RESEARCH ARTICLE

Complications of biliary stenting versus T-tube insertion after common bile duct exploration: A systematic review and meta-analysis

Reno Rudiman[1]*, **Ricarhdo Valentino Hanafi**[2], **Almawijaya**[1], **Freda Halim**[3]

1 Division of Digestive Surgery, Department of General Surgery, School of Medicine, Universitas Padjadjaran, Hasan Sadikin General Hospital, Bandung, Indonesia, **2** Faculty of Medicine, Universitas Pelita Harapan, Tangerang, Indonesia, **3** Department of General Surgery, Faculty of Medicine, Universitas Pelita Harapan, Tangerang, Indonesia

* rudiman@unpad.ac.id

Abstract

Background

Complications following the insertion T-tube or stent after common bile duct exploration (CBDE) remain problematic in nowadays surgical era. Based on our knowledge, we did not find any meta-analysis intentionally evaluating the complications between both groups. At this moment, we aimed to analyze and compare both procedures' complications, efficacy, efficiency, and feasibility.

Methods

We searched literature from four databases (EuroPMC, PubMed, Scopus, and Clinical-Trials.gov) up to June 2022 to compile the randomized controlled trials and pro-/retrospective cohort studies. Review Manager 5.4 was used to statistically analyze each outcome measured between biliary stenting and T-tube insertion.

Results

Sixteen studies with 1,080 patients (534 biliary stents and 546 T-tube) were included for qualitative and quantitative analysis. The pooled risk ratio (RR) of the overall postoperative complications rate was significantly lower in the biliary stent group compared to the T-tube group 0.43 [95% confidence interval (CI) 0.23–0.80, $p = 0.007$]. In terms of the operation time, length of hospital stay, and readmission rate was also decreased in stenting as biliary drainage over T-tube placement 1.02 minutes [95% CI -1.53, -0.52, $p < 0.0001$], 1.96 days [95% CI -2.63, -1.29, $p < 0.00001$], and RR 0.39 [95% CI 0.15–0.97, $p = 0.04$], respectively.

Conclusions

Stenting as biliary drainage after CBDE was superior to T-tube insertion. A shorter operation time and hospital stay in biliary drainage resulted in a lower overall postoperative complication rate. Other influences, including the complexity and shorter learning curve, might also affect the superiority of biliary stenting.

Introduction

Common bile duct exploration (CBDE), either open or laparoscopically, is a procedure to treat and prevent further complications such as cholangitis, pancreatitis, and obstructive jaundice due to common bile duct stones. Choledocholithiasis may be a silent disease that, over time, generates further troubles [1]. Up to 20% of patients with cholelithiasis were classified as choledocholithiasis [2].

Following the CBDE, biliary drainage with T-tube or biliary stent is inserted within the common bile duct to prevent biliary leakage, stenosis, and other choledocholithiasis [3, 4]. This T-tube insertion was commonly performed before the endoscopic retrograde cholangio-pancreatography (ERCP) era, the less invasive and renowned procedure in which safer internal biliary drainage could be achieved [5, 6]. Conversely, ERCP was not frequently utilized in developing countries due to the inequality of healthcare services.

The pioneer of T-tube drainage following choledochotomy was Deaver in 1904 [7]. Up to this day, T-tube has four types of material: polyvinyl chloride (PVC), red rubber, silicone, and latex. The latex T-tube is the most commonly used due to its superiority in complications, inflammatory reaction, and low bile sedimentation within the lumen. Generally, T-tube may be removed within 7 to 10 days if all clinical assessments improve [8]. It was a standard technique up to two decades ago due to its high association with numerous complications such as leakage, biliary peritonitis, T-tube dislodgment, vascular injury, and fistula. This procedure is a complex technique and requires an experienced operator to minimize the complications. Further damages, such as biliary leakage and biliary peritonitis, might occur when the T-tube is taken [9–11].

A biliary stent is a cylindrical device (plastic or metal) frequently used to establish the patency of the bile duct. Plastic and self-expanding metal stents (SEMs) showed a similar success rate in relieving bile duct stones and bile leakage [12]. Additionally, biliary stent removal can be removed safely endoscopically, which minimizes additional complications [13]. The previous report demonstrated the biliary complications from T-tube do not differ in open and laparoscopic procedures (15.5% vs 13.8%, respectively), and those complications were more related to the placement and removal of the T-tube drainage itself [14, 15]. Due to these controversies among surgeons, a shift towards biliary stenting occurred, demonstrating better outcomes and lower complication rates [16–18]. Previous meta-analysis conducted by Yin *et al.* 2013 showed primary duct closure (PDC) alone was superior to combination with T-tube insertion [19]. Moreover, Jiang *et al.* 2019 also stated that PDC alone or PDC combined with internal drainage (stenting) was superior to PDC with T-tube insertion [20].

Based on our awareness, we did not find any meta-analysis that purposefully compared T-tube complications and biliary stent drainage after CBDE (open or laparoscopically). In developed countries, T-tube insertion and open CBDE were left behind a decade ago. However, many developing countries still undergo those procedures due to the limitations of healthcare facilities. Consequently, we aimed to analyze and compare both procedures' complications, efficacy, efficiency, and feasibility.

Materials & methods

Eligibility criteria

The inclusion criteria are framed with the PICOS formula. (1) Population: patients with common bile duct (CBD) exploration (either open or laparoscopic), (2) Intervention: patients who were receiving biliary stenting, (3) Comparison: patients who were receiving T-tube drainage, (4) Primary outcomes: biliary leakage, wound infection, pancreatitis, overall postoperative

complications; secondary outcomes: operation time, blood loss volume, length of hospital stay, readmission rate, and reoperation rate, and lastly, (5) Study: randomized or non-randomized controlled trials, cohort, case-control, cross-sectional, and case-series.

We excluded any study with a population under 18 years old, pregnant women, and no control group. Non-English and Non-original studies, including review articles, editorials, letters to the editor, correspondences, and conference abstracts were also exclusions. This study concurs with the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines and is registered in the international prospective register of systematic reviews (PROSPERO) CRD42022360170.

Information sources

We conducted literature searches in four databases (EuroPMC, PubMed, Scopus, and Clinical-Trials.gov) until June 2022 with English-language restrictions.

Search strategy

The following keywords of this study are "(biliary OR bile duct OR common bile duct OR CBD) AND (exploration OR surgery OR open-choledochotomy OR laparoscopic OR decompression) AND (stent OR stenting) AND (T-tube)".

Selection process

Initial screening of titles and abstracts with Covidence software (https://covidence.org) by two researchers (RR, RVH) and any discrepancies were solved with the third researcher (FH) discussion and consultation.

Data collection process

Full-text screening and data extractions (author details, patient's characteristics, study design, outcomes measured) were performed by RR and RVH independently. Furthermore, FH merged and validated the two extracted data. Any incongruity was resolved through discussion with the third researcher.

Data items

The outcomes were operation time (from the first incision until wound closure), blood loss volume (total blood loss during operation), length of hospital stay (as defined by each study), biliary leakage (definition of leakage by each study), wound infection (definition of infection by each study), pancreatitis (as defined by each study), postoperative complications (determined by each study), readmission rate (hospitalized due to specific reason after operation), and reoperation rate (second operation due to particular reason after the procedure).

Study risk of bias assessment

We used the Newcastle-Ottawa scale (NOS) to evaluate the quality of case-control and cohort studies. The assessment reviews each study's comparability, selection, and outcome [21]. Meanwhile, a modified Jadad scale is a procedure to assess the quality of included clinical trial studies. It evaluates the four domains: the randomization process, allocation concealment, blindness, and withdrawals and drop-outs of the reported results [22]. Two researchers (RR, RVH) evaluated those risk of bias assessments, and a third researcher (FH) interceded with any divergence.

Effect measures

The effect measures used in synthesizing results depend on the variable outcomes. We used a risk ratio (RR) with a 95% confidence interval (CI) for the dichotomous variable and standardized mean difference (SMD) and its standard deviations (SD) for the continuous variable. The summarized synthesis is presented in the forest plot.

Synthesis methods

We utilized Review Manager 5.4 software for conducting meta-analysis. A Mantel-Haenszel formula with random-effect models was applied to calculate the RR and 95% CI. This formula allows to calculate an unconfounded, overall effect estimate of a given exposure for a specific outcome by combining the RR [23]. Meanwhile, an Inverse-Variance formula with random-effect models was used to assess the SMD and SD. This method involves a weighted average of the effect estimates from the separate studies, and the weight in each study is the inverse of the variance of the effect estimate [24]. We synthesized the heterogeneity using I^2 statistics. A 50% heterogeneity is considered substantial heterogeneity, which indicates half of the variability among effect sizes is due to significant heterogeneity among studies. Moreover, we applied Wan X *et al.* [25] formula to convert means and standard deviations (SD) for meta-analysis data synthesis.

Publication bias

We employed funnel plots analysis to visualize the qualitative risk of publication bias.

Results

Study selection

Our initial databases search revealed 838 titles and abstracts. After removing the duplicates, screening titles, and abstracts, 63 publications were eligible for further full-text assessment. The final 16 full-text publications were qualified for qualitative and quantitative synthesis [26–41]. However, we excluded 47 publications for several reasons, including 27 articles that did not include biliary stenting, 12 articles that did not have any comparison or control group, five articles that were not primary research, and three articles that were not English papers. The summarized PRISMA flow chart of study selection is presented in Fig 1.

Study characteristics

The final 16 full-text publications included 1,080 patients (534 biliary stents and 546 T-tube), published between 2004–2022. The study design were five prospective RCT studies, eight retrospective cohort studies, and three prospective cohort studies. Most of the included study participants received 7 or 10-Fr biliary stents. The detailed study characteristics are summarized in Table 1.

Risk of bias in studies

The results of NOS indicated all the included studies had good quality (Table 2). The modified Jadad scale revealed one RCT was graded as a high-quality study; on the other hand, four RCTs were graded as moderate-quality studies (Table 3).

Biliary stent vs. T-tube

Bile leakage. The pooled analysis from 12 studies (n = 811) demonstrated no differences between biliary stenting and T-tube drainage in bile leakage incidence [RR 0.67 (95% CI 0.36–1.27), $p = 0.22$, $I^2 = 0\%$, random-effect modeling] (Fig 2A).

838 Records identified through database searching
740 Europe PMC
54 PubMed
42 Scopus
2 ClinicalTrials.gov

838 Records screened

775 Records excluded on the basis of title and abstract and duplicates removed

63 Full-text articles assessed for eligibility

47 Full-text articles excluded, with reasons
27 Did not include stenting in the intervention nor comparison group
12 Did not have comparison/control group
5 Were not primary research
3 Were not in English language

16 Studies included in qualitative synthesis

16 Studies included in quantitative synthesis (meta-analysis)

Fig 1. The PRISMA flowchart of the studies selection process.

https://doi.org/10.1371/journal.pone.0280755.g001

Wound infection. In the pooled analysis of six studies (n = 269), biliary stenting and T-tube drainage after CBD exploration did not demonstrate any differences in wound infection outcome [RR 0.37 (95% CI 0.12–1.13), $p = 0.08$, $I^2 = 12\%$, random-effect modeling] (Fig 2B).

Pancreatitis. In the pooled analysis of eight studies (n = 363), the pancreatitis incidence after CBD exploration did not differ between biliary stenting and T-tube drainage [RR 0.55 (95% CI 0.13–2.28), $p = 0.41$, $I^2 = 41\%$, random-effect modeling] (Fig 2C).

Overall postoperative complications. In the pooled analysis of 16 studies (n = 1,080), the overall postoperative complications were lowered in the biliary stenting group than in the T-tube group after CBD exploration [RR 0.43 (95% CI 0.23–0.80), $p = 0.007$, $I^2 = 63\%$, random-effect modeling] (Fig 2D).

Table 1. Data characteristics of the included studies.

First author, year	Sample size		Design	Age (years)		Gender (male/ female)		Stent used	Outcomes*
	Stent	T-tube		Stent	T-tube	Stent	T-tube		
Abdelkader AM et al. [26] 2018	25	25	Prospective cohort	41.2 ± 8.1	40.6 ± 7.5	11/14	10/15	8 or 10 Fr Nelaton tube	1,2,3,4,7
Dietrich A et al. [27] 2014	13	35	Retrospective cohort	60.2 ± 12.5	64.1 ± 15	9/5	18/17	7-Fr plastic biliary stent (Cotton-Leung)	1,3,6,7,9
Gyalpo T et al. [28] 2018	20	20	Prospective RCT	51.1 ± 11.5	50.6 ± 12	4/16	3/17	7-Fr 10cm straight flap biliary stent (Indovasive, India)	1,3,4,5,7,8,9
Hassan AM et al. [29] 2017	15	9	Retrospective cohort	49.5 ± 6.6	49.7 ± 6	15/6	5/4	7-Fr plastic stent	1,3,6,7,9
Isla AM et al. [30] 2004	21	32	Retrospective cohort	54 ± 14	65.1 ± 17.7	5/16	9/23	10-Fr biliary stent (Olympus)	1,3,4,7
Kwon SU et al. [31] 2011	23	29	Retrospective cohort	73 ± 9.1	69.7 ± 10.5	5/18	12/17	Not mentioned in details	1,3,4,7
Xiao L et al. [32] 2018	120	116	Retrospective cohort	53.8 ± 12.8	51 ± 12.5	52/68	54/62	7 to 10-Fr biliary stent (ENDO-FLEX GmbH Company)	1,3,4,7,8
Lyon M et al. [33] 2015	82	34	Prospective cohort	43.8 ± 10	45.9 ± 12.5	21/61	6/28	7- Fr straight or duodenal curve biliary Diagmed™ stent	3,7,9
Mangla V et al. [34] 2012	31	29	Prospective RCT	46.8 ± 14.8	47.1 ± 12.3	9/22	5/24	7 or 10-Fr, 10-cm straight flap biliary stent (Devon, Agra, India)	1,2,3,4,5,7
Abd El Wahab A et al. [35] 2022	10	10	Prospective cohort	48.7 ± 4.9	53.1 ± 6.9	N/A	N/A	Not described in detail	1,2,3,4,5,6,7
Martinez-Baena D et al. [36] 2013	28	47	Retrospective cohort	61.9 ± 15.2	61.1 ± 16.9	9/19	24/23	Biliary stenting (Flexima®, Boston Scientific Corporation)	3,4,6,7,8,9
Mir IS et al. [37] 2016	11	20	Retrospective cohort	N/A	N/A	N/A	N/A	7 or 10-Fr biliary stent	1,3,4,5,6,7
Parra-Membrives P et al. [38] 2017	58	52	Retrospective cohort	63.2 ± 15.7	60.7 ± 15.2	18/40	25/27	6 to 8.5-Fr plastic biliary stent	3,4,7,8,9
Perez G et al.[39] 2005	37	44	Prospective RCT	56.9 ± 18.7	55 ± 16.3	34/10	28/9	5 or 6-Fr biliary stent (Zimmon, Wilson-Cook Medical Winston-Salem, NC, USA)	3,5,6,7,8,9
Redwan AA et al. [40] 2006	18	19	Prospective RCT	46 ± 12	46 ± 12	N/A	N/A	8.5-Fr biliary stent	1,3,4,5,6,7
Xu Y et al. [41] 2013	22	25	Prospective RCT	61.3 ± 21.8	62.1 ± 15.5	9/13	14/11	8.5 to 10-Fr biliary stent (Leadgem Medical Co., serial number FY0825)	1,2,3,4,6,7,9

*Outcomes: 1 = operation time; 2 = blood loss volume; 3 = length of hospital stay; 4 = bile leakage; 5 = wound infection; 6 = pancreatitis; 7 = post-operative complications; 8 = readmission rate; 9 = reoperations rate

Operation time. In the pooled analysis from 12 studies (n = 698), biliary stenting as the drainage method after CBD exploration demonstrated a shorter operative time than T-tube [SMD -1.02 (95% CI -1.53, -0.52), $p < 0.0001$, I^2 = 88%, random-effect modeling] (Fig 2E).

Blood loss volume. The pooled analysis from four studies (n = 177) demonstrated both biliary stenting and T-tube drainage after CBD exploration did not differ in terms of blood loss volume [SMD -0.45 (95% CI -1.11, 0.21), $p = 0.18$, I^2 = 77%, random-effect modeling] (Fig 3A).

Length of hospital stay. In the pooled analysis from 16 studies (n = 1,080), the length of hospital stay was shorter in the biliary stenting method than T-tube after CBD exploration [SMD -1.96 (95% CI -2.63, -1.29), $p < 0.00001$, I^2 = 95%, random-effect modeling] (Fig 3B).

Readmission rate. In the pooled analysis of four studies (n = 306), the biliary stenting group exhibited a lower hospital readmission rate compared with the T-tube group [RR 0.39 (95% CI 0.15–0.97), $p = 0.04$, I^2 = 0%, random-effect modeling] (Fig 3C).

Table 2. Newcastle-Ottawa quality assessment of observational studies.

First author, year	Study design	Selection[a]	Comparability[b]	Outcome[c]	Total score	Result
Abdelkader AM et al. [26] 2018	Cohort	***	**	**	7	Good
Dietrich A et al. [27] 2014	Cohort	***	**	***	8	Good
Hassan AM et al. [29] 2017	Cohort	***	**	**	7	Good
Isla AM et al. [30] 2004	Cohort	***	**	***	8	Good
Kwon SU et al. [31] 2011	Cohort	***	**	**	7	Good
Xiao L et al. [32] 2018	Cohort	***	**	***	8	Good
Lyon M et al. [33] 2015	Cohort	***	**	**	7	Good
Abd El Wahab A et al. [35] 2022	Cohort	***	**	**	7	Good
Martinez-Baena D et al. [36] 2013	Cohort	***	**	**	7	Good
Mir IS et al. [37] 2016	Cohort	***	**	**	7	Good
Parra-Membrives P et al. [38] 2017	Cohort	***	**	***	8	Good

[a](1) representativeness of the exposed cohort; (2) selection of the non-exposed cohort; (3) ascertainment of exposure; (4) demonstration that outcome of interest was not present at the start of the study

[b](1) comparability of cohorts based on design or analysis (maximum two stars)

[c](1) assessment of outcome; (2) was follow-up long enough for outcomes to occur; (3) adequacy of follow-up of cohorts

https://doi.org/10.1371/journal.pone.0280755.t002

Reoperation rate. In the pooled analysis of nine studies (n = 677), the reoperation rate between the biliary stenting and T-tube groups revealed no differences significantly [RR 0.59 (95% CI 0.25–1.42), p = 0.24, I^2 = 0%, random-effect modeling] (Fig 3D).

Publication bias

We assessed the risk of bias using Funnel plot analysis for each synthesis. Our analysis illustrated a relatively symmetrical inverted plot for all syntheses. Thus, our Funnel plot analysis indicates no publication bias in this study (Fig 4A–4I).

Discussion

Based on the included studies, T-tube insertion as biliary drainage after CBDE has been unpopular in the modern surgical era. Ten out of 16 studies were conducted before 2017. This trend is shifting towards the biliary stenting era in developed countries. A similar meta-analysis had been conducted by Yin *et al.* and Jiang *et al.*; nonetheless, our study did not discern the operative procedure (open or laparoscopic) because we aimed to solely analyze the safety and feasibility between T-tube and biliary stent insertion after CBDE [19, 20].

Table 3. Quality appraisal of studies included in the meta-analysis using the Jadad scale assessment.

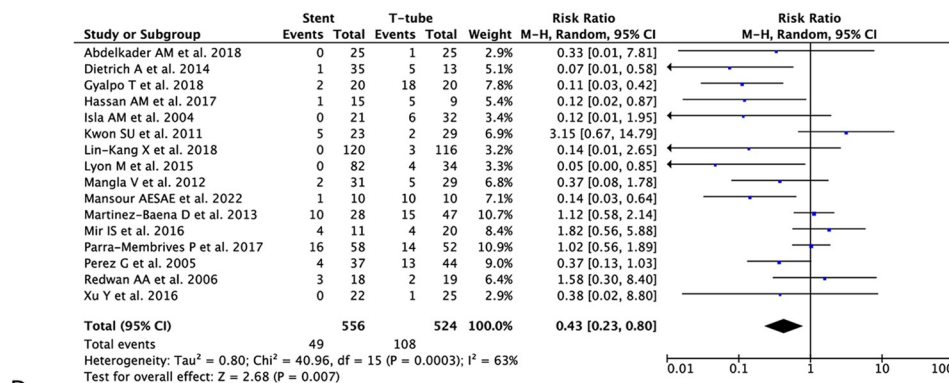| Study	Random allocation	Concealment schemes	Blinding	Withdrawals and Drop-out	Total score	Interpretation
Gyalpo T et al. [28] 2018	2	0	1	1	4	Moderate quality
Mangla V et al. [34] 2012	2	2	2	1	7	High quality
Perez G et al. [39] 2005	1	1	1	0	3	Moderate quality
Redwan AA et al. [40] 2006	1	1	1	1	4	Moderate quality
Xu Y et al. [41] 2013	1	1	1	0	3	Moderate quality

Interpretation:

More than 4 points : High quality

3–4 points : Moderate quality

Less than 3 points : Low quality

https://doi.org/10.1371/journal.pone.0280755.t003

A.

Study or Subgroup	Stent Events	Total	T-tube Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Abdelkader AM et al. 2018	0	25	1	25	4.0%	0.33 [0.01, 7.81]
Gyalpo T et al. 2018	0	20	1	20	4.0%	0.33 [0.01, 7.72]
Isla AM et al. 2004	0	21	3	32	4.7%	0.21 [0.01, 3.95]
Kwon SU et al. 2011	1	23	1	29	5.4%	1.26 [0.08, 19.09]
Lin–Kang X et al. 2018	0	120	2	116	4.4%	0.19 [0.01, 3.99]
Mangla V et al. 2012	1	31	2	29	7.3%	0.47 [0.04, 4.89]
Mansour AESAE et al. 2022	0	10	3	10	4.9%	0.14 [0.01, 2.45]
Martinez–Baena D et al. 2013	4	28	2	47	15.0%	3.36 [0.66, 17.16]
Mir IS et al. 2016	0	11	1	20	4.1%	0.58 [0.03, 13.22]
Parra–Membrives P et al. 2017	6	58	7	52	38.1%	0.77 [0.28, 2.14]
Redwan AA et al. 2006	0	18	1	19	4.1%	0.35 [0.02, 8.09]
Xu Y et al. 2016	0	22	1	25	4.0%	0.38 [0.02, 8.80]
Total (95% CI)		**387**		**424**	**100.0%**	**0.67 [0.36, 1.27]**
Total events	12		25			

Heterogeneity: Tau² = 0.00; Chi² = 7.24, df = 11 (P = 0.78); I² = 0%
Test for overall effect: Z = 1.22 (P = 0.22)

B.

Study or Subgroup	Stent Events	Total	T-tube Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Gyalpo T et al. 2018	1	20	11	20	27.3%	0.09 [0.01, 0.64]
Mangla V et al. 2012	1	31	0	29	11.6%	2.81 [0.12, 66.40]
Mansour AESAE et al. 2022	1	10	4	10	26.0%	0.25 [0.03, 1.86]
Mir IS et al. 2016	0	11	0	20		Not estimable
Perez G et al. 2005	1	37	2	44	19.7%	0.59 [0.06, 6.30]
Redwan AA et al. 2006	1	18	1	19	15.5%	1.06 [0.07, 15.64]
Total (95% CI)		**127**		**142**	**100.0%**	**0.37 [0.12, 1.13]**
Total events	5		18			

Heterogeneity: Tau² = 0.19; Chi² = 4.54, df = 4 (P = 0.34); I² = 12%
Test for overall effect: Z = 1.74 (P = 0.08)

C.

Study or Subgroup	Stent Events	Total	T-tube Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Dietrich A et al. 2014	0	35	2	13	13.8%	0.08 [0.00, 1.52]
Hassan AM et al. 2017	0	15	3	9	14.5%	0.09 [0.01, 1.55]
Mansour AESAE et al. 2022	0	10	5	10	15.0%	0.09 [0.01, 1.45]
Martinez–Baena D et al. 2013	0	28	1	47	12.7%	0.55 [0.02, 13.10]
Mir IS et al. 2016	2	11	1	20	18.4%	3.64 [0.37, 35.73]
Perez G et al. 2005	1	37	0	44	12.7%	3.55 [0.15, 84.69]
Redwan AA et al. 2006	1	18	0	19	12.9%	3.16 [0.14, 72.84]
Xu Y et al. 2016	0	22	0	25		Not estimable
Total (95% CI)		**176**		**187**	**100.0%**	**0.55 [0.13, 2.28]**
Total events	4		12			

Heterogeneity: Tau² = 1.48; Chi² = 10.14, df = 6 (P = 0.12); I² = 41%
Test for overall effect: Z = 0.82 (P = 0.41)

D.

Study or Subgroup	Stent Events	Total	T-tube Events	Total	Weight	Risk Ratio M-H, Random, 95% CI
Abdelkader AM et al. 2018	0	25	1	25	2.9%	0.33 [0.01, 7.81]
Dietrich A et al. 2014	1	35	5	13	5.1%	0.07 [0.01, 0.58]
Gyalpo T et al. 2018	2	20	18	20	7.8%	0.11 [0.03, 0.42]
Hassan AM et al. 2017	1	15	5	9	5.4%	0.12 [0.02, 0.87]
Isla AM et al. 2004	0	21	6	32	3.4%	0.12 [0.01, 1.95]
Kwon SU et al. 2011	5	23	2	29	6.9%	3.15 [0.67, 14.79]
Lin–Kang X et al. 2018	0	120	3	116	3.2%	0.14 [0.01, 2.65]
Lyon M et al. 2015	0	82	4	34	3.3%	0.05 [0.00, 0.85]
Mangla V et al. 2012	2	31	5	29	6.8%	0.37 [0.08, 1.78]
Mansour AESAE et al. 2022	1	10	10	10	7.1%	0.14 [0.03, 0.64]
Martinez–Baena D et al. 2013	10	28	15	47	10.7%	1.12 [0.58, 2.14]
Mir IS et al. 2016	4	11	4	20	8.4%	1.82 [0.56, 5.88]
Parra–Membrives P et al. 2017	16	58	14	52	10.9%	1.02 [0.56, 1.89]
Perez G et al. 2005	4	37	13	44	9.0%	0.37 [0.13, 1.03]
Redwan AA et al. 2006	3	18	2	19	6.4%	1.58 [0.30, 8.40]
Xu Y et al. 2016	0	22	1	25	2.9%	0.38 [0.02, 8.80]
Total (95% CI)		**556**		**524**	**100.0%**	**0.43 [0.23, 0.80]**
Total events	49		108			

Heterogeneity: Tau² = 0.80; Chi² = 40.96, df = 15 (P = 0.0003); I² = 63%
Test for overall effect: Z = 2.68 (P = 0.007)

E.

Study or Subgroup	Stent Mean	SD	Total	T-tube Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Abdelkader AM et al. 2018	65	20.5	25	90	17.32	25	8.7%	−1.30 [−1.91, −0.68]
Dietrich A et al. 2014	150	30	35	186.5	30	13	8.5%	−1.20 [−1.88, −0.51]
Gyalpo T et al. 2018	121.6	17.86	20	136.2	25.28	20	8.6%	−0.65 [−1.29, −0.02]
Hassan AM et al. 2017	146.73	12.34	15	191.33	10.13	9	5.6%	−3.72 [−5.13, −2.30]
Isla AM et al. 2004	102.5	7.5	21	112.5	5	32	8.6%	−1.61 [−2.25, −0.98]
Kwon SU et al. 2011	73	9.1	23	69.7	10.5	29	8.9%	0.33 [−0.22, 0.88]
Lin–Kang X et al. 2018	106.88	5.91	120	106.71	5.19	116	9.8%	0.03 [−0.22, 0.29]
Mangla V et al. 2012	139.19	18.26	31	161.1	19.21	29	8.9%	−1.15 [−1.70, −0.61]
Mansour AESAE et al. 2022	160.5	35.62	10	168	40.01	10	7.7%	−0.19 [−1.07, 0.69]
Mir IS et al. 2016	80	14.8	11	100	5	20	7.5%	−2.03 [−2.95, −1.12]
Redwan AA et al. 2006	117	17.5	18	128	22.5	19	8.6%	−0.53 [−1.19, 0.13]
Xu Y et al. 2016	93.75	18.75	22	145	45	25	8.6%	−1.43 [−2.08, −0.78]
Total (95% CI)			**351**			**347**	**100.0%**	**−1.02 [−1.53, −0.52]**

Heterogeneity: Tau² = 0.65; Chi² = 91.08, df = 11 (P < 0.00001); I² = 88%
Test for overall effect: Z = 4.00 (P < 0.0001)

Fig 2. Forest plots of (A) bile leakage, (B) wound infection, (C) pancreatitis, (D) overall postoperative complications, and (E) operation time.

The previous meta-analysis stated that T-tube insertion yielded higher biliary complications [19, 20]. On the other hand, our analytical synthesis demonstrated a similar outcome in terms of biliary leakage (n = 881) and pancreatitis (n = 363) with [RR 0.67 (95% CI 0.36–1.27), $p = 0.22$, $I^2 = 0\%$, random-effect modeling] and [RR 0.55 (95% CI 0.13–2.28), $p = 0.41$, $I^2 = 41\%$, random-effect modeling], respectively. These contradictory findings could be the limitation of the previous meta-analysis, which underwent the procedure laparoscopically. Visual limitation during a laparoscopic procedure when the CBD is fragile, edematous, and prone to bleeding might escalate higher complication rate [42]. Therefore, biliary complications will increase when the T-tube is inserted with the laparoscopic technique in the previous meta-analysis.

Another concern from the patient's point of view is having a 'tube' on their tummy skin for weeks or months. Hygiene, patient activities, and external exposures might raise the possibility of wound infection [43]. Based on our latest analysis, T-tube drainage did not increase the wound infection incidence compared to biliary stenting [RR 0.37 (95% CI 0.12–1.13), $p = 0.08$, $I^2 = 12\%$, random-effect modeling]. Somehow, if we examine the overall postoperative complications (consisting of bile leakage, pancreatitis, wound infection, stricture, residual tone, bleeding, and bile duct injury), biliary stenting exhibited lower incidences [RR 0.43 (95% CI 0.23–0.80), $p = 0.007$, $I^2 = 63\%$, random-effect modeling] compared to T-tube group. This analysis ensured that the complexity of T-tube insertion affected postoperative complications.
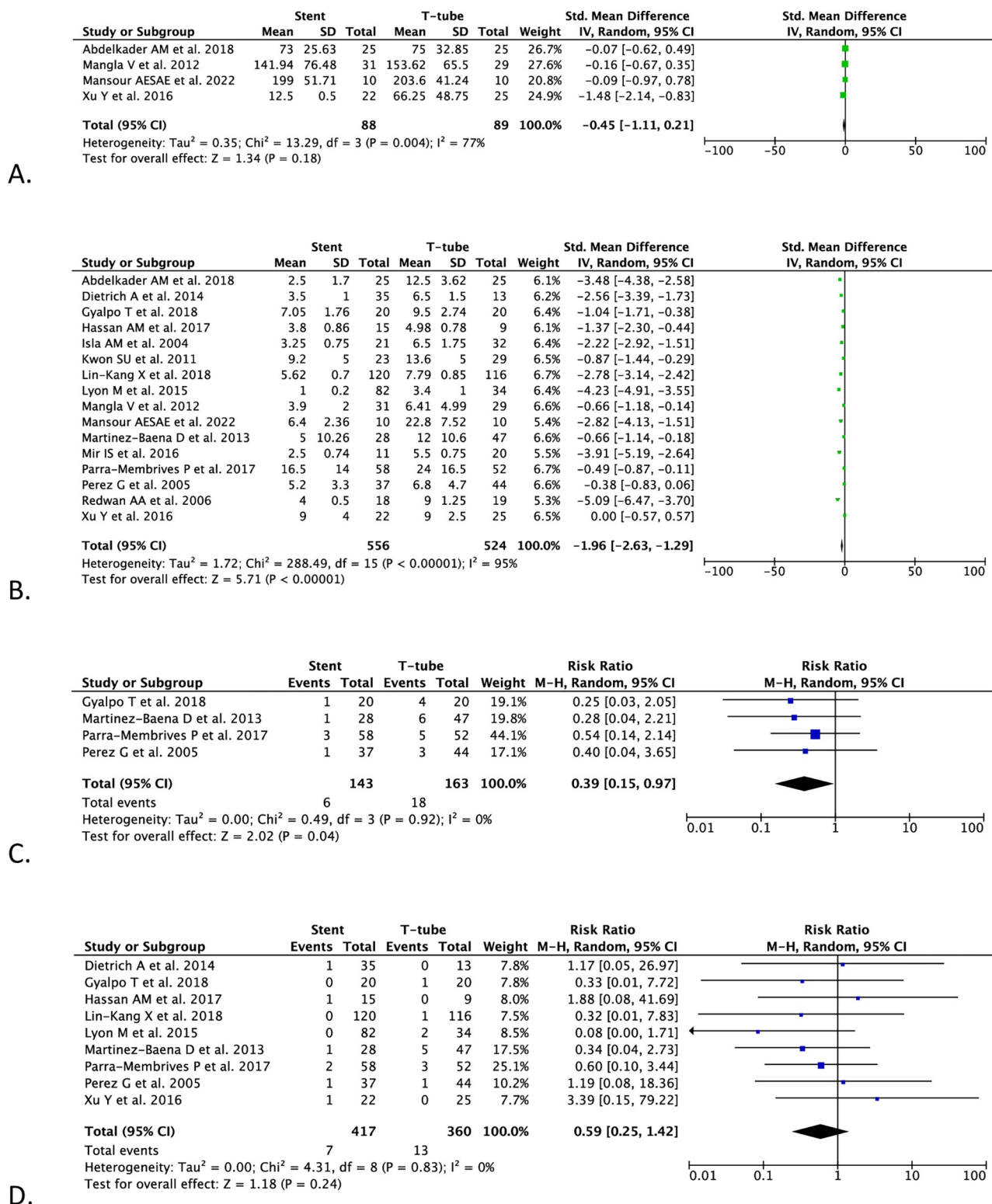
Regarding efficiency, our pooled analysis from 12 studies (n = 698) showed operation time in biliary stenting as the drainage method after CBDE was shorter than the T-tube group. This finding is concurrent with the previous statement about the difficulty of T-tube insertion, and surgeons are prone to prefer biliary stenting as biliary drainage due to a shorter learning curve [44]. Shorter operation time and fewer complications mean a safer and preferable option for patients and operators.

Furthermore, we analyzed a blood loss volume that the previous meta-analysis had not conducted. This outcome is essential for patient safety and further complications. The pooled analysis from four studies (n = 177) exhibited no difference in blood loss volume between both groups [SMD -0.45 (95% CI -1.11, 0.21), $p = 0.18$, $I^2 = 77\%$, random-effect modeling].

Length of hospital stays and readmission rates are also crucial regarding potential nosocomial infections in the hospital [45, 46]. Our statistical analysis of hospital stay in 16 studies (n = 1,080) showed a shorter duration of hospital stay in the biliary stent group [SMD -1.96 (95% CI -2.63, -1.29), $p < 0.00001$, $I^2 = 95\%$, random-effect modeling] and the readmission rate analysis from four studies (n = 306) was also significantly lower in the biliary stent group compared to the T-tube group [RR 0.39 (95% CI 0.15–0.97), $p = 0.04$, $I^2 = 0\%$, random-effect modeling]. Our findings were equivalent to prior meta-analysis [19, 20].

Lastly, the reoperation rate did not significantly differ between both groups [RR 0.59 (95% CI 0.25–1.42), $p = 0.24$, $I^2 = 0\%$, random-effect modeling]. Even though the overall postoperative complications were higher in the T-tube group, the reoperation rate did not differ statistically. This finding suggested that the postoperative complications could be managed with non-operative approaches.

We realize in today's era, a less invasive approach has been a favorable technique, and T-tube should be dropped off. We would like to emphasize to the physicians that biliary stent should be a preferred method due to its superiority in several aspects (shorter operation time,

Study or Subgroup	Stent Mean	SD	Total	T-tube Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Abdelkader AM et al. 2018	73	25.63	25	75	32.85	25	26.7%	−0.07 [−0.62, 0.49]
Mangla V et al. 2012	141.94	76.48	31	153.62	65.5	29	27.6%	−0.16 [−0.67, 0.35]
Mansour AESAE et al. 2022	199	51.71	10	203.6	41.24	10	20.8%	−0.09 [−0.97, 0.78]
Xu Y et al. 2016	12.5	0.5	22	66.25	48.75	25	24.9%	−1.48 [−2.14, −0.83]
Total (95% CI)			**88**			**89**	**100.0%**	**−0.45 [−1.11, 0.21]**

Heterogeneity: Tau² = 0.35; Chi² = 13.29, df = 3 (P = 0.004); I² = 77%
Test for overall effect: Z = 1.34 (P = 0.18)

A.

Study or Subgroup	Stent Mean	SD	Total	T-tube Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Abdelkader AM et al. 2018	2.5	1.7	25	12.5	3.62	25	6.1%	−3.48 [−4.38, −2.58]
Dietrich A et al. 2014	3.5	1	35	6.5	1.5	13	6.2%	−2.56 [−3.39, −1.73]
Gyalpo T et al. 2018	7.05	1.76	20	9.5	2.74	20	6.4%	−1.04 [−1.71, −0.38]
Hassan AM et al. 2017	3.8	0.86	15	4.98	0.78	9	6.1%	−1.37 [−2.30, −0.44]
Isla AM et al. 2004	3.25	0.75	21	6.5	1.75	32	6.4%	−2.22 [−2.92, −1.51]
Kwon SU et al. 2011	9.2	5	23	13.6	5	29	6.5%	−0.87 [−1.44, −0.29]
Lin–Kang X et al. 2018	5.62	0.7	120	7.79	0.85	116	6.7%	−2.78 [−3.14, −2.42]
Lyon M et al. 2015	1	0.2	82	3.4	1	34	6.4%	−4.23 [−4.91, −3.55]
Mangla V et al. 2012	3.9	2	31	6.41	4.99	29	6.6%	−0.66 [−1.18, −0.14]
Mansour AESAE et al. 2022	6.4	2.36	10	22.8	7.52	10	5.4%	−2.82 [−4.13, −1.51]
Martinez–Baena D et al. 2013	5	10.26	28	12	10.6	47	6.6%	−0.66 [−1.14, −0.18]
Mir IS et al. 2016	2.5	0.74	11	5.5	0.75	20	5.5%	−3.91 [−5.19, −2.64]
Parra–Membrives P et al. 2017	16.5	14	58	24	16.5	52	6.7%	−0.49 [−0.87, −0.11]
Perez G et al. 2005	5.2	3.3	37	6.8	4.7	44	6.6%	−0.38 [−0.83, 0.06]
Redwan AA et al. 2006	4	0.5	18	9	1.25	19	5.3%	−5.09 [−6.47, −3.70]
Xu Y et al. 2016	9	4	22	9	2.5	25	6.5%	0.00 [−0.57, 0.57]
Total (95% CI)			**556**			**524**	**100.0%**	**−1.96 [−2.63, −1.29]**

Heterogeneity: Tau² = 1.72; Chi² = 288.49, df = 15 (P < 0.00001); I² = 95%
Test for overall effect: Z = 5.71 (P < 0.00001)

B.

Study or Subgroup	Stent Events	Total	T-tube Events	Total	Weight	Risk Ratio M–H, Random, 95% CI
Gyalpo T et al. 2018	1	20	4	20	19.1%	0.25 [0.03, 2.05]
Martinez–Baena D et al. 2013	1	28	6	47	19.8%	0.28 [0.04, 2.21]
Parra–Membrives P et al. 2017	3	58	5	52	44.1%	0.54 [0.14, 2.14]
Perez G et al. 2005	1	37	3	44	17.1%	0.40 [0.04, 3.65]
Total (95% CI)		**143**		**163**	**100.0%**	**0.39 [0.15, 0.97]**
Total events	6		18			

Heterogeneity: Tau² = 0.00; Chi² = 0.49, df = 3 (P = 0.92); I² = 0%
Test for overall effect: Z = 2.02 (P = 0.04)

C.

Study or Subgroup	Stent Events	Total	T-tube Events	Total	Weight	Risk Ratio M–H, Random, 95% CI
Dietrich A et al. 2014	1	35	0	13	7.8%	1.17 [0.05, 26.97]
Gyalpo T et al. 2018	0	20	1	20	7.8%	0.33 [0.01, 7.72]
Hassan AM et al. 2017	1	15	0	9	8.0%	1.88 [0.08, 41.69]
Lin–Kang X et al. 2018	0	120	1	116	7.5%	0.32 [0.01, 7.83]
Lyon M et al. 2015	0	82	2	34	8.5%	0.08 [0.00, 1.71]
Martinez–Baena D et al. 2013	1	28	5	47	17.5%	0.34 [0.04, 2.73]
Parra–Membrives P et al. 2017	2	58	3	52	25.1%	0.60 [0.10, 3.44]
Perez G et al. 2005	1	37	1	44	10.2%	1.19 [0.08, 18.36]
Xu Y et al. 2016	1	22	0	25	7.7%	3.39 [0.15, 79.22]
Total (95% CI)		**417**		**360**	**100.0%**	**0.59 [0.25, 1.42]**
Total events	7		13			

Heterogeneity: Tau² = 0.00; Chi² = 4.31, df = 8 (P = 0.83); I² = 0%
Test for overall effect: Z = 1.18 (P = 0.24)

D.

Fig 3. Forest plots of (A) blood loss volume, (B) length of hospital stay, (C) readmission rate, and (D) reoperation rate.

Fig 4. Funnel plots of (A) bile leakage, (B) wound infection, (C) pancreatitis, (D) overall postoperative complications, (E) operation time, (F) blood loss volume, (G) length of hospital stay, (H) readmission rate, and (I) reoperation rate.

shorter hospital stay, and lower overall complications rate). Despite the advancement of the biliary stent in the last decade, these two candidates still can be compared. Our included studies in the last five years assessed both procedures, and T-tube remains in the modern era that gradually fades over time.

There are some considerations regarding our meta-analysis limitations. First, only five out of 16 studies are categorized as RCTs. Second, ten studies were conducted before 2017. More updated and high-quality RCTs are needed to improve further meta-analysis. Third, high heterogeneity among the included studies might affect the overall outcomes. The contributions of high heterogeneity derive from data characteristics, the definition of each outcome, and outcome parameters. Lastly, English-only studies were also limiting our meta-analysis to extend further included studies.

Conclusions

Stenting as biliary drainage after CBDE was superior to T-tube insertion. A shorter operation time and hospital stay in biliary drainage resulted in a lower overall postoperative complication rate. Other influences, including the complexity and shorter learning curve, might also affect the superiority of biliary stenting. We recommend stenting over T-tube insertion as biliary drainage; even though, T-tube cannot be left out entirely in developing countries with limited healthcare facilities.

Supporting information

S1 Checklist. PRISMA 2020 checklist.
(PDF)

Author Contributions

Conceptualization: Reno Rudiman, Ricarhdo Valentino Hanafi.

Data curation: Reno Rudiman, Ricarhdo Valentino Hanafi.

Formal analysis: Reno Rudiman, Ricarhdo Valentino Hanafi.

Investigation: Reno Rudiman, Ricarhdo Valentino Hanafi, Freda Halim.

Methodology: Reno Rudiman, Ricarhdo Valentino Hanafi, Freda Halim.

Project administration: Reno Rudiman.

Resources: Reno Rudiman.

Software: Reno Rudiman.

Supervision: Almawijaya.

Validation: Reno Rudiman, Ricarhdo Valentino Hanafi, Freda Halim.

Visualization: Reno Rudiman, Ricarhdo Valentino Hanafi, Freda Halim.

Writing – original draft: Reno Rudiman, Ricarhdo Valentino Hanafi, Almawijaya, Freda Halim.

Writing – review & editing: Reno Rudiman, Ricarhdo Valentino Hanafi, Almawijaya, Freda Halim.

References

1. Gurusamy KS, Koti R, Davidson BR. T-tube drainage versus primary closure after laparoscopic common bile duct exploration. Cochrane Database of Systematic Reviews 2013; 6:CD005641. https://doi.org/10.1002/14651858.CD005641.pub3 PMID: 23794201

2. Molvar C, Glaenzer B. Choledocholithiasis: Evaluation, Treatment, and Outcomes. Semin Intervent Radiol 2016; 33:268–76. https://doi.org/10.1055/s-0036-1592329 PMID: 27904245

3. Ahmed I, Pradhan C, Beckingham IJ, Brooks AJ, Rowlands BJ, Lobo DN. Is a T-tube Necessary after Common Bile Duct Exploration? World J Surg 2008; 32:1485–8. https://doi.org/10.1007/s00268-008-9475-2 PMID: 18270647

4. Lee JS, Yoon YC. Laparoscopic common bile duct exploration using V-Loc suture with insertion of endobiliary stent. Surg Endosc 2016; 30:2530–4. https://doi.org/10.1007/s00464-015-4518-x PMID: 26310532

5. Baiu I, Hawn MT. Choledocholithiasis. JAMA 2018; 320:1506. https://doi.org/10.1001/jama.2018.11812 PMID: 30304429

6. Hakuta R, Kawahata S, Kogure H, Nakai Y, Saito K, Saito T, et al. Endoscopic papillary large balloon dilation and endoscopic papillary balloon dilation both without sphincterotomy for removal of large bile duct stones: A propensity-matched analysis. Digestive Endoscopy 2019; 31:59–68. https://doi.org/10.1111/den.13220 PMID: 29943385

7. Deaver J. The surgery of jaundice. Ann Surg 1925; 81:287–98. https://doi.org/10.1097/00000658-192501010-00024 PMID: 17865173

8. Daldoul S, Moussi A, Zaouche A. T-tube drainage of the common bile duct choleperitoneum: Etiology and management. J Visc Surg 2012; 149:e172–8. https://doi.org/10.1016/j.jviscsurg.2012.03.008 PMID: 22537812

9. Quaresima S, Balla A, Guerrieri M, Campagnacci R, Lezoche E, Paganini AM. A 23 year experience with laparoscopic common bile duct exploration. HPB 2017; 19:29–35. https://doi.org/10.1016/j.hpb.2016.10.011 PMID: 27890483

10. Chen CC, Wu SD, Tian Y, Zeng XT, Siwo EA, Xian GZ. The Fading Role of T-Tube in Laparoscopic Choledochotomy: Primary Choledochorrhaphy and Over Pigtail J and Endonasobiliary Drainage Tubes. Journal of Laparoendoscopic & Advanced Surgical Techniques 2010; 20:807–11. https://doi.org/10.1089/lap.2010.0075 PMID: 21029026

11. Gharaibeh KI, Heiss HA. Biliary leakage following T-tube removal. Int Surg 2000; 85:57–63. PMID: 10817434

12. Pfau PR, Pleskow DK, Banerjee S, Barth BA, Bhat YM, Desilets DJ, et al. Pancreatic and biliary stents. Gastrointest Endosc 2013; 77:319–27. https://doi.org/10.1016/j.gie.2012.09.026 PMID: 23410693

13. Buxbaum JL, Abbas Fehmi SM, Sultan S, Fishman DS, Qumseya BJ, Cortessis VK, et al. ASGE guideline on the role of endoscopy in the evaluation and management of choledocholithiasis. Gastrointest Endosc 2019; 89:1075–1105.e15. https://doi.org/10.1016/j.gie.2018.10.001 PMID: 30979521

14. Garteiz Martínez D, Sánchez AW, López Acosta ME. Laparoscopic T-tube choledochotomy for biliary lithiasis. JSLS 2008; 12:326–31. PMID: 18765064

15. Wills VL, Gibson K, Karihaloo C, Jorgensen JO. Complications of biliary T-tubes after choledochotomy. ANZ J Surg 2002; 72:177–80. https://doi.org/10.1046/j.1445-2197.2002.02308.x PMID: 12071447

16. Zhu H, Wu L, Yuan R, Wang Y, Liao W, Lei J, et al. Learning curve for performing choledochotomy bile duct exploration with primary closure after laparoscopic cholecystectomy. Surg Endosc 2018; 32:4263–70. https://doi.org/10.1007/s00464-018-6175-3 PMID: 29602995

17. Lou J, Zhao H, Chen W, Wang J. T tube sinus tract duodenal fistula: a rare complication of postoperative choledochoscopy for treating retained intrahepatic stones. Surg Endosc 2021; 35:5567–72. https://doi.org/10.1007/s00464-020-08057-7 PMID: 33030589

18. Zhu QD, Tao CL, Zhou MT, Yu ZP, Shi HQ, Zhang QY. Primary closure versus T-tube drainage after common bile duct exploration for choledocholithiasis. Langenbecks Arch Surg 2011; 396:53–62. https://doi.org/10.1007/s00423-010-0660-z PMID: 20582601

19. Yin Z, Xu K, Sun J, Zhang J, Xiao Z, Wang J, et al. Is the End of the T-Tube Drainage Era in Laparoscopic Choledochotomy for Common Bile Duct Stones Is Coming? A Systematic Review and Meta-Analysis. Ann Surg 2013; 257:54–66. https://doi.org/10.1097/SLA.0b013e318268314b PMID: 23059495

20. Jiang C, Zhao X, Cheng S. T-Tube Use After Laparoscopic Common Bile Duct Exploration. JSLS 2019; 23:e2018.00077.

21. Margulis A v, Pladevall M, Riera-Guardia N, Varas-Lorenzo C, Hazell L, Berkman N, et al. Quality assessment of observational studies in a drug-safety systematic review, comparison of two tools: the

Newcastle-Ottawa Scale and the RTI item bank. Clin Epidemiol 2014; 6:359–68. https://doi.org/10.2147/CLEP.S66677 PMID: 25336990

22. Jadad AR, Moore RA, Carroll D, Jenkinson C, Reynolds DJM, Gavaghan DJ, et al. Assessing the quality of reports of randomized clinical trials: Is blinding necessary? Control Clin Trials 1996; 17:1–12. https://doi.org/10.1016/0197-2456(95)00134-4 PMID: 8721797

23. Tripepi G, Jager KJ, Dekker FW, Zoccali C. Stratification for Confounding–Part 1: The Mantel-Haenszel Formula. Nephron Clin Pract 2010; 116:c317–21. https://doi.org/10.1159/000319590 PMID: 20664286

24. Borenstein M, Hedges L v., Higgins JPT, Rothstein HR. A basic introduction to fixed-effect and random-effects models for meta-analysis. Res Synth Methods 2010; 1:97–111. https://doi.org/10.1002/jrsm.12 PMID: 26061376

25. Wan X, Wang W, Liu J, Tong T. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. BMC Med Res Methodol 2014; 14:135. https://doi.org/10.1186/1471-2288-14-135 PMID: 25524443

26. Abdelkader AM, Zidan AM, Younis MT. Temporary CBD Stenting with a Nelaton Tube Is a More Practical and Safer Option Than T-Tube Drainage after Conventional CBD Exploration for Choledocholithiasis. HPB Surgery 2018; 2018:1–5. https://doi.org/10.1155/2018/8035164 PMID: 30302070

27. Dietrich A, Alvarez F, Resio N, Mazza O, de Santibañes E, Pekolj J, et al. Laparoscopic management of common bile duct stones: Transpapillary stenting or external biliary drainage? Journal of the Society of Laparoendoscopic Surgeons 2015; 18:1–5.

28. Gyalpo T, Akram M, Dolma K, Azad TP. A Comparative Study of T-tube versus Ante grade Stenting of CBD after Open CBD Exploration for Choledocholithiasis. Journal of Medical Science And clinical Research 2018; 6:436–45.

29. Hassan A, Mohammed A, Shawky MEG. Common bile duct exploration with transpapillary stenting versus T-tube drainage for management of irretrievable common bile duct stones. Al-Azhar Assiut Medical Journal 2017; 15:117–21.

30. Isla AM, Griniatsos J, Karvounis E, Arbuckle JD. Advantages of laparoscopic stented choledochorrhaphy over T-tube placement. British Journal of Surgery 2004; 91:862–6. https://doi.org/10.1002/bjs.4571 PMID: 15227692

31. Kwon SU, Choi IS, Moon JI, Ra YM, Lee SE, Choi WJ, et al. Comparison of Bile Drainage Methods after Laparoscopic CBD Exploration. Korean J Hepatobiliary Pancreat Surg 2011; 15:117–22. https://doi.org/10.14701/kjhbps.2011.15.2.117 PMID: 26421026

32. Xiao LK, Xiang JF, Wu K, Fu X, Zheng MY, Song XX, et al. The reasonable drainage option after laparoscopic common bile duct exploration for the treatment of choledocholithiasis. Clin Res Hepatol Gastroenterol 2018; 42:564–9. https://doi.org/10.1016/j.clinre.2018.07.005 PMID: 30145281

33. Lyon M, Menon S, Jain A, Kumar H. Use of biliary stent in laparoscopic common bile duct exploration. Surg Endosc 2015; 29:1094–8. https://doi.org/10.1007/s00464-014-3797-y PMID: 25249145

34. Mangla V, Chander J, Vindal A, Lal P, Ramteke VK. A Randomized Trial Comparing the Use of Endobiliary Stent and T-Tube for Biliary Decompression After Laparoscopic Common Bile Duct Exploration. Surg Laparosc Endosc Percutan Tech 2012; 22:345–8. https://doi.org/10.1097/SLE.0b013e31825b297d PMID: 22874685

35. Abd El Wahab A, Tawila M, Khalil O. Comparative study between primary common bile duct repair with internal stent insertion versus t-tube drainage after common bile duct exploration. Al-Azhar International Medical Journal 2022; 3:107–11.

36. Martínez-Baena D, Parra-Membríves P, Díaz-Gómez D, Lorente-Herce JM. Laparoscopic common bile duct exploration and antegrade biliary stenting: Leaving behind the Kehr tube. Revista Española de Enfermedades Digestivas 2013; 105:125–30. https://doi.org/10.4321/s1130-01082013000300002 PMID: 23735018

37. Mir I, Hajini M, Rashid T, Sheikh V, Bhat S. Laparoscopic management of common bile duct stones: Stent Vs T-tube drainage. Archives of International Surgery 2016; 6:90–5.

38. Parra-Membrives P, Martínez-Baena D, Lorente-Herce J, Jiménez-Riera G. Comparative Study of Three Bile Duct Closure Methods Following Laparoscopic Common Bile Duct Exploration for Choledocholithiasis. Journal of Laparoendoscopic and Advanced Surgical Techniques 2018; 28:145–51. https://doi.org/10.1089/lap.2017.0433 PMID: 28976804

39. Pérez G, Escalona A, Jarufe N, Ibáñez L, Viviani P, García C, et al. Prospective randomized study of T-tube versus biliary stent for common bile duct decompression after open choledocotomy. World J Surg 2005; 29:869–72. https://doi.org/10.1007/s00268-005-7698-z PMID: 15951939

40. Redwan A, Omar M. Common bile duct clearance of stones by open surgery, laparoscopic surgery, and endoscopic approaches (comparative study). The Egyptian Journal of Surgery 2017; 36:76.

41. Xu Y, Dong C, Ma K, Long F, Jiang K, Shao P, et al. Spontaneously removed biliary stent drainage versus T-tube drainage after laparoscopic common bile duct exploration. Medicine (United States) 2016; 95. https://doi.org/10.1097/MD.0000000000005011 PMID: 27684867

42. Mooney MJ, Deyo GA, O'Reilly MJ. T-tube placement during laparoscopic cholecystectomy. Surg Endosc 1992; 6:32–32. https://doi.org/10.1007/BF00591184 PMID: 1344576

43. Asaduzzaman M, Mia MGM, Abdullah S, Islam MS, Hanif MA, Karim SR. Comparative Study between Primary Closure and T-tube Drainage after Open Choledochotomy. Med Today 2017; 29:15–8.

44. Kitagawa K, Mitoro A, Minami R, Nagamatsu S, Ozutsumi T, Fujinaga Y, et al. Efficacy of a dedicated plastic stent in endoscopic ultrasound-guided hepaticogastrostomy during the learning curve: cumulative multi-center experience. Scand J Gastroenterol 2022;1–8. https://doi.org/10.1080/00365521.2022.2118557 PMID: 36073949

45. Jia H, Li L, Li W, Hou T, Ma H, Yang Y, et al. Impact of Healthcare-Associated Infections on Length of Stay: A Study in 68 Hospitals in China. Biomed Res Int 2019; 2019:1–7. https://doi.org/10.1155/2019/2590563 PMID: 31119159

46. Stewart S, Robertson C, Pan J, Kennedy S, Haahr L, Manoukian S, et al. Impact of healthcare-associated infection on length of stay. Journal of Hospital Infection 2021; 114:23–31.