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SCIENTIFIC REVIEW

Laparoscopic Transcystic Versus Transductal Common Bile Duct Exploration: A Systematic Review and Meta-analysis

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Abstract

Objective To evaluate comparative outcomes of laparoscopic transcystic (TC) and transductal (TD) common bile duct (CBD) exploration.

Methods We systematically searched MEDLINE, EMBASE, CINAHL, CENTRAL, the World Health Organization International Clinical Trials Registry, ClinicalTrials.gov, ISRCTN Register, and bibliographic reference lists. CBD clearance rate, perioperative complications, and biliary complications were defined as the primary outcome parameters. Procedure time, length of hospital stay, conversion to open procedure were the secondary outcomes. Combined overall effect sizes were calculated using random-effects models.

Results We identified 30 studies reporting a total of 4073 patients comparing outcomes of laparoscopic TC (n = 2176) and TD (N = 1897) CBD exploration. The TC approach was associated with significantly lower overall complications (RD: −0.07, P = 0.001), biliary complications (RD: −0.05, P = 0.0003), and blood loss (MD: −16.20, P = 0.02) compared to TD approach. Moreover, the TC approach significantly reduced the length of hospital stay (MD: −2.62, $P < 0.00001$) and procedure time (MD: −12.73, P = 0.005). However, there was no significant difference in rate of CBD clearance (RD: 0.00, P = 0.77) and conversion to open procedure (RD: 0.00, P = 0.86) between two groups.

Conclusions Laparoscopic TC CBD exploration is safe and reduces overall morbidity and biliary complications compared to the TD approach. Moreover, it is associated with significantly shorter length of hospital stay and procedure time. High-quality randomised trials may provide stronger evidence with respect to impact of the cystic duct/CBD diameter, number or size of CBD stones, or cystic duct anatomy on the comparative outcomes of TC and TD approaches.

Introduction

Choledocholithiasis, the presence of gallstone in the common bile duct (CBD), is prevalent in 10–15% of patients with gallstone disease [1]. Appropriate management of choledocholithiasis in a timely manner is essential to prevent its associated complications including pancreatitis, cholangitis, or intrahepatic abscess which are associated with high morbidity and even mortality [2, 3].

Choledocholithiasis can be managed by endoscopic retrograde cholangiopancreatography (ERCP) before,

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during or after cholecystectomy, or open or laparoscopic CBD exploration during cholecystectomy [2–4]. Nevertheless, laparoscopic cholecystectomy with intraoperative CBD exploration has been demonstrated to have similar stone clearance, morbidity, and mortality rates when compared with ERCP [4–6].

Laparoscopic CBD exploration can be carried out via the transcystic (TC) approach or transductal (TD) approach; the latter is also known as choledochotomy [1, 7]. Although some reviews [8] did not find a strong evidence to support one approach over the other, a recent meta-analysis [9] demonstrated that the stone clearance of laparoscopic TC CBD exploration was equal to that of the TD approach, and the TC approach was associated with a shorter operative time, lower blood loss, and overall complications. However, the authors missed a large number of eligible studies that could have been included in their pooled analysis. Moreover, the meta-analytical model was not applied correctly in some of their outcome synthesis. Furthermore, most importantly, there was no analysis conducted on biliary complications which is an important outcome parameter when comparing laparoscopic TC and TD CBD exploration.

Therefore, we aimed to conduct a comprehensive systematic review and meta-analysis that reflect the best available evidence more accurately with more appropriate use of the meta-analytical model and consideration of relevant outcomes to evaluate comparative evidence of laparoscopic TC and TD CBD exploration.

Methods

Design and study selection

We highlighted our eligibility criteria, methods, and evaluated outcomes in a review protocol. Our study was conducted in line with preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement standards [10].

We included all comparative studies evaluating the outcomes of TC and TD CBD exploration in patients undergoing laparoscopic cholecystectomy. We considered patients aged 18 years or older and of any gender undergoing laparoscopic exploration of CBD using the TC or TD approach.

The intervention of interest was TC CBD exploration which was defined as exposure of cystic duct by making an incision followed by introduction of a cholangiogram catheter into the cystic duct in order to visualise the CBD under fluoroscopic guidance. The primary intervention was compared with TD CBD exploration (choledochotomy) which was defined as exposure of the CBD using a vertical incision on the anterior surface of the duct, distal to the cystic-CBD junction followed by introduction of a cholangiogram catheter into the CBD in order to visualise the CBD under fluoroscopic guidance. With regards to the CBD stone extraction, we considered any technical manoeuvres including the CBD irrigation with any solution, basket manipulation with or without fluoroscopic guidance or choledochoscopy using flexible choledochoscope of any size.

Primary outcome measures were defined as CBD clearance rate, overall perioperative complications (biliary, cardiac, pulmonary, cerebrovascular, renal, gastrointestinal, infective, thromboembolic, etc.), biliary complications (bile leakage or biliary stricture) and were defined as the primary outcome parameters. Procedure time, length of hospital stay, and conversion to open procedure were the secondary outcome parameters.

Literature search strategy

Two authors independently searched the following electronic databases: MEDLINE, EMBASE, CINAHL, and the Cochrane Central Register of Controlled Trials (CENTRAL). The literature search was conducted on 27 October 2018. Our search strategy was adapted according to thesaurus headings, search operators, and limits in the aforementioned databases (Appendix). Furthermore, we searched World Health Organization International Clinical Trials Registry http://apps.who.int/trialsearch/, ClinicalTrials.gov http://clinicaltrials.gov/, and ISRCTN Register http://www.isrctn.com/ to identify ongoing and unpublished studies. Finally, the bibliographic lists of relevant articles and reviews were screened for further potentially eligible trials.

Selection of studies

The title and abstract of identified articles were evaluated by two independent authors. Subsequently, if relevant, the full-texts of identified articles were retrieved and evaluated against the eligibility criteria of our study. Those studies that met our eligibility criteria were included. Discrepancies in this process were resolved by discussion between the authors. However, if the disagreement still existed, an independent author was consulted.

Data extraction and management

We created an electronic data extraction spreadsheet according to the Cochrane's recommendations for intervention reviews. The data extraction spreadsheet was pilot-tested in randomly selected articles and adjusted

accordingly. The following information was extracted from the included studies by two independent authors:

- Study-related data (first author, publication year, country of origin of the corresponding author, journal in which the study was published, study design, and study size).
- Baseline demographic and clinical information of the study populations.
- Primary and secondary outcome data.

Disagreements during data extraction and management were resolved following consultation with a third independent author.

Assessment of risk of bias

The methodological quality and risk of bias assessment were carried out by two authors using the methodological index for non-randomised studies (MINORS) quality assessment scale [11] as all of our included studies were observational studies. The items were scored 0 if not reported; 1 when reported but inadequate; 2 when reported and adequate. The maximum score was 24. Studies with score of 24 were deemed to be at low risk of bias, studies with score of 20–23 were deemed to be at moderate risk of bias, and those that scored less than 20 were judged to be at high risk of bias. We resolved discrepancies in risk of bias assessment by discussion between the assessing authors. Nevertheless, if no agreement could be reached, a third reviewer was involved as an adjudicator.

Summary measures and synthesis

For dichotomous outcome variables (CBD clearance, overall perioperative complications, biliary complications, and conversion to open), we calculated risk difference (RD) as the summary measures. The RD is the difference in risk of an adverse event in the TC group compared to the TD group. A RD of less than one would favour the TC group except in the analysis of duct clearance where a RD of more than one would favour the TC group. For continuous parameters (length of hospital stay, procedure time, and volume of blood loss), we calculated the mean difference (MD) between the TC and TD groups.

The individual patient was used as the unit of analysis in this study. Information with regards to dropouts, withdrawals, and any other missing data was recorded. We planned to contact authors of the included studies where information about our outcome of interest was not reported. Our final analysis respected the intention-to-treat concept.

One independent review author entered the extracted data into Review Manager 5.3 software for data synthesis [12]. The entered data were subsequently checked by a second independent review author. Random-effects modelling was used for analysis. We reported the results of our analysis for each outcome parameter in a forest plot with 95% confidence intervals (CIs).

Heterogeneity among the studies was assessed using the Cochran's Q test (χ^2). We quantified inconsistency by calculating I^2 and interpreted it using the following guide: [12] 0–25% might not be important; 25–75% may represent moderate heterogeneity; 75–100% may represent substantial heterogeneity. Moreover, where more than 10 studies were available in analysis of an outcome parameter, we assessed publication bias visually by evaluating the symmetry of funnel plots and formally by using the Egger's regression test.

We conducted sensitivity analyses to explore potential sources of heterogeneity and assess the robustness of our results. For each outcome parameter, we repeated the primary analysis using random-effects or fixed-effect models. Moreover, for each of our defined dichotomous variable, we calculated the pooled OR, risk ratio (RR), or RD. Finally, we evaluated the effect of each study on the overall effect size and heterogeneity by repeating the analysis following excluding one study at a time.

Results

Our literature search through the aforementioned databases resulted in 1172 articles. After further evaluation of the identified articles, 30 articles [13–42] were deemed appropriate for inclusion (Fig. 1). The included studies consisted of 10 prospective and 20 retrospective observational studies reporting a total of 4073 patients of whom 2176 underwent TC CBD exploration and the remaining 1897 had TD CBD exploration during laparoscopic cholecystectomy.

Table 1 presents the date of publication and country of origin, journal, and study design of the included studies. Baseline demographic and clinical characteristics of the study populations were variable with little difference between the groups in each study. Most studies did not report the diameter of the cystic duct or CBD in their study populations. Eight out of 10 studies that reported the CBD diameter of their included patients demonstrated comparable CBD diameter in their TC and TD groups. Furthermore, the included studies heterogeneously reported the size and number of CBD stones in their included patients.

Methodological appraisal

The methodological appraisal of the included 30 observational studies is presented in Table 2. The risk of bias was

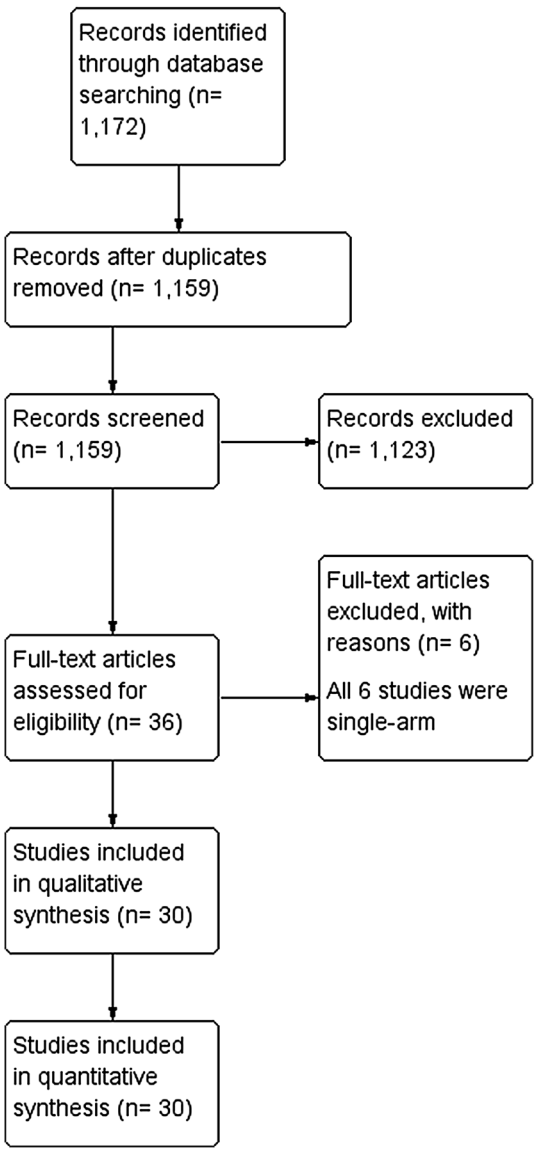


Fig. 1 Study flow diagram

judged as moderate in 11 studies and high in the remaining 19 studies.

Data synthesis

Outcomes are summarised in Figs. 2 and 3.

CBD clearance

Nineteen studies (2413 patients) reported duct clearance as an outcome. The duct clearance rate in the TC and TD groups was 91.1% and 94.1%, respectively. The pooled analysis did not find a significant difference between both groups (RD: 0.00; 95% CI −0.03 to 0.02, $P = 0.77$). Moderate heterogeneity among the studies existed ($I^2 = 45\%$, $P = 0.02$). The likelihood of publication bias was low ($P = 0.39$).

Overall perioperative complications

This outcome was evaluated by 20 studies. There were 136 (8.4%) perioperative complications in the TC group and 181 (13.7%) perioperative complications in the TD group. Our pooled analysis of 2938 patients found a significant reduction in overall perioperative complications associated with the TC approach compared to the TD approach (RD: −0.07; 95% CI −0.12 to −0.03, $P = 0.001$). Heterogeneity among the included studies was moderate ($I^2 = 73\%$, $P < 0.00001$). The likelihood of publication bias was low ($P = 0.11$).

Biliary complications

Twelve studies reported biliary complications as an outcome. A total of 81 biliary complications were reported, 17 (1.6%) in the TC group and 64 (7.0%) in the TD group. The pooled analysis of 1995 patients demonstrated that the TC approach significantly reduced the risk of biliary complications compared to the TD approach (RD: −0.05; 95% CI −0.07 to −0.02, $P = 0.0003$). Moderate between-study heterogeneity was identified ($I^2 = 43\%$, $P = 0.05$). The likelihood of publication bias was also low ($P = 0.92$).

Conversion to open

The pooled analysis included 3396 patients from 26 studies. The rate of conversion to open procedure in the TC and TD groups was 3.2% and 2.4%, respectively. No significant difference in favour of either intervention was identified (RD: 0.00; 95% CI −0.01 to 0.02, $P = 0.86$). Heterogeneity among the included studies was low ($I^2 = 0\%$, $P = 0.87$). The likelihood of publication bias was also low ($P = 0.34$).

Blood loss

Only six studies (601 patients) reported the mean volume of blood loss of their included patients. Our analysis showed that the TC approach was associated with a significantly lower volume of blood loss compared to TD approach (23.6 mls vs 40.0 mls, MD: −16.20; 95% CI −29.45 to −2.95, $P = 0.02$). A significant heterogeneity existed among the included studies ($I^2 = 99\%$, $P < 0.00001$).

Table 1 Included studies related data

Author	Year	Journal	Country	Study design	TC	TD
Martin [13]	1998	Ann Surg	Australia	Retrospective observational study	158	55
Rhodes [14]	1998	Lancet	UK	Prospective observational study	28	12
Cuschieri [15]	1999	Surg Endosc	UK	Prospective observational study	56	53
Sgourakis [16]	2002	Minerva Chir	Greece	Prospective observational study	16	12
Tokumura [17]	2002	J Hepatobiliary Pancreat Surg	Japan	Retrospective observational study	91	126
Waage [18]	2002	Surg Endosc	Sweden	Retrospective observational study	118	57
Paganini [19]	2007	Surg Endosc	Italy	Retrospective observational study	191	138
Topal [20]	2007	Surg Endosc	Belgium	Prospective observational study	83	30
Chen [21]	2007	J Clin Surg	China	Retrospective observational study	40	24
Jameel [22]	2008	Ann R Coll Surg Engl	UK	Prospective observational study	9	50
Noble [23]	2009	J Laparoendosc Adv Surg Tech A	UK	Prospective observational study	8	30
ElGeidie [24]	2011	Dig Surg	Egypt	Prospective observational study	57	49
Grubnik [25]	2012	Surg Endosc	Ukraine	Prospective observational study	76	62
Chen [26]	2013	J Laparoendosc Adv Surg Tech A	China	Retrospective observational study	100	110
Zhou [27]	2013	Chin J Clin Med	China	Retrospective observational study	45	44
Tao [28]	2013	Chin J Min Inv Surg	China	Retrospective observational study	59	59
Wang [29]	2014	J Xinjiang Med Univ	China	Retrospective observational study	26	32
Tulati [30]	2014	Front Med	NR	Retrospective observational study	50	50
Poh [31]	2014	HPB	Australia	Retrospective observational study	80	3
Wu [32]	2014	Anhui Med J	China	Retrospective observational study	29	33
Abdelrahman [33]	2014	J Am Coll Surg	UK	Retrospective observational study	47	30
Zhang [34]	2015	BMC Surg	China	Prospective observational study	237	93
Hongjun [35]	2015	Surg Laparosc Endosc Percutan Tech	China	Retrospective observational study	80	209
Aawsaj [36]	2015	Surg Endosc	UK	Prospective observational study	85	233
Huang [37]	2015	Mod Pract Med	China	Retrospective observational study	53	45
Li [38]	2016	Mod Diagn Treat	China	Retrospective observational study	40	40
Han [39]	2016	J Pract Med	China	Retrospective observational study	46	41
Liu [40]	2016	China J Endosc	China	Retrospective observational study	60	60
Sun [41]	2017	J Clin Med	China	Retrospective observational study	105	105
Al-Temimi [42]	2018	J Laparoendosc Adv Surg Tech A	USA	Retrospective observational study	103	12

TC Transcystic, *TD* transductal, *NR* not reported

Length of hospital stay

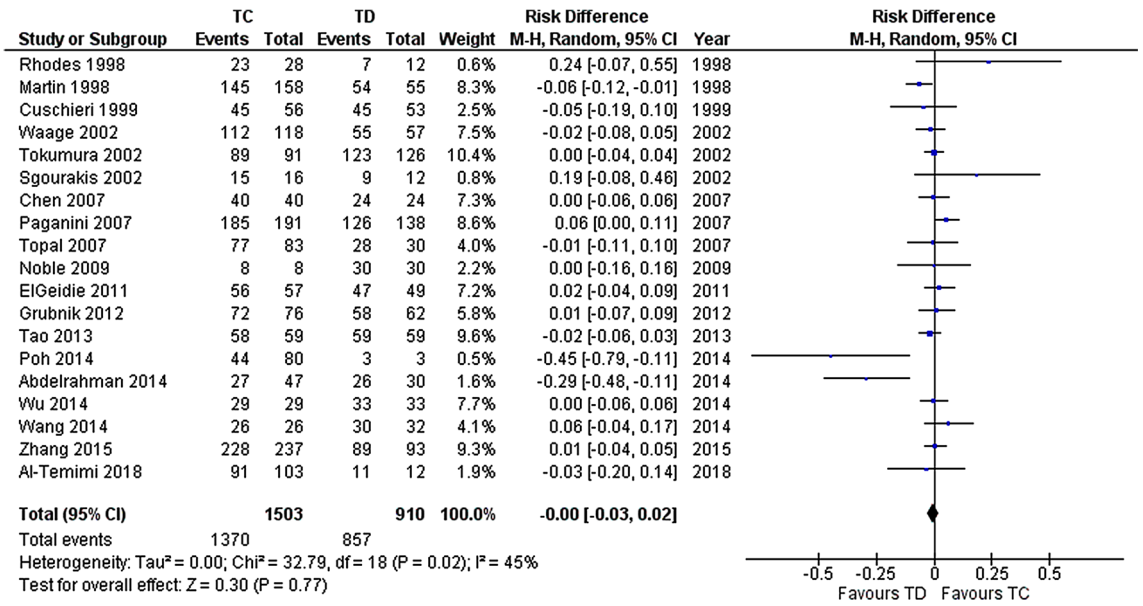
Twenty-three studies reported the length of hospital stay as an outcome. The pooled analysis, which included 3334 patients, demonstrated that the TC approach was associated with significantly shorter length of hospital stay compared to the TD approach (5.2 days vs 7.8 days, MD: −2.62; 95% CI −3.46 to −1.77, $P < 0.00001$). Substantial heterogeneity among the included studies was detected ($I^2 = 98\%$, $P < 0.00001$). The likelihood of publication bias was significant ($P = 0.04$).

Procedure time

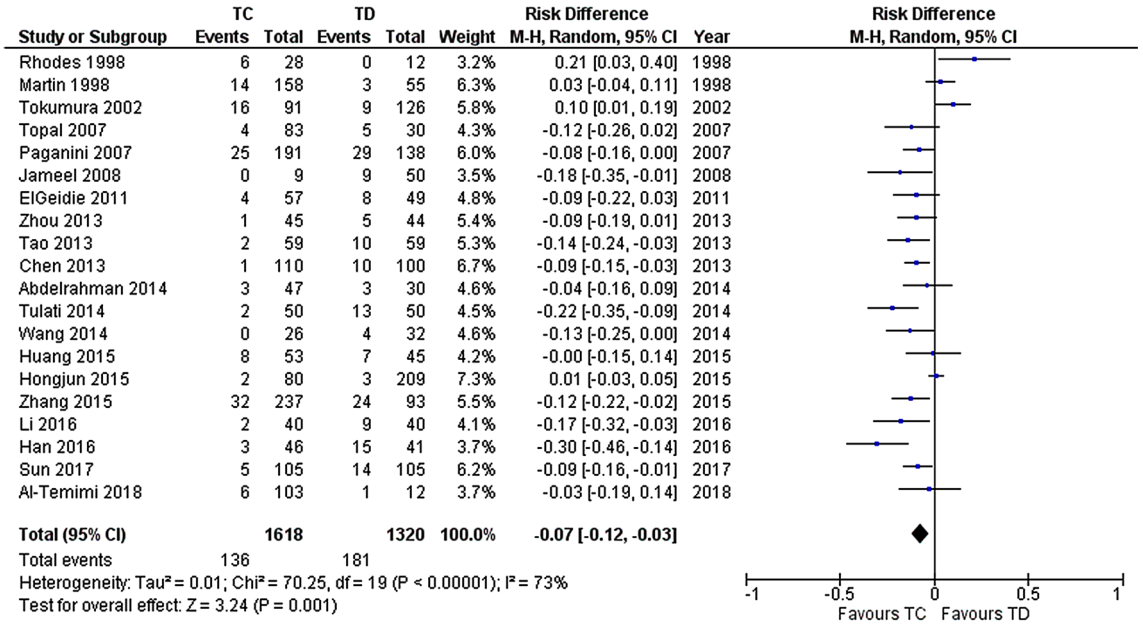
Twenty studies (3084 patients) reported their mean procedure time as an outcome. Our analysis showed that the TC approach was associated with a significantly shorter procedure time than TD approach (113.8 min vs. 126.3 min, MD: −12.73; 95% CI −21.52 to −3.94, $P = 0.005$). Heterogeneity among the studies was substantial ($I^2 = 96\%$, $P < 0.00001$). The likelihood of publication bias was low ($P = 0.16$).

Sensitivity analysis

Using random-effects or fixed-effect models did not affect the pooled effect size in analysis of any of the reported



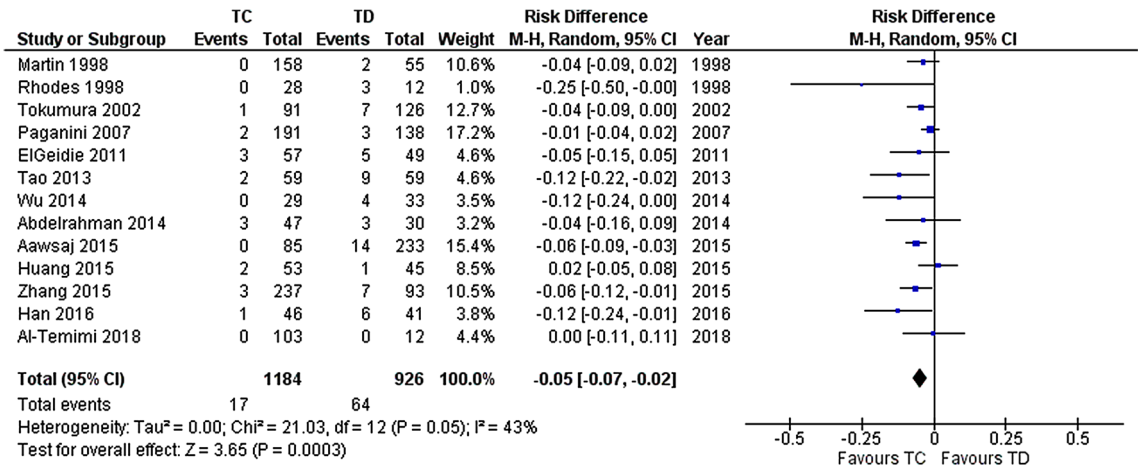
(a) CBD clearance



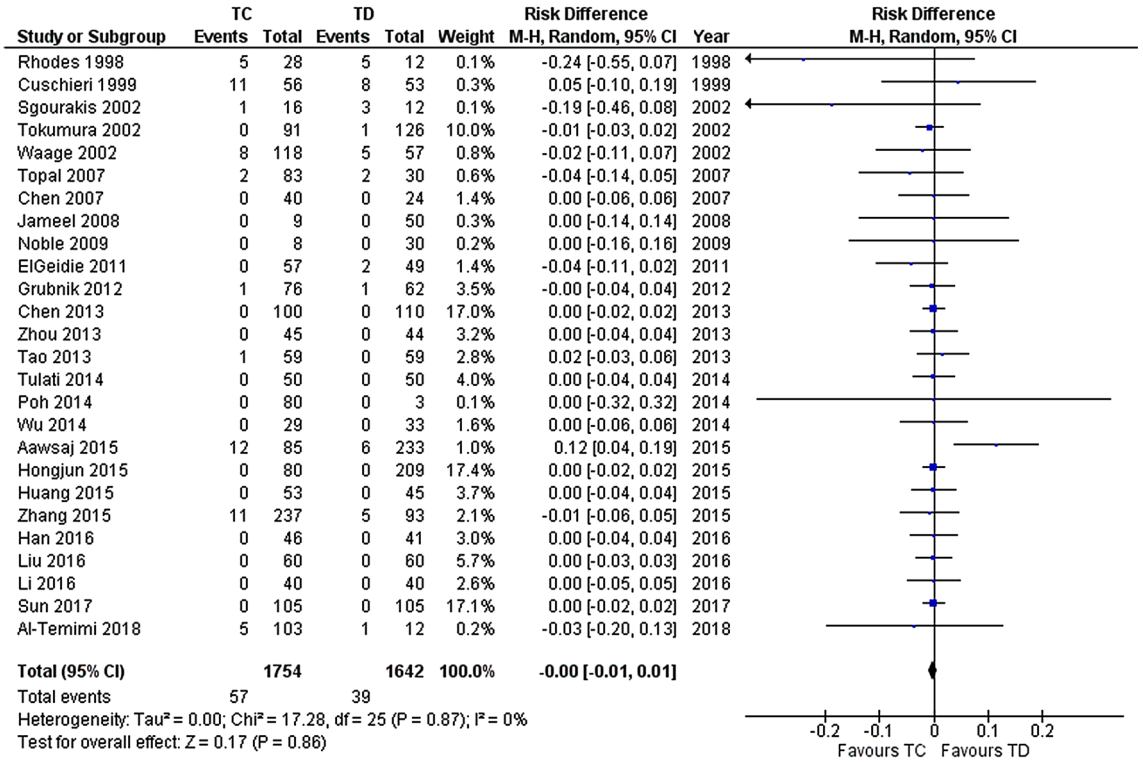
(b) Overall postoperative complications

Fig. 2 Forest plots of comparison of **a** common bile duct (CBD) clearance, **b** overall postoperative complications, **c** biliary complications, **d** conversion to open, **e** length of hospital stay, **f** procedure time, and **g** blood loss. The solid squares denote the risk difference (RD) or mean difference (MD). The horizontal lines represent the 95% confidence intervals (CIs), and the diamond denotes the pooled effect size. M–H, Mantel–Haenszel test

outcomes. The direction of pooled effect size remained unchanged when OR, RR, or RD were calculated for dichotomous variables. However, in the analysis of blood loss, removal of study of Liu et al. [40] affected the direction of pooled effect size and the reduction in volume of blood loss was no longer statistically significant in favour of the TC approach (MD: −7.78, 95% CI −17.73 to 1.98, $P = 0.12$). Moreover, in the analysis of CBD clearance, removal of study of Abdelrahman et al. [33] reduced the heterogeneity from 30 to 0%.



(c) Biliary complications

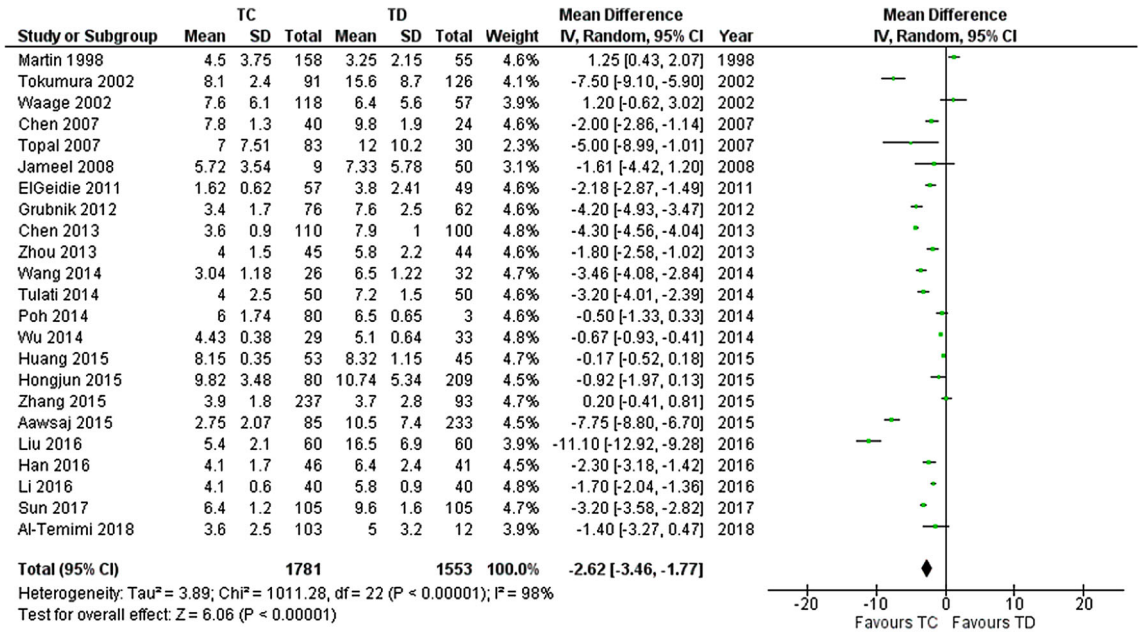


(d) Conversion to open

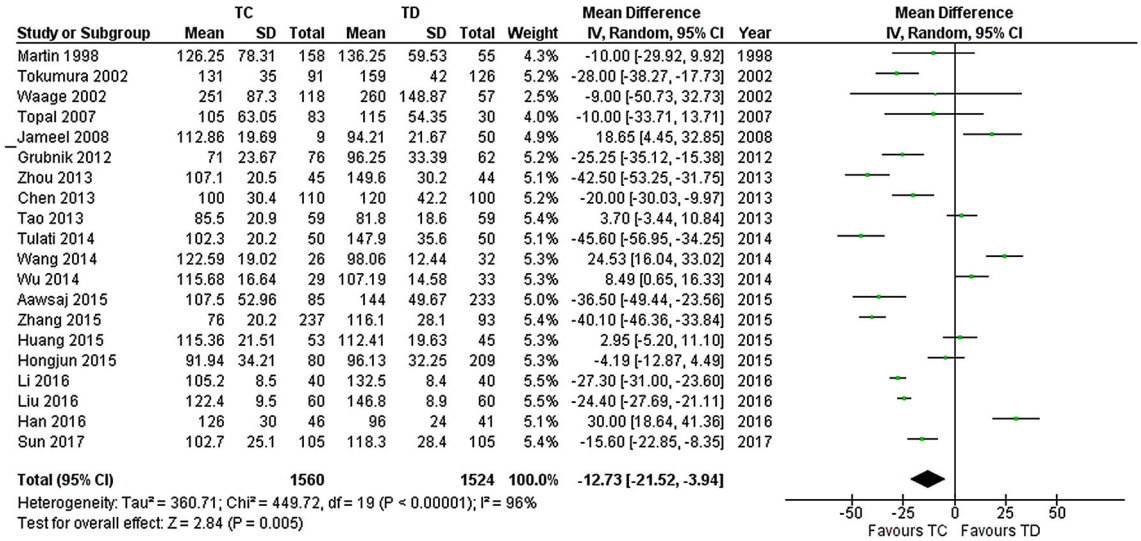
Fig. 2 continued

Discussion

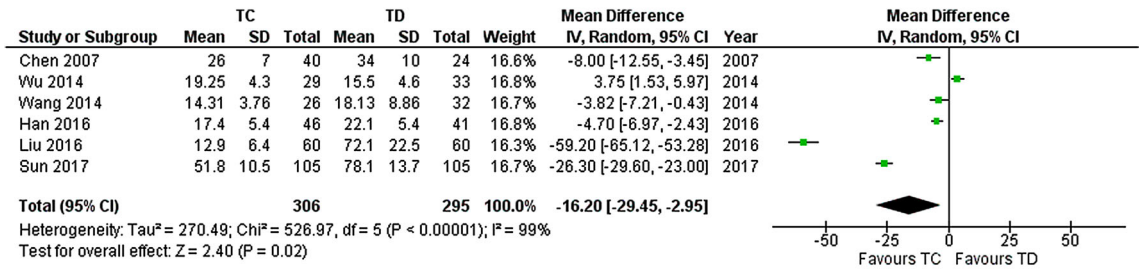
In view of existence of controversy regarding the most appropriate approach for laparoscopic CBD exploration, we conducted a comprehensive systematic review and meta-analysis of comparative studies to evaluate outcomes of laparoscopic TC and TD CBD exploration. Our literature review identified 30 observational studies enrolling a total of 4073 patients of whom 2176 underwent laparoscopic TC CBD exploration and the remaining 1897 had TD CBD exploration. The meta-analyses of outcomes demonstrated that the TC approach was associated with significantly lower rate of overall complications, biliary complications, and blood loss compared to the TD approach. Moreover, the TC approach significantly reduced the length of hospital stay and procedure time. However,



(e) Length of hospital stay



(f) Procedure time



(g) Blood loss

Fig. 2 continued

Table 2 Methodological quality of the observational studies assessed with the methodological index for non-randomised studies (MINORS)

Author	Clearly stated aim	Inclusion of consecutive patients	Prospective data collection	Endpoints appropriate to study aim	Unbiased assessment of study endpoint	Follow-up period appropriate to study aim	<5% lost to follow-up	Prospective calculation of study size	Adequate control group	Contemporary groups	Baseline equivalence of groups	Adequate statistical analyses	Total
Martin [13]	2	2	0	2	2	2	2	0	1	2	0	2	18
Rhodes [14]	2	2	2	2	2	2	2	2	1	2	0	2	21
Cuschieri [15]	2	2	2	2	2	2	2	2	2	2	0	2	22
Sgourakis [16]	2	2	2	2	2	2	2	2	1	2	0	2	21
Tokumura [17]	2	2	0	2	2	2	2	0	2	2	0	2	18
Waage [18]	2	2	0	2	2	2	2	0	1	2	1	2	18
Paganini [19]	2	2	0	2	2	2	2	0	2	2	1	2	19
Topal [20]	2	2	2	2	2	2	2	2	1	2	1	2	22
Chen [21]	2	2	0	2	1	2	1	0	1	2	0	2	15
Jameel [22]	2	2	2	2	2	2	2	2	1	1	1	2	21
Noble [23]	2	2	2	2	2	2	2	2	1	2	0	2	21
ElGeidie [24]	2	2	2	2	2	2	2	2	2	2	1	2	23
Grubnik [25]	2	2	2	2	2	2	2	2	2	2	1	2	23
Chen [26]	2	2	0	2	2	2	1	0	2	2	0	2	17
Zhou [27]	2	2	0	2	1	2	0	0	2	2	0	2	15
Tao [28]	2	2	0	2	2	2	0	0	2	2	0	2	16
Wang [29]	2	2	2	2	2	2	2	2	2	2	1	2	23
Tulati [30]	2	2	0	2	1	2	0	0	2	2	0	2	15
Poh [31]	2	2	0	2	2	2	1	0	0	2	0	2	15
Wu [32]	2	2	0	2	2	2	0	0	2	2	0	2	16
Abdelrahman [33]	2	2	0	2	2	2	1	0	2	2	0	2	17
Zhang [34]	2	2	2	2	2	2	2	2	2	2	1	2	23
Hongjun [35]	2	2	0	2	2	2	2	0	1	2	1	2	19
Aawsaj [36]	2	2	2	2	2	2	2	2	2	1	1	2	22
Huang [37]	2	2	0	2	2	2	0	0	2	2	0	2	16
Li [38]	2	2	0	2	2	2	0	0	2	2	0	2	16
Han [39]	2	2	0	2	2	2	0	0	2	2	0	2	16
Liu [40]	2	2	0	2	2	2	0	0	2	2	0	2	16
Sun [41]	2	2	0	2	2	2	0	0	2	2	0	2	16
Al-Temimi [42]	2	2	0	2	2	2	2	0	1	2	0	2	17

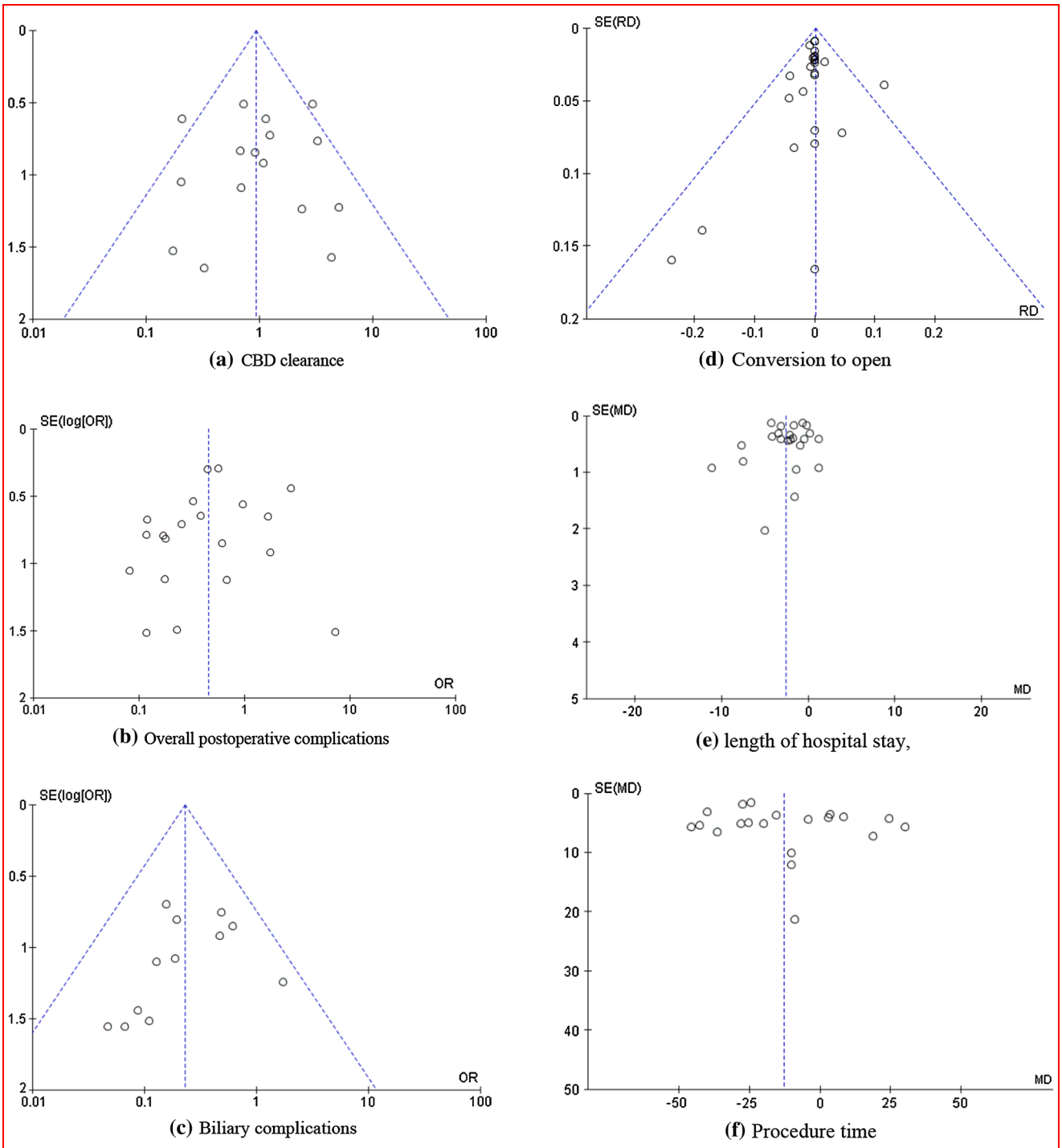


Fig. 3 Funnel plots of comparison of **a** common bile duct (CBD) clearance, **b** overall postoperative complications, **c** biliary complications, **d** conversion to open, **e** length of hospital stay, and **f** procedure time

there was no significant difference in rate of CBD clearance and conversion to open procedure between two groups. The between-study heterogeneity in the analyses of biliary complications and conversion to open were low, indicating that our findings about these outcomes may be robust. Moreover, the heterogeneity among the included studies in the analysis of CBD clearance and overall complications was moderate which may suggest variation of reporting in the analysed studies. High between-study heterogeneity in the analyses of length of hospital stay, procedure time, and blood loss indicates that our findings about these outcomes may be less robust.

Our findings are consistent with findings of a recent meta-analysis conducted by Peng et al. [9]. However, we believe that the findings of our meta-analysis reflect the best available evidence more accurately with more appropriate use of the meta-analytical model and consideration of an additional important outcome. We have included nine more comparative studies in our analyses compared to Peng et al. [9] which increased the number of the pooled population by just over 1000 patients. Moreover, Peng et al. [9] applied fixed-effect models in all of their outcome analyses even when the between-study heterogeneity was considerable in their analyses of length of hospital stay, procedure time, and blood loss while in the existence of such high heterogeneity random-effects models should be applied as recommended by Higgins et al. [12]. This, although did not change the direction of pooled effect size, affected the reliability of their provided ORs, confidence intervals, and *P* values. Most importantly, unlike Peng et al. [9], we have conducted an independent analysis for biliary complications which may be a more interesting outcome than overall complications when comparing TC and TD CBD exploration.

The laparoscopic TC CBD exploration was introduced in an attempt to reduce the biliary complications associated with TD approach. It eliminates the need for insertion of a T-tube which is not only time-consuming but also associated with a high risk of biliary morbidities [43]. Fluid and electrolyte disturbance, sepsis, premature dislodgement, bile leakage, prolonged biliary fistula, bile duct stricture, and possible peritonitis following removal of the T-tube have been reported to be associated with T-tube insertion [43]. These, together with the requirement of satisfactory follow-up cholangiography, increase the length of hospital stay and subsequent hospital expenses [44]. Consistent with these, our findings indicate that the TC approach significantly reduces overall and biliary complications, procedure time, and length of hospital stay compared to TD CBD exploration.

Although our meta-analysis of all available comparative studies suggests that the TC approach may be associated with better outcomes than the TD approach in laparoscopic CBD exploration, we would like to highlight some important confounding factors associated with the available evidence: the cystic duct diameter, the CBD diameter, number of CBD stones, and size of CBD stones. Petelin et al. [1] and Puhalla et al. [7] recommended that cystic duct diameter <4 mm, CBD stone diameter >6 mm, multiple stones, intrahepatic stone, and posterior or distal cystic duct entrance into the CBD are contraindications to TC CBD exploration. In addition, Al-Temimi et al. [42] found that stone size: cystic duct ratio >1 was a predictor of failed TC CBD exploration. Unfortunately, most of our included studies have not reported the CBD diameter or cystic duct diameter of their included patients. Although some studies reported the CBD diameter of their intervention groups, no meaningful meta-analysis could be conducted with respect to the CBD diameter. The size and number of CBD stones were even more poorly reported by the included studies. Therefore, we were not able to conduct a meta-regression analysis to correlate the value of our effect estimates with the distribution of the covariates. These might have masked the potential limitations of the TC approach in our study and biased our findings in favour of the TC approach.

Despite the popularity of laparoscopic CBD exploration, interestingly, a recent network meta-analysis [45] has demonstrated that laparoscopic cholecystectomy and intraoperative ERCP, also known as rendezvous, should be the first choice for patients with gallstone disease and CBD stones. Nevertheless, laparoscopic CBD exploration may be associated with lower risk of acute pancreatitis but higher biliary leakage. The comparative evidence to evaluate outcomes of TC CBD exploration only or TD CBD exploration only versus the rendezvous approach is lacking.

Considering the best available evidence, in the absence of any contraindications, the TC CBD exploration is safe and effective with lower morbidity and shorter length of hospital stay compared to the traditional TD approach. We do not hesitate to encourage surgeons to choose the TC approach to laparoscopically explore the CBD considering the existence of surgical expertise and adequate equipment. The beneficial impact of laparoscopic TC CBD exploration in the presence of unfavourable cystic duct/CBD diameter or stone size/numbers has not been evaluated by high-level research yet and remains unknown. Our study has some limitations which should be taken into account when interpreting our findings. The current literature lacks randomised controlled trials, the gold standard study design for comparative studies, to provide high-quality evidence for or against TC or TD CBD exploration. The best available evidence comes mainly from non-randomised comparative observational studies which are inevitably subject to selection bias. Considering the data provided by the included studies, we could not report our outcomes with respect to diameter of the cystic duct or CBD, number or size of CBD stones, or cystic duct anatomy and no meta-regression analysis could be conducted. This might have biased our findings in favour of the TC approach. In our analysis of length of hospital stay and procedure time, the between-study heterogeneity was significant which may affect the robustness of our findings with respect to these outcomes. Additionally, although we found a significantly lower volume of blood loss in favour of the TC approach, the reduction (MD only −16.20 ml) is statistically significant but may not be of clinically significant. Furthermore,

the risk of bias was moderate or high in all studies which may bias our results in favour of an intervention. Finally, one of our included studies, Tulati et al. [30] was identified in the reference list of the study of Peng et al. [9]. As we could not find the full text of this study, we considered the data reported by Peng et al. [9]. Nevertheless, we repeated our analysis with exclusion of the study of Tulati et al. [30] and the direction of pooled effect size and the heterogeneity remained unchanged.

Conclusions

Our meta-analysis demonstrated that laparoscopic TC CBD exploration is safe and reduces overall and biliary complications compared to the TD approach. Moreover, it is associated with significantly shorter length of hospital stay and procedure time. We strongly encourage surgeons to use the TC approach in the absence of known contraindications and the presence of surgical expertise and adequate equipment. The available evidence comes mainly from observational studies which do not provide appropriate data to evaluate impact of the cystic duct/CBD diameter, number or size of CBD stones, or cystic duct anatomy on the comparative outcomes of the TC and TD approaches. High-quality randomised trials may provide stronger evidence in this context.

Authors' contribution Shahin Hajibandeh and Shahab Hajibandeh equally contributed to this paper and joined first authorship is proposed. Shahin H, YK, SK contributed to design and conception. Shahin H and Shahab H contributed to the literature search and study selection, data collection, analysis and interpretation, and writing of the article. All authors critically revised the article and provided final approval.

Compliance with ethical standards

Conflict of interest There are no funding sources for this work and no conflicts of interest and financial disclosures for the authors.

Appendix

Search No	Search strategy[a]
#1	MeSH descriptor: [transcystic] explode all trees
#2	Transcystic: TI, AB, KW
#3	MeSH descriptor: [transductal] explode all trees
#4	Transductal: TI, AB, KW
#5	MeSH descriptor: [choledochotomy] explode all trees
#6	Choledochotomy: TI, AB, KW
#7	MeSH descriptor: [transductal] explode all trees
#8	Transductal: TI, AB, KW
#9	MeSH descriptor: [bile duct exploration] explode all trees
#10	Bile duct exploration: TI, AB, KW
#11	#1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10
#12	Common bile duct stone: TI, AB, KW
#13	CBD stone: TI, AB, KW
#14	Choledocholithiasis: TI, AB, KW
#15	#12 OR #13 OR #14
#16	#11 AND #15

[a]This search strategy was adopted for following databases: MEDLINE, EMBASE, CINAHL and the Cochrane Central Register of Controlled Trials (CENTRAL)

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