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REVIEW ARTICLE

# Transcystic versus traditional laparoscopic common bile duct exploration: its advantages and a meta-analysis

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## Abstract

**Background** The best approach for treating common bile duct stones remains a matter of debate. Traditional laparoscopic common bile duct exploration (LCBDE) can cause adverse events such as stenosis of the bile duct. Moreover, with advances in technology and surgical skills, the use of laparoscopic transcystic common bile duct exploration (LTCBDE) is gradually rising.

**Objectives** To compare the safety, feasibility, and short-term clinical benefits of LTCBDE and LCBDE through matched cases.

**Methods** Web of science, Cochrane, PubMed, and CNKI were searched systematically to identify studies published between January 2007 and December 2017 that compared LTCBDE and LCBDE without a restriction of languages. This meta-analysis was performed using Review Manager 5.3.

**Results** Twenty-one studies matched the selection criteria, including 1561 cases of LTCBDE and 1500 cases of LCBDE. There was no obvious difference in stone clearance (OR 1.44, 95% CI 0.84–2.47; $P=0.18$). However, LTCBDE had a shorter operative time (MD −17.72, 95% CI −19.42 to −16.02; $P<0.00001$) and shorter hospital stay (MD −2.20, 95% CI −2.32 to −2.08; $P<0.00001$). Besides, the LTCBDE group showed significantly better results for blood loss (MD −7.61, 95% CI −8.85 to −6.37; $P<0.00001$) and postoperative complications (OR 0.28, 95% CI 0.19–0.41; $P<0.00001$). In addition, LTCBDE was more cost efficient (MD −2.51, 95% CI −2.72 to −2.30; $P<0.00001$). Further, we calculated the absolute mean of operative time (LTCBDE:LCBDE = 97.56:117.81 min), hospital stay (LTCBDE:LCBDE = 5.22:8.91 days), hospital expenses (LTCBDE:LCBDE = 8646.121:11848.31 RMB), blood loss (LTCBDE:LCBDE = 29.3:52.0 ml), the rate of CBD stone clearance (LTCBDE:LCBDE = 92.8:95.0%), and postoperative complications (LTCBDE:LCBDE = 6.7:14.6%) in both groups to obtain more convincing results.

**Conclusions** The stone clearance of LTCBDE was equal to that of LCBDE, and LTCBDE demonstrated a shorter operative time, lower blood loss, and other advantages. Thus, the surgical procedure of laparoscopic transcystic choledochotomy is feasible and safe.

**Keywords** LTCBDE · LCBDE · Meta-analysis · Transcystic · Laparoscopic

The incidence of choledocholithiasis in patients with cholelithiasis is approximately 10% [1, 2], 5% of which were found by unsuspected LC or examination such as CT. Common bile duct (CBD) stones can lead to serious complications such as cholangitis and pancreatitis. Nevertheless, in the era of advancements in minimally invasive technology, the treatment of CBD stones still remains controversial with respect to endoscopic retrograde cholangiopancreatography (ERCP) or laparoscopic common bile duct exploration (LCBDE) or preoperative ERCP plus LC as the best treatment option. In ERCP, there is a substantial risk of potentially lethal complications in the form of pancreatitis, bleeding, and perforation [3]. In LCBDE, the problems caused by the T tube: inconvenience to the patient, bile-induced peritonitis after removal of the T tube, accidental slipping

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of the T tube from the CBD, and postoperative stenosis of bile duct gradually aroused the concerns of surgeons [4, 5]. To address these problems, a few scholars [6–8] have performed a novel procedure: transcystic exploration of the CBD, which avoids choledochotomy and eliminates the subsequent requirement of a T tube. However, the LTCBDE has not been universally accepted and no large multi-center studies have been conducted to investigate its safety and efficacy. Thus, we performed this meta-analysis to explore the safety and feasibility of LTCBDE.

## Methods

This study was designed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. We searched medical databases for articles using the terms: LTCBDE versus LCBDE. This search strategy was designed and executed by an experienced information specialist and reviewed by two writers (Liwei Pang and Jing Kong).

### Inclusion criteria

1. Study design: randomized, controlled trials, Retrospective cohort studies, case-control studies were included.
2. Interventions: studies comparing LCBDE and LTCBDE.
3. Participants: cholelithiasis with suspected or confirmed CBD stones.
4. Language: without restriction to languages.
5. Type of article: only studies published as full-text articles.
6. Studies comparing LTCBDE with LCBDE reporting on at least ten patients among all age groups, with at least one of the meaningful conclusions.

### Exclusion criteria

1. Non-comparable or non-human studies, review articles, editorials, letters and case reports.
2. Articles not reporting the outcomes of interest.

### Literature strategy

A detailed literature search was performed using the following keywords: LCBDE, laparoscopic common bile duct exploration, LTCBDE, laparoscopic transcystic common bile duct exploration, common bile duct stones, CBD stones in the following online databases: Web of science (239), Cochrane (121), PubMed (183), and CNKI (169) (last search date: December 30, 2017), without restriction to regions, publication types, or languages. The search strategy applied to PubMed is listed as below: ((“laparoscopic common bile duct exploration” [Supplementary Concept]) OR LCBDE) AND ((“laparoscopic transcystic common bile duct exploration” [Supplementary Concept]) OR LTCBDE) AND (“common bile duct stones” [Mesh] OR CBD stones). When similar reports describing the same population were published, the most recent or complete report was used. The research was conducted independently by Liwei Pang and Jing Kong, and subsequently all authors compared their results. References from the articles were investigated manually. Any differences were resolved by consensus. This meta-analysis adhered to the guidelines outlined in the PRISMA statement.

### Data extraction

The following data were extracted: name of authors, study design, number of patients treated using in the laparoscopic or hybrid approach, age, operative time, estimated blood loss, hospital stay, postoperative complications, stone clearance, and hospital expenses.

### Quality assessment and statistical analysis

Studies were rated for the level of evidence provided according to criteria by the Centre for Evidence-Based Medicine in Oxford, UK. The methodological quality was assessed using the modified Newcastle–Ottawa scale (Table 1) [9], consisting of three factors: patient selection, comparability of the study groups, and assessment of outcomes. A score of 0–9 (allocated as stars) was allocated to each study, and observational studies achieving Z6 stars were considered to be of high quality.

We used Review Manager 5.3 (Cochrane collaboration, Oxford, England) for all statistical analyses. Considering that patients were selected by different surgical teams and operated at different centers, we chose the random effects model to assess this heterogeneity. I2 was used for heterogeneity assessment, and values of $>50\%$ were considered significant. Dichotomous variables were analyzed and assessed with an odds ratio (OR); a value of $<1$ favored the laparoscopic cohort, while values of $P<0.05$ and 95% confidence intervals (CIs) without the value of 1 supported the statistical significance of OR. Continuous variables were analyzed using the weighted mean difference. The Mantel–Haenszel method was used to combine the ORs for the outcomes of interest; Peto OR was used when necessary. This study was performed according to the Preferred Reporting Items for Systematic reviews (PRISMA) [10] guidelines.

### Outcomes of interest

Data were collected on all outcomes in a pre-structured proforma as follows.

**Table 1** Assessment of study quality based on the modified Newcastle–Ottawa scale

| Author | Is the case definition adequate? | Representativeness of the cases | Selection of controls | Definition of controls | Comparability of cases and controls on the basis of the design or analysis | Ascertainment of exposure | Same method of ascertainment for cases and controls | Non-response rate | Total score |
|---|---|---|---|---|---|---|---|---|---|
| Panganii [11] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | 8 |
| Topal [12] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | 8 |
| Chen [13] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | | 7 |
| Jameel [14] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | 8 |
| ElGeidie [15] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | 8 |
| Grubnik [16] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | 8 |
| Chen [17] | ☆ | ☆ | | ☆ | ☆ | ☆ | ☆ | | 6 |
| Zhou [18] | ☆ | ☆ | | ☆ | | ☆ | ☆ | | 5 |
| Tao [19] | ☆ | ☆ | | ☆ | | ☆ | ☆ | | 5 |
| Wang [20] | ☆ | ☆ | | ☆ | | ☆ | ☆ | | 5 |
| Tu [21] | ☆ | ☆ | | | | ☆ | ☆ | | 4 |
| Poh [22] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | | 7 |
| Wu [23] | ☆ | ☆ | | ☆ | ☆ | ☆ | ☆ | | 6 |
| Zhang [24] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | | 7 |
| Huang [25] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | 8 |
| Aawsaj [26] | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | ☆ | 8 |
| Huang [27] | ☆ | ☆ | ☆ | ☆ | | ☆ | ☆ | | 6 |
| Li [28] | ☆ | ☆ | | | | ☆ | ☆ | | 4 |
| Han [29] | ☆ | ☆ | | ☆ | | ☆ | ☆ | | 5 |
| Liu [30] | ☆ | ☆ | | ☆ | | ☆ | ☆ | | 5 |
| Sun [31] | ☆ | ☆ | ☆ | ☆ | | ☆ | ☆ | | 6 |

### Primary outcome

1. Surgical success: clearance of bile duct stones and removal of the gall bladder by the intended approach. Any conversion to open procedure or the LTCBDE converted to LCBDE was considered as a failure.

### Secondary outcomes

1. CBD stone clearance
2. Operative time
3. Hospital stay
4. Hospital expenses
5. Blood loss
6. Postoperative complications

## Results

The literature search referred to 712 studies initially. No other eligible studies were found from other sources. At first time, 40 potential meaningful articles were included for a full-text browsing after reading their titles and abstracts. Of these, we excluded two articles after browsing the entire paper because they were from the same institution. Further, nine papers were excluded because the data were not impactful and the authors could not provide information in detail. We also excluded another eight studies that lacked comparative analysis. Finally, a total of 21 studies (7 in Chinese and 14 in English) representing 1561 cases of laparoscopic transcystic common bile duct exploration and 1500 cases of traditional LCBDE were included in the meta-analysis. Figure 1 illustrates the PRISMA flow chart of literature search strategies, and Table 2 describes the included articles.

## Meta-analysis

### Primary outcome

All 21 studies reported the success rates of two procedures, and an article [22] with an extremely high failure rate was excluded. A total of 1481 patients were treated with LTCBDE and 1497 with LCBDE. Overall, LTCBDE was successful in 95.1% of patients and LCBDE in 96.7%. There was no significant difference between the two groups which demonstrated that the surgical procedure of laparoscopic

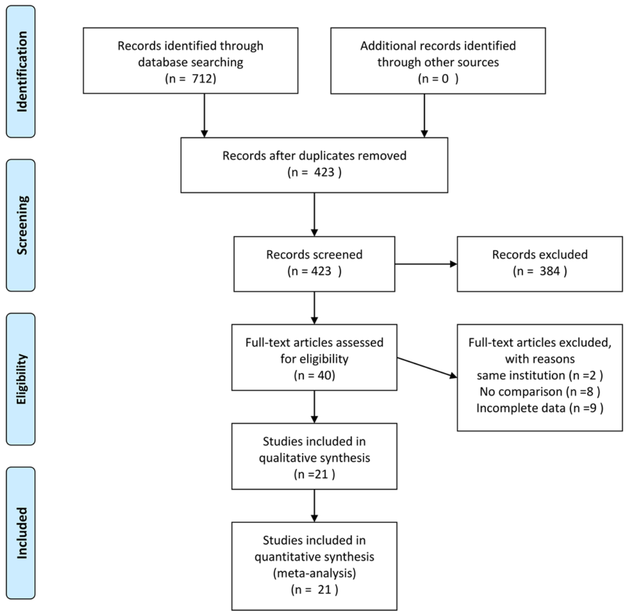


**Fig. 1** PRISMA flow diagram

transcystic choledochotomy was feasible and safe (Fig. 2). However, it is noteworthy that most articles in this meta-analysis represented retrospective and case–control studies; so the success rate of these two procedures may have been overestimated.

## Sensitivity analysis and subgroup analysis

We performed sensitivity and subgroup analysis for surgical success by evaluating differences in the outcome and significance by using fixed and random effects models for the meta-analysis or after removing the studies with extremely high failure rate. Moreover, we divided the studies into two subgroups: prospective or non-prospective studies. We did not find a difference in the statistical significance of these subgroups, which suggests that the choice of patients in these studies might be successful cases, which lead to a relatively higher success rate.

### Secondary outcomes

**CBD stone clearance** Ten articles presented this outcome; total clearance was observed in 92.8% of patients (815 of 878) in the LTCBDE group and 95.0% (497 of 523) in the LCBDE group. There was no significant difference between the two groups (OR 1.44, 95% CI 0.84–2.47; $P=0.18$) (Fig. 3A).

**Operative time** Seventeen trials included data on operative time. The LTCBDE had an obvious advantage of a shorter operative time (MD −17.72, 95% CI −19.42 to −16.02; $P<0.00001$). The absolute mean of operative time was LTCBDE:LCBDE = 97.56:117.81 min (Fig. 3B).

**Hospital stay** We identified 19 trials with relevant data. The length of hospital stay in the LTCBDE group was 2.32 days shorter than that of the LCCBDE group (MD −2.20, 95% CI −2.32 to −2.08; $P<0.00001$). The absolute mean value of hospital stay was LTCBDE:LCBDE = 5.22:8.91 days (Fig. 3C).

**Hospital expenses** The hospital charges were recorded in only seven trials (all in China). LTCBDE was more cost efficient (MD −2.51, 95% CI −2.72 to −2.30; $P<0.00001$), and the absolute mean value of hospital expenses was LTCBDE:LCBDE = 8646.121:11848.31 RMB (Fig. 4A).

**Blood loss** Blood loss data were reported by even fewer, i.e., only 6 articles. LTCBDE could reduce intraoperative bleeding compared to LCBDE (MD −7.61, 95% CI −8.85 to −6.37; $P<0.00001$). The absolute mean value of blood loss was LTCBDE:LCBDE = 29.3:52.0 ml (Fig. 4B).

**Postoperative complications** The incidence of postoperative complications was evaluated in 11 studies. LTCBDE had a lower probability of postoperative complications (OR 0.28, 95% CI 0.19–0.41; $P<0.00001$, LTCBDE:LCBDE = 6.7:14.6%) including bile leakage and fever which suggested LTCBDE was safer (Fig. 4C).

**Publication bias** In this meta-analysis, the funnel plot shapes for CBD stone clearance, operative time, and postoperative complications showed basic symmetry. No significant publication bias was observed. The results were similar and the combined results were highly reliable (Fig. 5).

## Sensitivity analysis and subgroup analysis

We performed sensitivity and subgroup analyses for operative time and hospital stay by evaluating the differences in outcomes and significance using fixed and random effects models in the meta-analysis or after removing studies with a large bias. Moreover, we divided the studies into the following subgroups: prospective or non-prospective; publication in China or not; NOS score > 6 or less; patient number in LTCBDE > 50 or less; patient number in LTCBDE > 80 or less; ITT or PP; number of CBD stones > 5 or less; and diameter of CBD > 8 mm or less. However, we could find a significant source of heterogeneity in any parameter. The underlying reasons may be as follows: (1) most articles in this meta-analysis were retrospective or case–control studies; (2) differences in the surgical experience of different operators; (3) the learning curve of LTCBDE; (4) differences in indications and technical approaches of LTCBDE

**Table 2** Description of included articles

| Author | Year | LTCBDE/LCBDE | Stone clearance | Operative time (min) | Hospital stay (day) | Hospital expense (RMB) | Blood loss (ml) | Complications | Diameter of CBD (mm) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | LTCBDE | LCBDE |
| Panganini (Italy) [11] | 2007 | 191/138 | 185/126 | – | – | – | – | – | < 8 (126)<br>> 8 (61) | – |
| Topal (Belgium) [12] | 2007 | 83/30 | 77/28 | 105 ± 63.05/115 ± 54.35 | 7 ± 7.51/12 ± 10.2 | – | – | 4/5 | 5 (2–14) | 11.5 (5–30) |
| Chen (China) [13] | 2007 | 40/24 | 40/24 | – | 7.8 ± 1.3/9.8 ± 1.9 | 8690 ± 1090/10,760 ± 1240 | 26 ± 7/34 ± 10 | – | – | – |
| Jameel (UK) [14] | 2008 | 9/50 | – | 112.86 ± 19.69/94.21 ± 21.67 | 5.72 ± 3.54/7.33 ± 5.78 | – | – | 0/9 | – | – |
| ElGeidie (Egypt) [15] | 2011 | 57/49 | 56/47 | – | 1.6 ± 0.62/3.8 ± 2.41 | – | – | – | – | – |
| Grubnik (Ukraine) [16] | 2012 | 76/62 | 72/58 | 71 ± 23.67/96.25 ± 33.39 | 3.4 ± 1.7/7.6 ± 2.5 | – | – | – | 8.5 (6–10) | 10.5 (6–20) |
| Chen (China) [17] | 2013 | 110/100 | – | 100 ± 30.4/120 ± 42.2 | 3.6 ± 0.9/7.9 ± 1 | – | – | – | < 8 (37)<br>> 8 (73) | < 8 (20)<br>> 8 (80) |
| Zhou (China) [18] | 2013 | 45/44 | – | 107.1 ± 20.5/149.6 ± 30.2 | 4 ± 1.5/5.8 ± 2.2 | 9932 ± 862/12,879 ± 702 | – | 1/5 | – | – |
| Tao (China) [19] | 2013 | 59/59 | 58/59 | 85.5 ± 20.9/81.8 ± 18.6 | – | – | – | 2/9 | > 8 (59) | > 8 (59) |
| Wang (China) [20] | 2014 | 26/32 | 26/30 | 122.59 ± 19.02/98.06 ± 12.44 | 3.04 ± 1.18/6.5 ± 1.22 | 14568.81 ± 1470.40/16571.37 ± 1247.07 | 14.31 ± 3.76/18.13 ± 8.86 | 0/4 | > 8 (26) | > 8 (32) |
| Tu (China) [21] | 2014 | 50/50 | – | 102.3 ± 20.2/147.9 ± 35.6 | 4.0 ± 2.5/7.2 ± 1.5 | – | – | 2/13 | – | – |
| Poh (Australia) [22] | 2014 | 80/3 | 44/3 | – | 6 ± 1.74/6.5 ± 0.65 | – | – | – | – | – |
| Wu (China) [23] | 2014 | 29/33 | 29/33 | 115.68 ± 16.64/107.19 ± 14.58 | 4.43 ± 0.38/5.1 ± 0.64 | 7944 ± 833/11,197 ± 794 | 19.25 ± 4.3/15.5 ± 4.6 | – | – | – |
| Zhang (China) [24] | 2015 | 237/93 | 228/89 | 76 ± 20.2/116.1 ± 28.1 | 3.9 ± 1.8/6.7 ± 2.8 | 7435.3 ± 994.8/10968.7 ± 1156.4 | – | 31/24 | 5.3 ± 2.1 | 12.0 ± 3.5 |
| HuangHJ (China) [25] | 2015 | 80/209 | – | 91.94 ± 34.21/96.13 ± 32.25 | 9.82 ± 3.48/10.74 ± 5.34 | – | – | 2/3 | 4.7 ± 0.8 | 4.7 ± 0.9 |
| Aawsaj (UK) [26] | 2015 | 85/233 | – | 107.5 ± 52.96/144 ± 48.67 | 2.75 ± 2.07/10.5 ± 7.4 | – | – | – | – | – |
| Huang (China) [27] | 2015 | 53/45 | – | 115.36 ± 21.51/112.41 ± 19.63 | 8.15 ± 0.35/8.32 ± 1.15 | – | – | – | – | – |
| Li (China) [28] | 2016 | 40/40 | – | 105.2 ± 8.5/132.5 ± 8.4 | 4.1 ± 0.6/5.8 ± 0.9 | 6852 ± 125/8563 ± 131 | – | 2/9 | – | – |
| Han (China) [29] | 2016 | 46/41 | – | 126 ± 30/96 ± 24 | 4.1 ± 1.7/6.4 ± 2.4 | 12243.5 ± 2379.6/14098.1 ± 1 897.3 | 17.4 ± 5.4/22.1 ± 5.4 | 3/15 | 13.5 ± 3.6 | 12.9 ± 3.4 |
| Liu (China) [30] | 2016 | 60/60 | – | 122.4 ± 9.5/146.8 ± 8.9 | 5.4 ± 2.1/16.5 ± 6.9 | – | 12.9 ± 6.4/72.1 ± 22.5 | – | – | – |
| Sun (China) [31] | 2017 | 105/105 | – | 102.7 ± 25.1/118.3 ± 28.4 | 6.4 ± 1.2/9.6 ± 1.6 | – | 51.8 ± 10.5/78.1 ± 13.7 | 5/14 | – | – |

| Study or Subgroup | LTCBDE Events | LTCBDE Total | LCBDE Events | LCBDE Total | Weight | Risk Ratio M-H, Random, 95% CI |
|---|---|---|---|---|---|---|
| **8.1.1 Prospective study** | | | | | | |
| 2007 Topal | 75 | 83 | 26 | 30 | 0.6% | 1.04 [0.89, 1.22] |
| 2008 Jameel | 9 | 9 | 50 | 50 | 0.7% | 1.00 [0.87, 1.16] |
| 2011 ElGeidie | 52 | 57 | 46 | 49 | 1.2% | 0.97 [0.87, 1.08] |
| 2012 Grubnik | 71 | 76 | 56 | 62 | 1.4% | 1.03 [0.93, 1.14] |
| 2015 Aawsaj | 63 | 85 | 219 | 233 | 0.9% | 0.79 [0.69, 0.90] |
| 2015 Zhang | 212 | 237 | 86 | 93 | 2.5% | 0.97 [0.90, 1.04] |
| **Subtotal (95% CI)** | | **547** | | **517** | **7.3%** | **0.96 [0.89, 1.04]** |
| Total events | 482 | | 483 | | | |
| Heterogeneity: Tau² = 0.01; Chi² = 14.48, df = 5 (P = 0.01); I² = 65% | | | | | | |
| Test for overall effect: Z = 0.93 (P = 0.35) | | | | | | |
| **8.1.2 not Prospective study** | | | | | | |
| 2007 Chen | 40 | 40 | 24 | 24 | 3.0% | 1.00 [0.94, 1.07] |
| 2007 Panganini | 185 | 191 | 126 | 138 | 3.7% | 1.06 [1.00, 1.12] |
| 2013 Chen | 110 | 110 | 100 | 100 | 13.1% | 1.00 [0.98, 1.02] |
| 2013 Tao | 58 | 59 | 59 | 59 | 5.1% | 0.98 [0.94, 1.03] |
| 2013 Zhou | 45 | 45 | 44 | 44 | 5.7% | 1.00 [0.96, 1.04] |
| 2014 Poh | 41 | 80 | 3 | 3 | 0.0% | 0.59 [0.38, 0.90] |
| 2014 Tu | 50 | 50 | 50 | 50 | 6.6% | 1.00 [0.96, 1.04] |
| 2014 Wang | 26 | 26 | 30 | 32 | 1.2% | 1.06 [0.95, 1.19] |
| 2014 Wu | 29 | 29 | 33 | 33 | 3.3% | 1.00 [0.94, 1.06] |
| 2015 Huang | 53 | 53 | 45 | 45 | 6.4% | 1.00 [0.96, 1.04] |
| 2015 HuangHJ | 80 | 80 | 209 | 209 | 13.2% | 1.00 [0.98, 1.02] |
| 2016 Han | 46 | 46 | 41 | 41 | 5.5% | 1.00 [0.96, 1.05] |
| 2016 Li | 40 | 40 | 40 | 40 | 4.9% | 1.00 [0.95, 1.05] |
| 2016 Liu | 60 | 60 | 60 | 60 | 8.2% | 1.00 [0.97, 1.03] |
| 2017 Sun | 105 | 105 | 105 | 105 | 13.1% | 1.00 [0.98, 1.02] |
| **Subtotal (95% CI)** | | **934** | | **980** | **92.7%** | **1.00 [0.99, 1.01]** |
| Total events | 927 | | 966 | | | |
| Heterogeneity: Tau² = 0.00; Chi² = 10.31, df = 13 (P = 0.67); I² = 0% | | | | | | |
| Test for overall effect: Z = 0.25 (P = 0.80) | | | | | | |
| **Total (95% CI)** | | **1481** | | **1497** | **100.0%** | **1.00 [0.99, 1.01]** |
| Total events | 1409 | | 1449 | | | |
| Heterogeneity: Tau² = 0.00; Chi² = 29.18, df = 19 (P = 0.06); I² = 35% | | | | | | |
| Test for overall effect: Z = 0.08 (P = 0.94) | | | | | | |
| Test for subgroup differences: Chi² = 0.90, df = 1 (P = 0.34), I² = 0% | | | | | | |

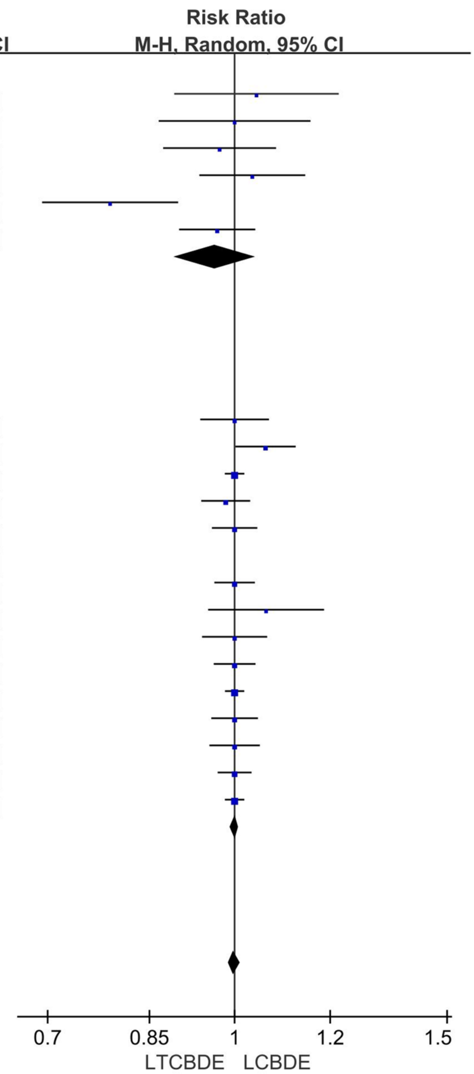


**Fig. 2** Forest plots of the meta-analysis. Surgical success rate in studies on the two procedures, according to their prospective nature

by different operators; and (5) no consistent standard on the patient choice.

## Discussion

Currently, there is no standard surgical treatment for choledocholithiasis. There are a few preferred approaches for treating CBD stones: traditional common bile duct exploration (open or laparoscopic), ERCP, and preoperative ERCP plus LC [16, 32]. ERCP is associated with a high complication rate including pancreatitis, cholangitis, bleeding (19%), failure (10–15%), and mortality (3%) [5, 33], even though it is still a widely used first-line technique. Moreover, ERCP was reported as unfeasible in 3 to 10% of patients [12]. LCBDE and open CBD exploration have a proven efficacy and safety [34, 35]. However, it does have potential risks of bile duct injury and strictures, as well as defects in the T tube drainage leading to (1) prolonged hospitalization; (2) lower quality of life of the patients; (3) bile loss caused by body fluid imbalance; (4) increased infection rate of the biliary tract; and (5) complications caused by the loss of the T tube [25, 36].

Moreover, with rapid advances in technology and the growth of patient needs, biliary surgery could be safer, more efficient, and cost effective, and have lower recurrence rates. LTCBDE emerges according to the needs of current time. LTCBDE removes CBD stones through the cystic duct instead of a direct incision over the CBD, which greatly reduces the occurrence of complications, especially biliary stricture and bile leakage. The reported success rate of LTCBDE varies from 80 to 95% [6, 37, 38]. In this

**A**

| Study or Subgroup | LTCBDE Events | LTCBDE Total | LCBDE Events | LCBDE Total | Weight | Odds Ratio M-H, Fixed, 95% CI |
|---|---|---|---|---|---|---|
| 2007 Chen | 40 | 40 | 24 | 24 | | Not estimable |
| 2007 Panganini | 185 | 191 | 126 | 138 | 21.2% | 2.94 [1.07, 8.03] |
| 2007 Topal | 77 | 83 | 28 | 30 | 13.7% | 0.92 [0.17, 4.81] |
| 2011 ElGeidie | 56 | 57 | 47 | 49 | 4.1% | 2.38 [0.21, 27.11] |
| 2012 Grubnik | 72 | 76 | 58 | 62 | 15.5% | 1.24 [0.30, 5.18] |
| 2013 Tao | 58 | 59 | 59 | 59 | 6.9% | 0.33 [0.01, 8.21] |
| 2014 Poh | 44 | 80 | 3 | 3 | 13.9% | 0.17 [0.01, 3.48] |
| 2014 Wang | 26 | 26 | 30 | 32 | 2.3% | 4.34 [0.20, 94.59] |
| 2014 Wu | 29 | 29 | 33 | 33 | | Not estimable |
| 2015 Zhang | 228 | 237 | 89 | 93 | 22.4% | 1.14 [0.34, 3.79] |
| **Total (95% CI)** | | **878** | | **523** | **100.0%** | **1.44 [0.84, 2.47]** |
| Total events | 815 | | 497 | | | |

Heterogeneity: Chi² = 5.78, df = 7 (P = 0.57); I² = 0%
Test for overall effect: Z = 1.34 (P = 0.18)

**B**

| Study or Subgroup | LTCBDE Mean | LTCBDE SD | LTCBDE Total | LCBDE Mean | LCBDE SD | LCBDE Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| 2007 Topal | 105 | 63.05 | 83 | 115 | 54.35 | 30 | 0.5% | -10.00 [-33.71, 13.71] |
| 2008 Jameel | 112.86 | 19.69 | 9 | 94.21 | 21.67 | 50 | 1.4% | 18.65 [4.45, 32.85] |
| 2012 Grubnik | 71 | 23.67 | 76 | 96.25 | 33.39 | 62 | 3.0% | -25.25 [-35.12, -15.38] |
| 2013 Chen | 100 | 30.4 | 110 | 120 | 42.2 | 100 | 2.9% | -20.00 [-30.03, -9.97] |
| 2013 Tao | 85.5 | 20.9 | 59 | 81.8 | 18.6 | 59 | 5.7% | 3.70 [-3.44, 10.84] |
| 2013 Zhou | 107.1 | 20.5 | 45 | 149.6 | 30.2 | 44 | 2.5% | -42.50 [-53.25, -31.75] |
| 2014 Tu | 102.3 | 20.2 | 50 | 147.9 | 35.6 | 50 | 2.3% | -45.60 [-56.95, -34.25] |
| 2014 Wang | 122.59 | 19.02 | 26 | 98.06 | 12.44 | 32 | 4.0% | 24.53 [16.04, 33.02] |
| 2014 Wu | 115.68 | 16.64 | 29 | 107.19 | 14.58 | 33 | 4.7% | 8.49 [0.65, 16.33] |
| 2015 Aawsaj | 107.5 | 52.96 | 85 | 144 | 49.67 | 233 | 1.7% | -36.50 [-49.44, -23.56] |
| 2015 Huang | 115.36 | 21.51 | 53 | 112.41 | 19.63 | 45 | 4.4% | 2.95 [-5.20, 11.10] |
| 2015 HuangHJ | 91.94 | 34.21 | 80 | 96.13 | 32.25 | 209 | 3.9% | -4.19 [-12.87, 4.49] |
| 2015 Zhang | 76 | 20.2 | 237 | 116.1 | 28.1 | 93 | 7.4% | -40.10 [-46.36, -33.84] |
| 2016 Han | 126 | 30 | 46 | 96 | 24 | 41 | 2.2% | 30.00 [18.64, 41.36] |
| 2016 Li | 105.2 | 8.5 | 40 | 132.5 | 8.4 | 40 | 21.1% | -27.30 [-31.00, -23.60] |
| 2016 Liu | 122.4 | 9.5 | 60 | 146.8 | 8.9 | 60 | 26.7% | -24.40 [-27.69, -21.11] |
| 2017 Sun | 102.7 | 25.1 | 105 | 118.3 | 28.4 | 105 | 5.5% | -15.60 [-22.85, -8.35] |
| **Total (95% CI)** | | | **1193** | | | **1286** | **100.0%** | **-17.72 [-19.42, -16.02]** |

Heterogeneity: Chi² = 445.18, df = 16 (P < 0.00001); I² = 96%
Test for overall effect: Z = 20.39 (P < 0.00001)

**C**

| Study or Subgroup | LTCBDE Mean | LTCBDE SD | LTCBDE Total | LCBDE Mean | LCBDE SD | LCBDE Total | Weight | Mean Difference IV, Fixed, 95% CI |
|---|---|---|---|---|---|---|---|---|
| 2007 Chen | 7.8 | 1.3 | 40 | 9.8 | 1.9 | 24 | 1.9% | -2.00 [-2.86, -1.14] |
| 2007 Topal | 7 | 7.51 | 83 | 12 | 10.2 | 30 | 0.1% | -5.00 [-8.99, -1.01] |
| 2008 Jameel | 5.72 | 3.54 | 9 | 7.33 | 5.78 | 50 | 0.2% | -1.61 [-4.42, 1.20] |
| 2011 ElGeidie | 1.6 | 0.62 | 57 | 3.8 | 2.41 | 49 | 2.9% | -2.20 [-2.89, -1.51] |
| 2012 Grubnik | 3.4 | 1.7 | 76 | 7.6 | 2.5 | 62 | 2.6% | -4.20 [-4.93, -3.47] |
| 2013 Chen | 3.6 | 0.9 | 110 | 7.9 | 1 | 100 | 20.6% | -4.30 [-4.56, -4.04] |
| 2013 Zhou | 4 | 1.5 | 45 | 5.8 | 2.2 | 44 | 2.2% | -1.80 [-2.58, -1.02] |
| 2014 Poh | 6 | 1.74 | 80 | 6.5 | 0.65 | 3 | 2.0% | -0.50 [-1.33, 0.33] |
| 2014 Tu | 4 | 2.5 | 50 | 7.2 | 1.5 | 50 | 2.1% | -3.20 [-4.01, -2.39] |
| 2014 Wang | 3.04 | 1.18 | 26 | 6.5 | 1.22 | 32 | 3.6% | -3.46 [-4.08, -2.84] |
| 2014 Wu | 4.43 | 0.38 | 29 | 5.1 | 0.64 | 33 | 20.6% | -0.67 [-0.93, -0.41] |
| 2015 Aawsaj | 2.75 | 2.07 | 85 | 10.5 | 7.4 | 233 | 1.3% | -7.75 [-8.80, -6.70] |
| 2015 Huang | 8.15 | 0.35 | 53 | 8.32 | 1.15 | 45 | 11.3% | -0.17 [-0.52, 0.18] |
| 2015 HuangHJ | 9.82 | 3.48 | 80 | 10.74 | 5.34 | 209 | 1.2% | -0.92 [-1.97, 0.13] |
| 2015 Zhang | 3.9 | 1.8 | 237 | 3.7 | 2.8 | 93 | 3.7% | 0.20 [-0.41, 0.81] |
| 2016 Han | 4.1 | 1.7 | 46 | 6.4 | 2.4 | 41 | 1.8% | -2.30 [-3.18, -1.42] |
| 2016 Li | 4.1 | 0.6 | 40 | 5.8 | 0.9 | 40 | 12.2% | -1.70 [-2.04, -1.36] |
| 2016 Liu | 5.4 | 2.1 | 60 | 16.5 | 6.9 | 60 | 0.4% | -11.10 [-12.92, -9.28] |
| 2017 Sun | 6.4 | 1.2 | 105 | 9.6 | 1.6 | 105 | 9.4% | -3.20 [-3.58, -2.82] |
| **Total (95% CI)** | | | **1311** | | | **1303** | **100.0%** | **-2.20 [-2.32, -2.08]** |

Heterogeneity: Chi² = 887.18, df = 18 (P < 0.00001); I² = 98%
Test for overall effect: Z = 36.73 (P < 0.00001)

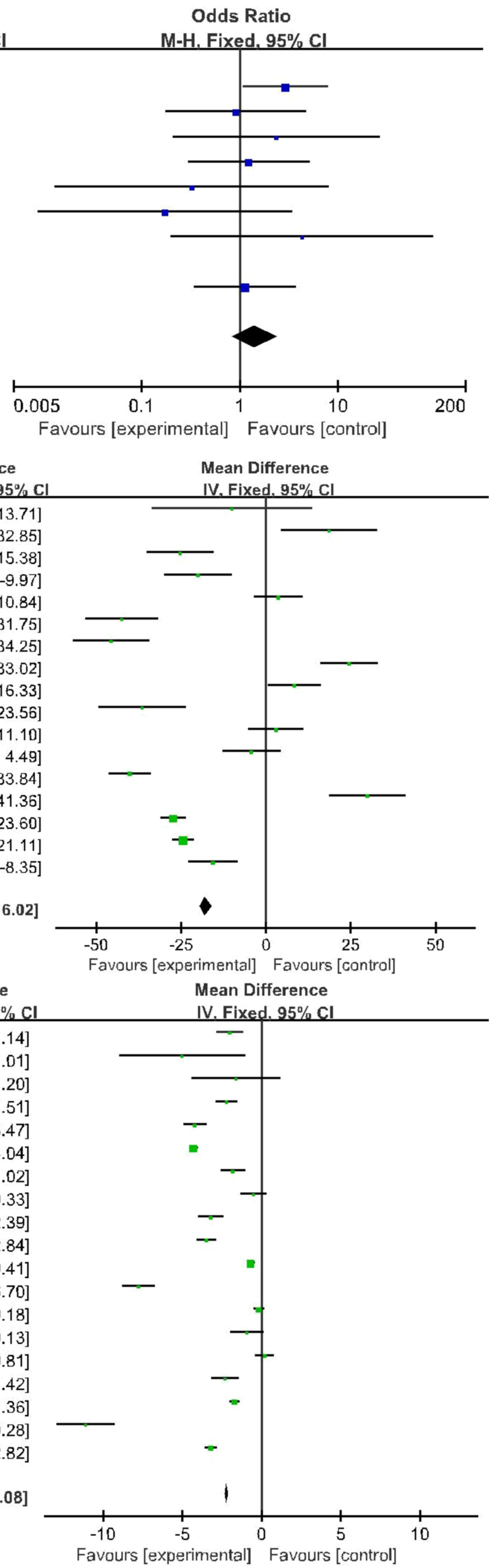


**Fig. 3** Forest plots of meta-analysis. **A** CBD stone clearance; **B** operative time; **C** duration of hospital stays

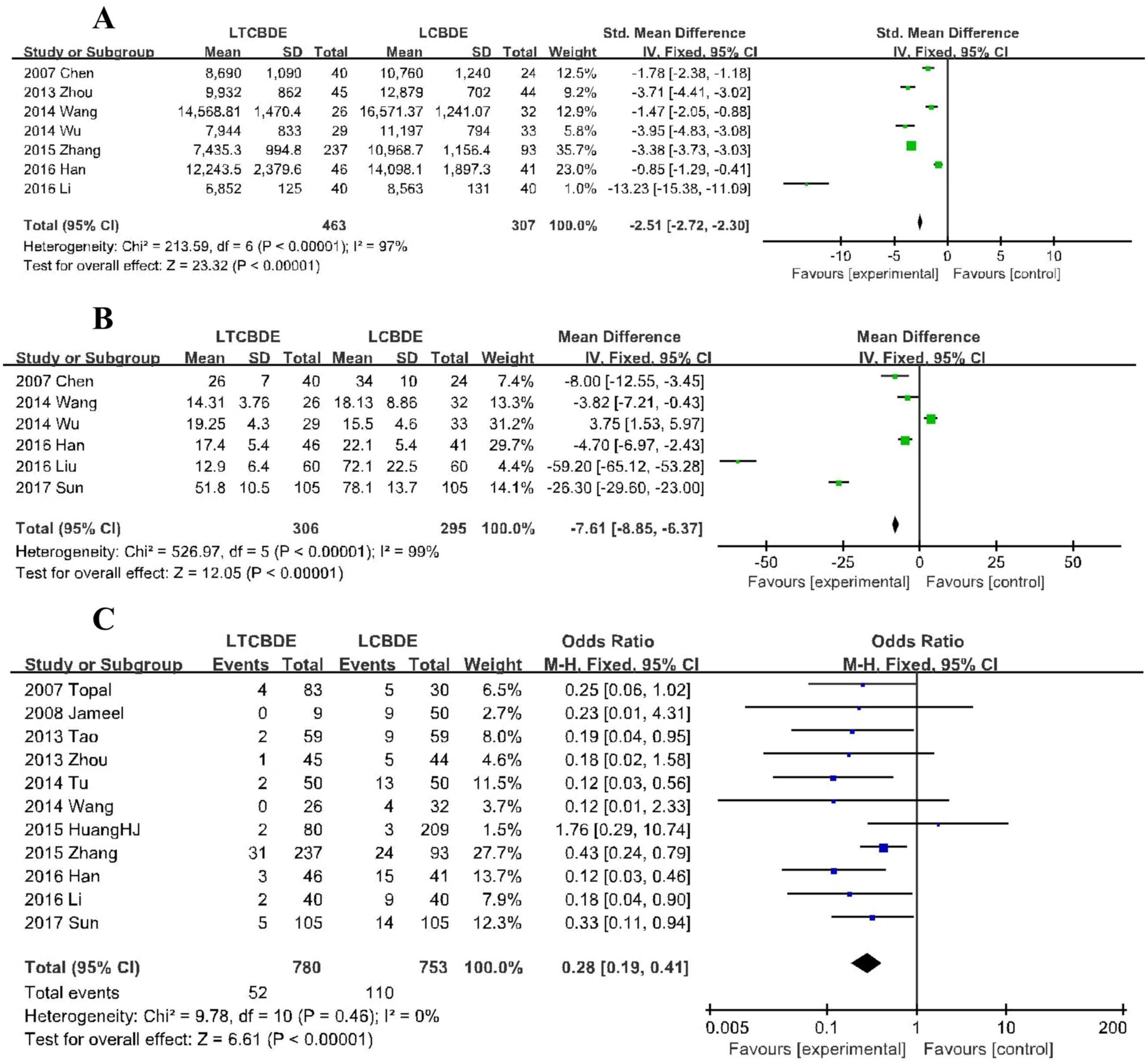


**Fig. 4** Forest plots of meta-analysis. **A** Hospital expenses; **B** blood loss; **C** postoperative complications

meta-analysis, total clearance was achieved in 92.3% of patients (815 of 878) in the LTCBDE group, which was not significantly different than that of LCBDE. An important advantage of the transcystic approach is that it leaves the CBD and sphincter of the duodenal papilla intact. The transcystic duct approach using the lumen of cystic duct avoids the need to open the CBD; therefore, it may be preferred over a choledochotomy incision and would greatly reduce the occurrence of complications [39]. In this meta-analysis, the incidence of postoperative complications in LTCBDE was significantly lower than that in LCBDE. As it preserves the integrity of the CBD and does not need the T tube, the transcystic approach is quicker than laparoscopic CBD exploration [7]. Furthermore, in aspects such as hospital stay, and blood loss, LTCBDE has an obvious superiority. Additionally, without the T tube, complications caused by T tube drainage, including water and electrolyte balance disorders, digestive dysfunction, retrograde infection, and prolapse displacement are prevented and patient does not repeatedly need choledochoscopic examination in the hospital. Although LTCBDE has many advantages, it also has some limitations. The most common major complication in the present series was retaining of stones [37, 40]. One important consideration is that the size of CBD stones should be less than or equal to the diameter of cystic duct [41]. Meanwhile, it is only suitable for fewer and proximal

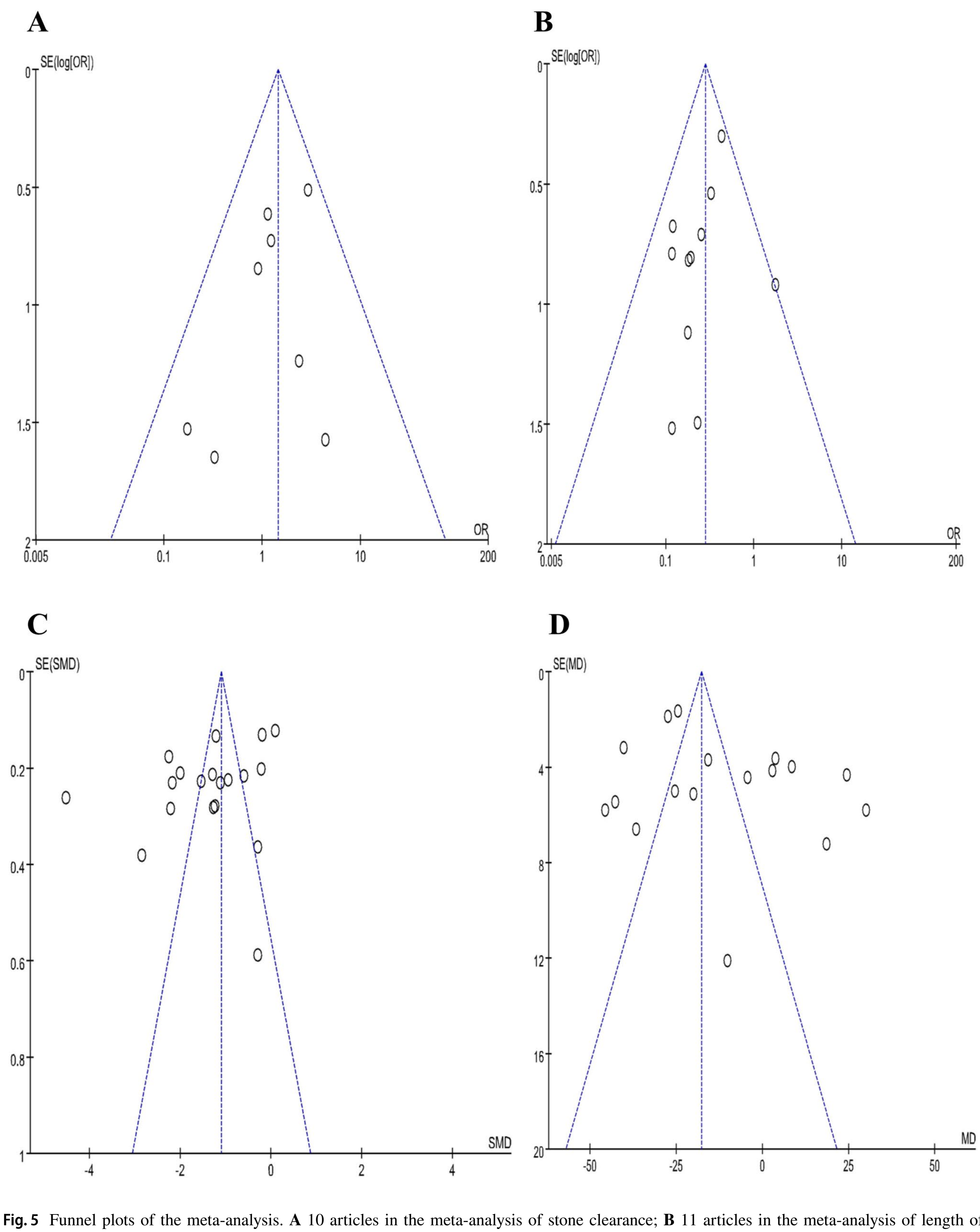


**Fig. 5** Funnel plots of the meta-analysis. **A** 10 articles in the meta-analysis of stone clearance; **B** 11 articles in the meta-analysis of length of postoperative complications. **C** 19 articles in the meta-analysis of hospital stay; **D** 17 articles in the meta-analysis of operative time

**Table 3** Technical approaches and indications for LCBDE/LTCBDE

| Author | Conversion to LCBDE | ITT/PP | Technical approaches | | Indication | |
|---|---|---|---|---|---|---|
| | | | LCBDE | LTCBDE | LCBDE | LTCBDE |
| Panganini (Italy) [11] | 0 | ITT | – | Blind basketing; a complete choledochoscopy is performed with a 7.5 Fr; choice to position an external biliary drain | CBD stones larger than the lumen of cystic duct; > 5 CBD stones; low and medial cystic duct-CBD junction; common hepatic duct stones | In the absence of any of the above conditions |
| Topal (Belgium) [12] | 2 | PP | If stones could not be extracted through the cystic duct a choledochotomy was performed | Dissect and clip the cystic duct; FCD through a small incision in the cystic duct | Small stones in a small bile duct | – |
| Chen (China) [13] | 0 | pp | – | 1/2 of the lateral incision of cystic duct; choledocoscope; ligated with Hem-o-lock | – | – |
| Jameel (UK) [14] | 0 | ITT | A longitudinal supraduodenal choledochotomy; Fogarty catheter; T tube; 3.0 vicryl sutures | Dissection of Calot's triangle; Routine transcystic IOC; choledochoscope; double clipped or ligated | – | – |
| ElGeidie (Egypt) [15] | 4 | PP | LC; intraoperative cholangiography (IOC); choledochotomy | LC; intraoperative cholangiography (IOC); transcystic CBD exploration | CBD was wider than 10 mm, stones > 10 mm in size or multiple stones > 4, in cases of proximal location, unfavorable cystic duct-CBD junction | – |
| Grubnik (Ukraine) [16] | 1 | PP | Exposure of the porta hepatis; cut anterior wall about 10–20 mm; choledochoscope control; absorbable running suture | Intraoperative cholangiography; 3 mm flexible choledochoscope; a complete cholangiography | Impacted stones, stones with diameter larger than 5–7 mm, multiple stones, unfavorable anatomy | |
| Chen (China) [17] | 0 | ITT | A longitudinal incision; flexible choledochoscope; a T tube of appropriate size | The confluence part was cut open 3–5 mm at the supra and inferior margins; flexible choledochoscope; wire<br>Basket; incision was sutured and the cystic duct was ligated | Cystic duct anatomy, presence of stones of diameter > 0.6 cm, or a large number of stones | - |
| Zhou (China) [18] | 0 | ITT | Anterior wall longitudinal incision about 0.6–1.8 cm; choledocoscope; T tube drainage | A longitudinal incision 0.8–1.0 cm away from CBD; balloon dilatation; choledocoscope; ligated cystic duct | – | – |
| Tao (China) [19] | 0 | PP | Anterior wall longitudinal incision; choledocoscope; primary suture without T tube | The confluent part was cut open 3–5 mm at the supra and inferior margins; choledochoscope; wire<br>Basket; incision was sutured | – | CBD > 8 mm |

**Table 3** (continued)

| Author | Conversion to LCBDE | ITT/PP | Technical approaches | | Indication | |
|---|---|---|---|---|---|---|
| | | | LCBDE | LTCBDE | LCBDE | LTCBDE |
| Wang (China) [20] | 0 | ITT | Anterior wall longitudinal incision; choledococscope; T tube drainage | 1/2 of the lateral incision of the cystic duct 10 mm away from CBD; choledococscope; clip cystic duct 5–10 mm away from CBD | more than 10 CBD stones; cystic duct anatomy; cystic duct < 4 mm; stones > 10 mm | 8mm < CBD < 12 mm; less than 10 CBD stones; stones < 10 mm; cystic Duct > 4 mm; extrahepatic bile duct stone |
| Tu (China) [21] | 0 | ITT | Anterior wall longitudinal incision about 1.5 cm; choledococscope; T tube drainage | A longitudinal incision 1.0 cm away from CBD; balloon dilatation; choledococscope | – | – |
| Poh (Australia) [22] | 0 | PP | – | A longitudinal incision; 5-mm flexible choledochoscope; Dormia-type basket | – | – |
| Wu (China) [23] | 3 | PP | Anterior wall longitudinal incision; choledococscope; T tube drainage | 1/2 of the lateral incision of the cystic duct; choledococscope; ligated with Hem-o-lock | – | – |
| Zhang (China) [24] | 16 | PP | Dissect and clip the cystic duct; Further dissection towards CBD; flexible choledochoscopy | Dilatation was carried out first with blunt; 5-mm flexible choledochoscope | Dilated CBD in the diameter of ≥ 9 mm, stone size ≥ 9 mm, stone number > 5, failure of LTSE, and proximal bile ductal calculi | Stones smaller than 9 mm, < 5 in number, and cystic duct lateral entrance to CBD |
| HuangHJ (China) [25] | 0 | ITT | – | A longitudinal incision; choledochoscope; washed via suction with a soft pipe; ligated with a Hem-o-lock | – | – |
| Aawsaj (UK) [26] | 22 | PP | A longitudinal incision using a Berci knife and micro-scissors; choledococscope; closed primarily or over a T tube | 3 or 5-mm choledococscope | – | – |
| Huang (China) [27] | 0 | PP | – | 1/2 of the lateral incision of the cystic duct; choledococscope; ligated or sutured | – | – |
| Li (China) [28] | 0 | ITT | Anterior wall longitudinal incision; choledococscope; T tube drainage | 1/2 of the lateral incision of the cystic duct 5 mm away from CBD; choledococscope; ligated with Hem-o-lock | cystic duct < 5 mm | – |
| Han (China) [29] | 0 | ITT | Anterior wall longitudinal incision; choledococscope; T tube drainage | 1/2 of the lateral incision of the cystic duct 10 mm away from CBD; choledococscope; clip cystic duct 5–10 mm away from CBD | – | – |

**Table 3** (continued)

| Author | Conversion to LCBDE | ITT/PP | Technical approaches | | Indication | |
|---|---|---|---|---|---|---|
| | | | LCBDE | LTCBDE | LCBDE | LTCBDE |
| Liu (China) [30] | 0 | ITT | – | 1/2 of the lateral incision of the cystic duct; Dilatation; choledocoscope; incision was sutured | – | – |
| Sun (China) [31] | 0 | ITT | LC; anterior wall longitudinal incision about 10 mm; choledocoscope; T tube drainage | 1/2 of the lateral incision of the cystic duct 10 mm away from CBD; choledocoscope; clip cystic duct 5 mm away from CBD | – | – |

stones, but unsuitable for treating intrahepatic bile duct stones because of an angle between the cystic and CBDs [42]. As noted by some authors, complete stone clearance is impossible and the success rate of LTCBDE is about 85% among all patients [37, 40]. In retrospect of stone clearance and risk factors for failure in LTCBDE, a research pointed out that larger stone size is a strong risk factor for failure of stone clearance although, laparoscopic transcystic exploration of the common bile duct is suitable in a majority of common bile duct stone patients [3]. Aimed at this problem, a few researchers [7, 17, 35] slit the cystic duct 3–5 mm at the supra and inferior margins, and used balloon dilation or ultrathin choledochoscope, electrohydraulic and laser lithotripsy, or even blinded use of the reticular basket. These methods are worth trying when the choledochoscope is unable to enter the CBD. Another obvious limitation is the long-term learning curve. In the literature, we clearly found that the surgeon's performance was not manifested by obviously shorter operating time and postoperative hospital stay in the early period. A learning curve [7] indicated that the maximum CUSUM duration of operation occurred at 250 procedures.

Through the review of analyzed studies, we can conclusively describe the technical processes of LCBDE and LTCBDE. In LCBDE, the first step was to achieve good exposure of the porta hepatis, followed by creating a longitudinal incision of about 1.0–2.0 cm using a Berci knife or micro-scissors at the anterior wall. Intraoperative cholangiography (IOC) was optional depending on the preoperative image findings using the choledochoscope. The CBD was closed primarily or over a T tube in some cases [14, 16, 24, 26]. In LTCBDE, first LC was performed, and the residual cystic duct diameter was retained at 1–2.0 cm. Next, the cystic duct was cut longitudinally on its ventral side up to the confluence of the cystic duct and CBD or to retain the cystic duct at about 1 cm. Intraoperative cholangiography (IOC) was also optional depending on the preoperative image findings. A choledochoscope (preferably 3 or 5 mm) was then inserted through the enlarged opening for exploration. The mucous layer was continuously sutured from the distal end of the combined incision to the cystic duct, or the retained cystic duct was controlled by clips [11, 16, 17, 28, 31] (the technical approaches of all studies are shown in Table 3).

It is also worth mentioning that there are no fixed standards for LTCBDE. The standards could be different for different teams, because they are affected by differences in the level of technology and the anatomical conditions. Based on our surgical experience and some studies [11, 15, 20, 24], the transcystic approach was favored as the first-line method if the following conditions were satisfied: number of stones $< 10$, stone located in the extrahepatic bile duct, diameter of the cystic duct $> 4$ mm, diameter of the stones $< 10$ mm, and no obvious abnormalities of the cystic duct. Otherwise, a choledocotomy was performed if necessary rather than blindly pursuing the transcystic method. (The indications used in all studies are shown in Table 3). According to these operation indications, LTCBDE has the advantages of reduced trauma, fewer complications, low cost, and high quality of life after operation.

## Limitations

The advantage of this review is that it provides a comprehensive comparison of LTCBDE and LCBDE. To our knowledge, this is one of the few meta-analyses to explore these two techniques. Of course, this meta-analysis has some limitations, which should be noted. First, publication and selection bias could be a substantial issue because of retrospective matching of cases such as, choice of patients, and the assessment of complications such as biliary fistula. Second, the small number of patients and studies decreased the reliability, even though we searched through several databases. The size of this study was not large enough, and the results need more effective evidence in further high-quality trials. Furthermore, we did not further analyze the surgical techniques such as types of choledochoscope, cut position of the cystic duct, different levels of technology, and anatomical conditions, which may influence the complication rate. Finally, we did not discuss the prognosis and long-term complications of LTCBDE and LCBDE.

## Conclusion

In conclusion, LTCBDE can avoid postoperative T tube drainage, decrease complications, shorten hospital stay, and increase the quality of life. The safety, feasibility, and short-term clinical benefits of LTCBDE deserve affirmation and praise. We believe that this approach deserves to be promoted and be extended to several patients because of its high clinical efficacy.

**Author contributions** LP: Literature research, Manuscript preparation. YZ: Data acquisition and analysis. YW: Data acquisition and analysis. JK: Manuscript final version approval.

## Compliance with ethical standards

**Disclosure** Liwei Pang, Yan Zhang, Yuwen Wang, and Jing Kong have no conflicts of interest or financial ties to disclose.

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