in choledocholithiasis with bile duct dilatation [24]; Qian et al. (2024) found ERCP offered faster recovery but lower efficacy than surgical hepaticojejunostomy in pancreaticobiliary maljunction

[12]; and Lehane et al. (2025) suggested that surgery may remain preferable for most cases of pediatric choledocholithiasis [25].

4.3. Comparison to adult literature

In adults, two comprehensive meta-analyses compared one-stage versus two-stage management. Nie et al. (2023), pooling nine randomized trials, reported that the one-stage approach significantly reduced overall morbidity, postoperative pancreatitis, length of hospital stay, and the need for repeat ERCP, while maintaining equivalent duct clearance rates [26]. Similarly, Li et al. (2020), analyzing 11 randomized trials, found no significant differences between single- and two-stage strategies in terms of bile duct clearance, morbidity, mortality, or hospital stay, though the one-stage approach offered the practical advantage of avoiding repeated interventions and preserving sphincter function [13].

Our findings suggest that ERCP is safe and effective in children, and that in adults, single-stage strategies may offer clinical and system-level advantages without compromising efficacy, supporting the rationale for their selective use in pediatric practice where expertise and resources allow.

Health-system considerations also favor one-stage care where feasible. Recent cost analyses suggest meaningful per-patient savings with one-stage strategies, driven by fewer admissions and procedures, representing an important complement to the clinical advantages described above [27]. Gee et al. reported hospital stay costs of USD 45,597 ± 11,513 in the one-stage group and USD 61,008 ± 17,960 in the two-stage group.

4.4. Limitations

Several limitations inherent to the aggregated data warrant careful acknowledgment. Methodologically, the predominance of retrospective and observational studies introduces an inherent risk of bias. Confounding by indication is particularly relevant, as patients selected for the one-stage versus two-stage management often differed systematically in baseline characteristics, such as stone burden, comorbidities, or institutional expertise, which may have independently influenced the reported outcomes. Furthermore, selection bias is evident, as most included studies were single-center and hospital-based, which limits the generalizability of our findings, potentially underrepresenting patients treated in low-resource or community settings. Substantial heterogeneity further complicates interpretation, stemming from variability in outcome definitions (e.g., complication assessment, retained stones), the specific timing of cholecystectomy following ERCP, and the length of follow-up.

Beyond these methodological constraints, the routine adoption of the single-stage approach faces significant practical and logistical hurdles that restrict its widespread applicability. The foremost constraint is the necessity for simultaneous coordination of specialized teams, demanding the concurrent availability of an advanced biliary endoscopist and a surgeon, alongside dedicated operating room access [12,13,14]. This resource-intensive requirement frequently results in an allocation bias, as patient assignment is often dictated by the schedules of specialized personnel [12,13]. This factor further restricts generalizability, given that most reported procedures have been concentrated in a limited number of high-volume centers [14]. This internal difficulty in coordination may explain the observed efficiency paradox, where the time from patient presentation to the initiation of the first procedure was, counterintuitively, slightly longer in the single-stage cohort [14]. Finally, the combined procedure carries technical limitations: intestinal distension secondary to the ERCP component can occasionally compromise the surgical field,

impeding the completion of the laparoscopic cholecystectomy in the same session and potentially leading to procedural failure and rescheduling [12,14]. These findings collectively highlight the critical need for high-quality prospective studies directly comparing one-stage and two-stage management of choledocholithiasis in the pediatric population.

The exclusion of studies utilizing Intraoperative Cholangiography (IOC) and/or Laparoscopic Common Bile Duct Exploration (LCBDE) represents a significant methodological limitation to the broad applicability of our findings. We recognize LCBDE as an important alternative, and a potentially more useful tool in the pediatric population, particularly in settings constrained by the availability of specialized endoscopic personnel [28]. Since our analysis focused strictly on ERCP-based strategies, we could not evaluate the comparative safety, efficacy, and cost-effectiveness of this surgical approach. Moving forward, the critical need for high-quality prospective studies directly comparing LCBDE against both ERCP-based strategies (single-stage and two-stage) must be emphasized to establish the optimal management algorithm for pediatric choledocholithiasis, especially when considering global resource disparities.

Finally, this systematic review and meta-analysis provide the first comprehensive comparison of one-stage versus two-stage management of pediatric choledocholithiasis. The one-stage strategy significantly reduces anesthesia exposure without increasing overall complications, hospital stay, or readmission rates, highlighting a potential equivalence in perioperative safety and efficiency. These results support its adoption in appropriately selected patients, particularly in centers with expertise in combined surgical and endoscopic techniques.

5. Conclusion

This systematic review and meta-analysis demonstrates that the one-stage approach, combining laparoscopic cholecystectomy and endoscopic retrograde cholangiopancreatography (ERCP) under a single anesthetic episode, confers a significant procedural advantage over the traditional two-stage strategy in pediatric choledocholithiasis. Specifically, the one-stage technique results in a marked reduction in cumulative anesthesia duration without an associated increase in postoperative complications, hospital length of stay, or readmission risk. These findings support the clinical feasibility, safety, and efficiency of procedural consolidation in children requiring biliary intervention. However, given the heterogeneity of available data and the predominance of retrospective studies, high-quality prospective trials are warranted to validate these observations and guide evidence-based practice in pediatric biliary surgery.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

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