Review Article

EUS-guided biliary drainage: A systematic review and meta-analysis

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ABSTRACT

ERCP is the current procedure of choice for patients with jaundice caused by biliary obstruction. EUS-guided biliary drainage (EUS-BD) has emerged as an alternative to ERCP in patients requiring biliary drainage. The aim of the study was to conduct a systematic review and meta-analysis to report the overall efficacy and safety of EUS-BD. We conducted a comprehensive search of several databases including PubMed, EMBASE, Web of Science, Google Scholar, and LILACS databases (earliest inception to June 2018) to identify studies that reported EUS-BD in patients. The primary outcome was to look at the technical and clinical success of the procedure. The secondary analysis focused on calculating the pooled rate of re-interventions and all adverse-events, along with the commonly reported adverse-event subtypes. Twenty-three studies reporting on 1437 patients were identified undergoing 1444 procedures. Majority of the patient population were male (53.86%), with an average age of 67.22 years. The pooled technical success rates and clinical success rates were 91.5% (95% confidence interval [CI]: 87.7–94.2, I^2 = 76.5) and 87% (95% CI: 82.3–90.6, I^2 = 72.4), respectively. The total adverse event rates were 17.9% (95% CI: 14.3–22.2, I^2 = 69.1). Subgroup analysis of three major individual adverse events was bile leak: 4.1% (2.7–6.2, I^2 = 46.7), stent migration: 3.9% (2.5–6.2, I^2 = 43.5), and infection: 3.8% (2.8–5.1, I^2 = 0) Substantial heterogeneity was noted in the analysis. EUS-BD has high technical and clinical success rate and hence a very effective procedure. Concerns about publication bias exist. Careful consideration should be given to the adverse events and weighing the risks and benefits of the alternative nonsurgical/surgical approaches.

Key words: Biliary drainage, Biliary obstruction, ERCP, EUS guided, jaundice

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INTRODUCTION

ERCP is the current procedure of choice for patients with jaundice caused by biliary obstruction. It has a high success rate and a low major adverse event rate.[1] Failure of ERCP can be secondary to surgically altered anatomy, inaccessible papilla due to malignancy, or (rarely) cannulation failure. Percutaneous drainage has historically been the treatment of choice in patients with failed ERCP.

EUS-biliary drainage (BD) was first described by Giovannini in 2001.[2] Since then, EUS-BD has emerged as an alternative to ERCP in patients requiring BD. Various studies have reported high technical success associated with EUS-BD.

The aim of this study was to evaluate the technical success, clinical success, and adverse events of EUS-BD.

METHODS

Search strategy

We conducted a comprehensive search of several databases and conference proceedings including PubMed, EMBASE, Web of Science, Google Scholar, and LILACS databases (earliest inception to June 2018). We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines, using a predefined protocol, to identify studies reporting EUS-guided BD. An experienced medical librarian using inputs from the study authors helped with the literature search.

Keywords used in search included a combination of "Endoscopic ultrasound," "EUS," "biliary," "drainage," and "complications." The search was restricted to studies in human subjects and published in the English language in peer-reviewed journals. Two authors (BSD and HSM) independently reviewed the title and abstract of studies identified in primary search and excluded studies that did not address the research question, based on prespecified exclusion and inclusion criteria. The full text of the remaining articles was reviewed to determine whether it contained relevant information. Any discrepancy in article selection was resolved by consensus and in discussion with a coauthor.

The bibliographic section of the selected articles as well as the systematic and narrative articles on the topic was manually searched for additional relevant articles.

Study selection

In this meta-analysis, we included cohort studies that met the following criteria: (1) EUS-BD (2) information on adverse events, (3) information on subcategories of adverse events, (4) technical success rate, and (5) clinical success rate. Studies irrespective of the geography and abstract/manuscript status were included as long as they provided data needed for the analysis.

We excluded the studies that (1) provided insufficient data to allow the estimation of adverse events and (2) insufficient data on the subcategories of adverse events.

In case of multiple publications from the same cohort, data from the most recent comprehensive report were included. We did not encounter any such study in our analysis.

Data abstraction and quality assessment

Data on study-related outcomes in the individual studies were abstracted onto a standardized form by at least two authors (BSD and HSM) independently, and two authors (BSD and HSM) did the quality scoring independently.

Using a scale modified from the Newcastle-Ottawa scale for cohort studies assessed the quality of the included studies.[3] This quality score consisted of three categories: (1) selection – included four questions and maximum one star per question could be awarded (2) comparability – included one question and maximum two stars could be awarded, and (3) exposure – included three questions and maximum one star per question could be awarded. Good-quality study was defined as 3 or 4 stars in the selection domain and 1 or 2 stars in comparability domain and 2 or 3 stars in the outcome domain. Fair-quality study was defined as 2 stars in the selection domain and 1 or 2 stars in comparability domain and 2 or 3 stars in the outcome domain. Poor-quality study was defined as 0 or 1 star in the selection domain and 0 stars in comparability domain and 0 or 1 star in the outcome domain.

Quality assessment for randomized controlled trials (RCTs) was done with Jadad–Oxford scale. A maximum of 5 points could be given to a study on the basis of randomization, blinding, and withdrawals from the study. A score of ≤2 was defined as a poor-quality study.

Outcomes assessed

The primary analysis of this study focused on calculating the pooled rate of overall technical success and clinical success in EUS-BD.

Our secondary analysis focused on calculating the pooled rate of re-interventions and all adverse events, along with the commonly reported adverse-event subtypes (pneumoperitoneum, infection, bleeding, bile leak, and stent migration).

Statistical analysis

We used meta-analysis techniques to calculate the pooled estimated in each case following the methods suggested by DerSimonian and Laird using the random-effect model, and our application can be seen to fit within their general approach (where the effect is measured by the probability of risk).[4] When the incidence of an outcome was zero in a study, a correction of 0.5 was added to the number of incident cases before the statistical analysis.[5] We assessed heterogeneity between study-specific estimates using two methods: Cochrane's Q statistics and I^2 statistics.[6,7] In this, values of <30%, 30%–60%, 61%–75%, and >75% were suggestive of low, moderate, substantial, and considerable heterogeneity, respectively.[8] Publication bias was ascertained qualitatively by visual inspection of funnel plot and quantitatively by the Egger test.[9] When publication bias was present, further statistics using the fail-Safe N test and Duval and Tweedie's "Trim and Fill test" was used to ascertain the impact of the bias.[10] Three levels of impact were reported based on the concordance between the reported results and the actual estimate if there was no bias. The impact was reported as minimal if both versions were estimated to be the same; modest if effect size changed substantially, but the final finding would still remain the same; and severe if the basic final conclusion of the analysis is threatened by the bias.[11]

All analyses were performed using Comprehensive Meta-Analysis software, version 3 (BioStat, Englewood, NJ, USA).

RESULTS

Search results and population characteristics

From a total of 761 citations identified by our search criteria, 47 studies reported the use of EUS-BD.

The schematic diagram of the study selection is illustrated in Supplementary Figure 1.

Table 1 describes the study characteristics. Majority of the patient population were males (53.86%), with an average age of 67.22 years. The indications for the EUS-BD included malignant obstructive jaundice, cholangitis, bile leak, and other benign causes. In the majority of studies, technical success was defined as successful deployment of the stent and clinical success was defined as a reduction in serum total bilirubin by 50% at 1 week or <3 mg/dL at 2 weeks after the procedure.

The type of intervention during the EUS was through transgastric (29.5%), transduodenal (34.34%), and other techniques (19.8%). One of the studies did not mention the technique used, so the above numbers exclude that study.

Characteristics and quality of the included studies

Table 1 describes the characteristics of the included studies.

The meta-analysis included 20 independent cohort studies and 3 RCTs with a total of 1437 patients.

None of the studies were population based. Ten studies were multicenter based, and the rest were from single center. Thirteen studies had more than 40 patients, 3 studies had 30–40 patients, and 7 studies had <30 patients. All of the included studies had clear information reported on the technical success, clinical success, and adverse-event rates, including the subcategory of the adverse events. All the studies were published in the original manuscript form. Overall, 18 studies were considered to be of high quality and rest 5 were considered medium quality. None were of low quality.

Supplementary Table 1 details the study quality assessment.

Technical success and clinical success

The calculated pooled rate of technical success was 91.5% (95% confidence interval [CI]: 87.7–94.2, I^2 = 76.5).

The calculated pooled rate of clinical success was 87% (95% CI: 82.3–90.6, I^2 = 72.4).

Figures 1 and 2 show the forest plot for technical and clinical success, respectively.

Table 1. Study description and clinical outcomes

	Study year	Study type	Single center or multicenter	Abstract or manuscript	Cohort/case control/RCT	Number of patients	Mean age
Minaga *et al.*[12]	2019	Prospective	Multicenter	Manuscript	RCT	47	73
Park *et al.*[13]	2018	Prospective	Single	Manuscript	RCT	14	66.8
Tsuchiya *et al.*[14]	2018	Prospective	Multicenter	Manuscript	Cohort	19	70.6
Kahaleh *et al.*[15]	2016	Retrospective	Multicenter	Manuscript	Cohort	35	81
Tyberg *et al.*[16]	2016	Prospective	Single	Manuscript	Cohort	52	68
Khashab *et al.*[17]	2016	Retrospective	Multicenter	Manuscript	Cohort	121	65.5
Will *et al.*[18]	2015	Prospective	Single	Manuscript	Cohort	94	67
Dhir *et al.*[19]	2015	Retrospective	Multicenter	Manuscript	Cohort	104	66.7
Artifon *et al.*[20]	2015	Prospective	Single	Manuscript	RCT	49	66
Gupta *et al.*[21]	2014	Retrospective	Multicenter	Manuscript	Cohort	234	67.3
Weilert[22]	2014	Prospective	Single	Manuscript	Cohort	21	67.4
Song *et al.*[23]	2014	Prospective	Single	Manuscript	Cohort	27	67
Poincloux *et al.*[24]	2015	Retrospective	Single	Manuscript	Cohort	101	70.8
Dhir *et al.*[25]	2014	Retrospective	Multicenter	Manuscript	Cohort	68	NA
Kawakubo *et al.*[26]	2014	Retrospective	Multicenter	Manuscript	Cohort	64	72
Park *et al.*[27]	2013	Prospective	Single	Manuscript	Cohort	45	64.9
Bapaye *et al.*[28]	2013	Retrospective	Single	Manuscript	Cohort	25	59.9
Dhir *et al.*[29]	2013	Retrospective	Single	Manuscript	Cohort	35	53.4
Khashab *et al.*[30]	2013	Retrospective	Single	Manuscript	Cohort	35	66.1
Prachayakul and Aswakul[31]	2013	Retrospective	Single	Manuscript	Cohort	21	62.8
Vila *et al.*[32]	2012	Retrospective	Multicenter	Manuscript	Cohort	125	69.03
Kim *et al.*[33]	2012	Retrospective	Multicenter	Manuscript	Cohort	13	68.8
Shah *et al.*[34]	2011	Retrospective	Single	Manuscript	Cohort	88	65

	Males	Females	Total number of procedures	Technical success	Clinical success	Total adverse effects	Pneumoperitoneum	Infection	Bleeding	Bile leak
Minaga *et al.*[12]	24	23	54	46	46	10	0	3	0	1
Park *et al.*[13]	9	5	14	13	13	2	0	0	0	0
Tsuchiya *et al.*[14]	12	7	19	19	18	7	1	2	0	0
Kahaleh *et al.*[15]	16	19	35	32	31	9	0	2	2	0
Tyberg *et al.*[16]	27	25	52	50	40	5	0	1	4	0
Khashab *et al.*[17]	70	51	121	112	93	20	1	7	2	3
Will *et al.*[18]	45	49	94	80	79	15	0	2	1	0
Dhir *et al.*[19]	58	46	104	97	93	9	0	1	2	2
Artifon *et al.*[20]	25	24	49	46	39	8	0	1	4	1
Gupta *et al.*[21]	119	115	234	207	NA	81	12	8	26	27
Weilert[22]	12	9	21	20	19	2	0	0	0	1
Song *et al.*[23]	13	14	27	27	26	5	3	0	1	0
Poincloux *et al.*[24]	58	43	101	99	93	12	2	3	1	5
Dhir *et al.*[25]	34	34	68	65	65	14	0	5	1	4
Kawakubo *et al.*[26]	35	29	64	61	NA	12	1	1	2	5
Park *et al.*[27]	28	17	45	41	39	4	1	1	0	0
Bapaye *et al.*[28]	13	12	25	23	23	5	0	1	0	4
Dhir *et al.*[29]	22	13	35	34	34	12	2	0	0	2
Khashab *et al.*[30]	18	17	35	33	32	4	1	1	0	0
Prachayakul *et al.*[31]	11	10	21	20	19	2	1	0	0	1
Vila *et al.*[32]	71	54	125	84	79	29	0	1	6	0
Kim *et al.*[33]	9	4	13	12	11	5	0	2	0	0
Shah *et al.*[34]	45	43	88	62	62	6	1	1	1	1

RCT: Randomized controlled trial, NA: Not available

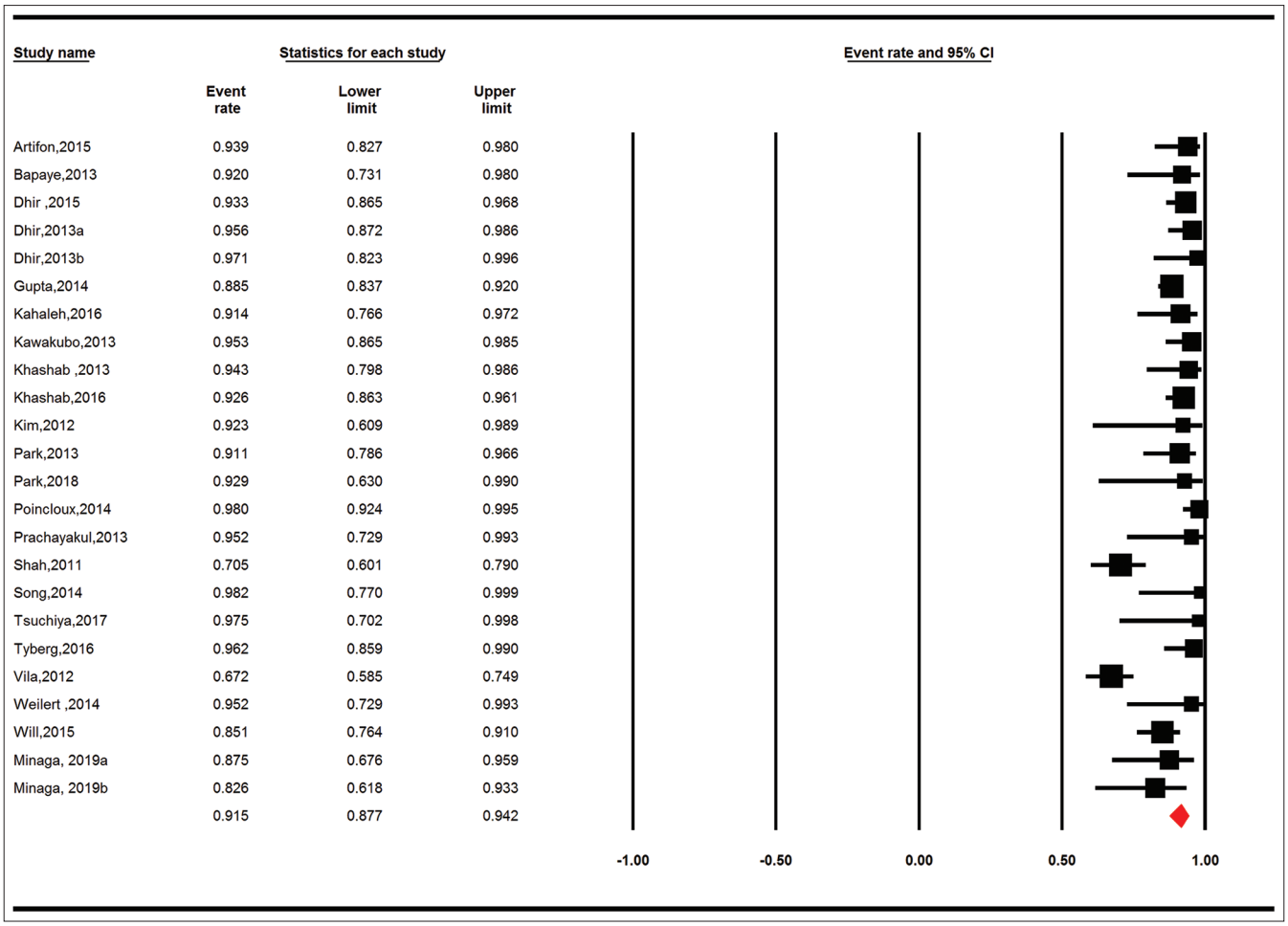

Figure 1. Forest plot – Technical success

Re-intervention and adverse events

The calculated pooled rate of re-intervention was 6.5% (95% CI: 3.8–10.8, I^2 = 69.3) [Figure 3].

The calculated pooled rate of adverse events was 17.9% (95% CI: 14.3–22.2, I^2 = 69.1) [Figure 4].

All results along with the adverse-event subtypes are summarized in Supplementary Figures 2-6.

At this stage, the authors decided to conduct a subgroup analysis on the data to explore reasons for the observed heterogeneity. Studies were subgrouped based on the study center (single center *vs.* multicenter) and study type (prospective *vs.* retrospective; RCT *vs.* observational). The observed heterogeneity was not explained by this subgrouping. We were not able to subgroup and combine the studies based on the approach to BD (gastric *vs.* duodenal) due to the fact that the majority of the studies used a combination of these approaches.

Validation of meta-analysis results

Sensitivity analysis

To assess whether anyone study had a dominant effect on the meta-analysis, we excluded one study at a time and analyzed its effect on the main summary estimate. In this analysis, no single study significantly affected the outcome or the heterogeneity.

Heterogeneity

Based on Q statistics and I^2 analysis for heterogeneity, substantial heterogeneity (I^2 = 69.1) was noted in the analysis of all adverse events, none (I^2 = 0) with infection, moderate (I^2 = 46.7) with bile leak, moderate (I^2 = 41.8) with bleeding, low with pneumo-peritoneum (I^2 = 2), and moderate with stent migration (I^2 = 43.5).

Substantial heterogeneity (I^2 = 76.5) was noted with the analysis of technical success and clinical success (I^2 = 72.4).

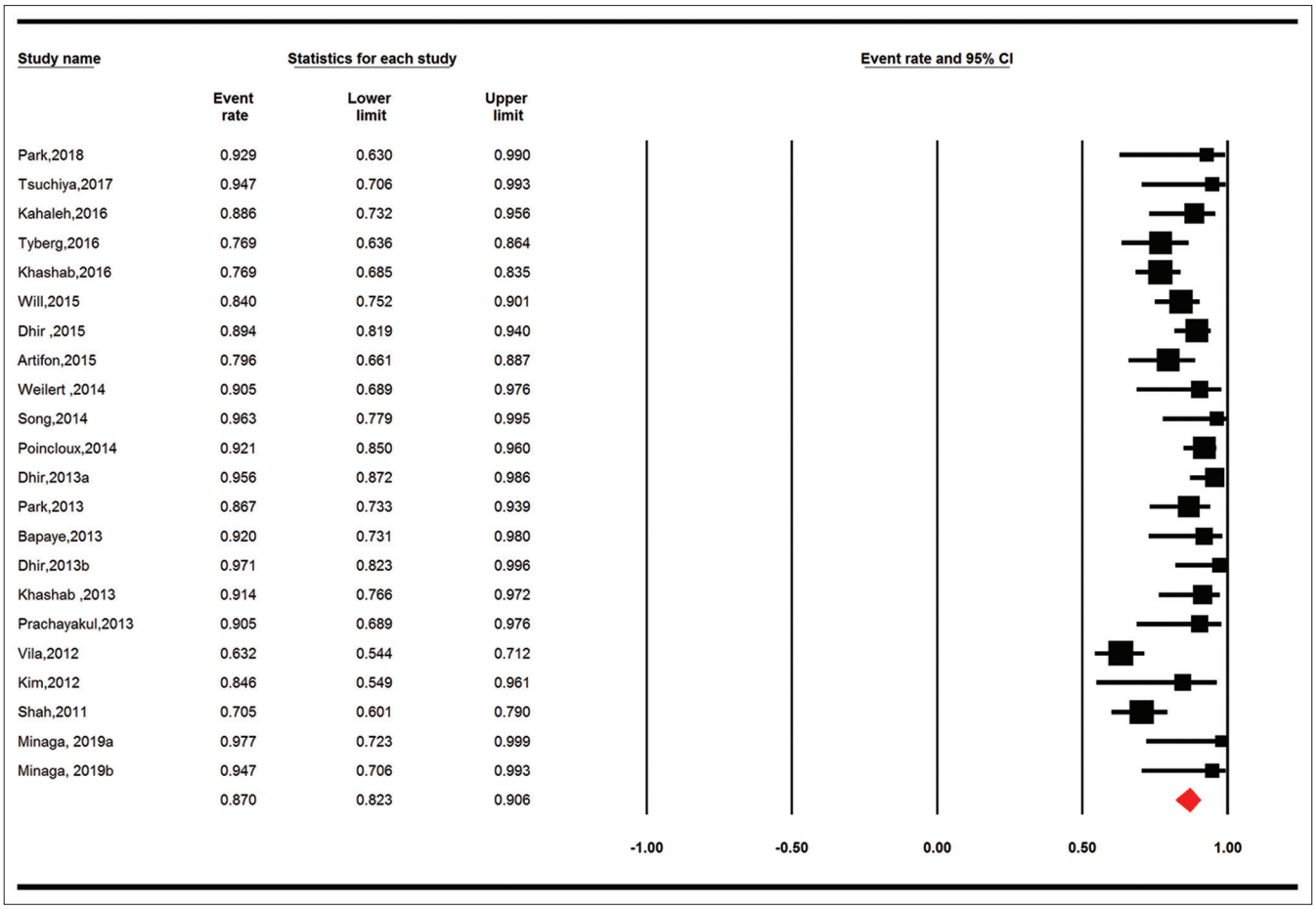

Figure 2. Forest plot – Clinical success

Publication bias

Based on the visual inspection of the funnel plot [Supplementary Figure 7] as well as the quantitative measurement that used the Egger regression test, there was evidence of publication bias. Further statistics using the fail-Safe N test and Duval and Tweedie's "Trim and Fill" test revealed the impact of the possible publication bias to be minimal and not to change the calculated estimate or the conclusion of this meta-analysis.

DISCUSSION

Based on the meta-analysis of EUS-guided gallbladder drainage done in 1437 patients from 23 studies, we report a pooled technical success rate of 91.5%, a pooled clinical success rate of 87%, and a pooled adverse event rate of 17.9%.

ERCP remains the preferred procedure for providing internal BD. EUS-BD is utilized in patients who need biliary decompression when ERCP has either failed or is technically not feasible due to an inaccessible papilla and/or surgically altered anatomy and/or malignancy. The reported success and safety of EUS-BD have been variable across many studies. We report a pooled technical success rate of 91.5% with EUS-BD, and our calculated rate is on par with the currently reported values in literature, although with a heterogeneity percentage of 76.5%, which may be due to one or more of the following reasons: (1) different techniques to access routes the gallbladder, including hepatogastrostomy (EUS-HG), cholecystostomy, choledochoduodenostomy (EUS-CDD), and other techniques; (2) use of different modalities of drainage, such as plastic stents, metal stents, lumen-apposing metal stents, nasobiliary drainage tubes, and a combination of these; and (3) the steep learning curve with the use of EUS in BD with accumulating experience. In the study by Vila *et al.*,[32] endoscopists with >500 EUS procedures had higher success rates than endoscopists who had performed fewer than 500 EUS procedures.

We report a clinical success rate of 87% with EUS-BD. Clinical success has also been variable across many studies, with reported clinical success in the range of

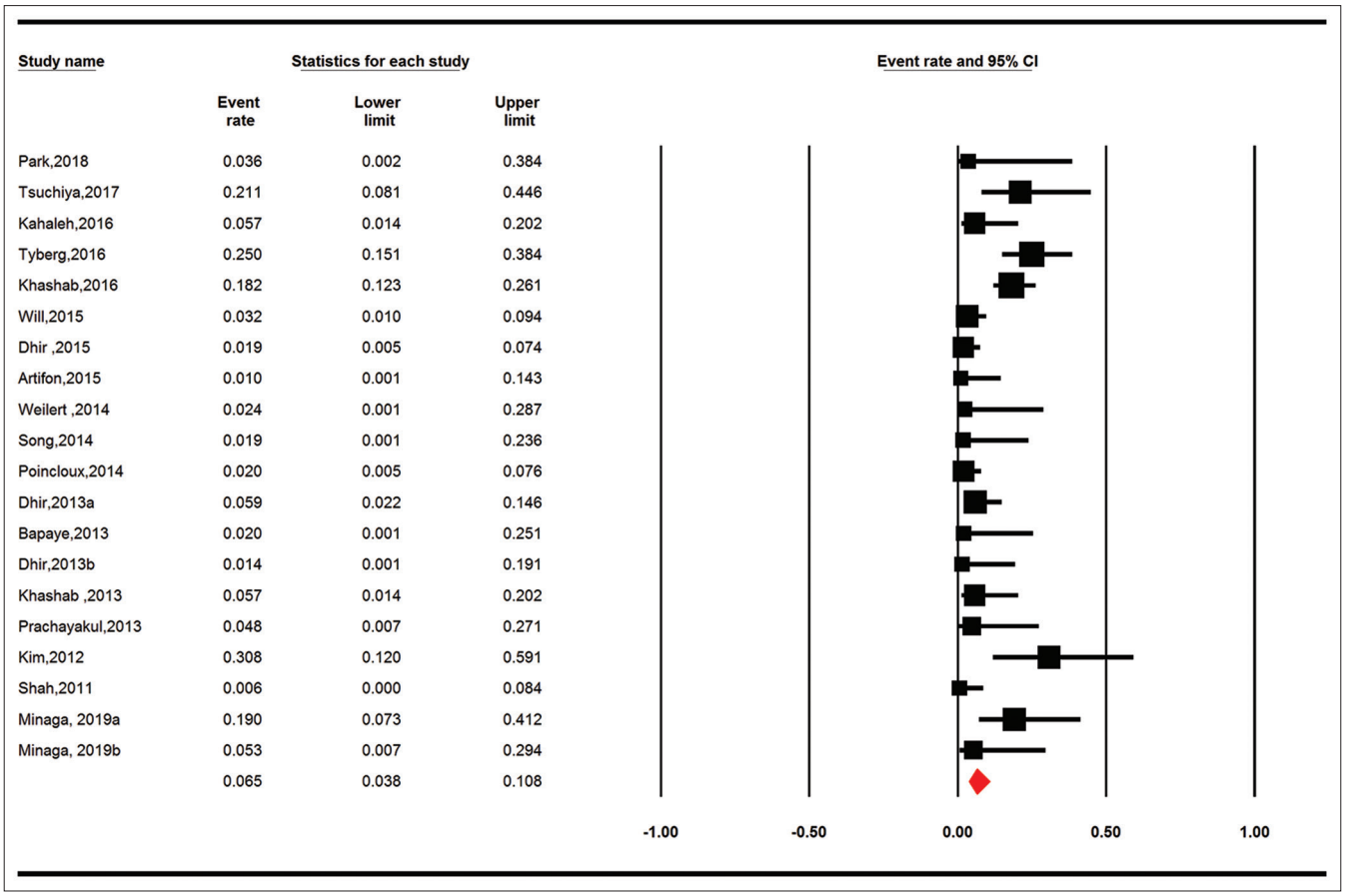

Figure 3. Forest plot – Reintervention

63.2%–76.9%.[16,17,32,34] Other studies have shown clinical success in the range of 84%–97%.[13,14,18,19,22-25,27-31,33] In the majority of studies,[13-15,18,19,22-25,27-34] clinical success has been closely related to technical success, indicating the importance of a successful procedure. A recent randomized controlled trial by Park *et al.*[13] compared EUS- and ERCP-guided BD and showed no significant difference in technical and clinical success, with similar adverse events. However, it was a single-center study with a small population size.

Our analysis of the adverse events demonstrated an overall pooled rate of 17.9%. The most commonly reported adverse events were biliary leak and infection. The pooled rate of biliary leaks was 4%, and the pooled rate of infection and stent migration was 3.8%. Our reported rates of the adverse events with EUS-BD are the key findings of this analysis, as studies vary widely in the reported rates of adverse events with EUS-BD. A recently published meta-analysis of studies[35] reporting on EUS-guided CDD reported an overall pooled adverse event rate of 14.5% with EUS-CDD and 20.9% with EUS-HG.[35] The overall adverse events were higher as compared to ERCP, which are reported to be 9.8% as per Enochsson *et al.*[1]

Our analysis of the subgroups, based on the study type (prospective *vs.* retrospective) and study center (single *vs.* multi), showed comparable technical success and clinical success rates in EUS-BD. We, however, noticed a reduction in the heterogeneity I^2 values with prospectively done studies as compared to the retrospective ones, suggesting that this could be one another contributing factor to our overall observed heterogeneity. We noted that the pooled rate of adverse events reported from multicenter studies was statistically higher when compared to single-center studies (28% *vs.* 14%, $P = 0.02$). The pooled re-intervention rate was numerically higher with multicenter-based studies as compared to single-center ones (11% *vs.* 4%, $P = 0.07$) and approached statistical significance.

The strengths of this review are as follows: systematic literature search with well-defined inclusion criteria, carefully excluding redundant studies, detailed extraction

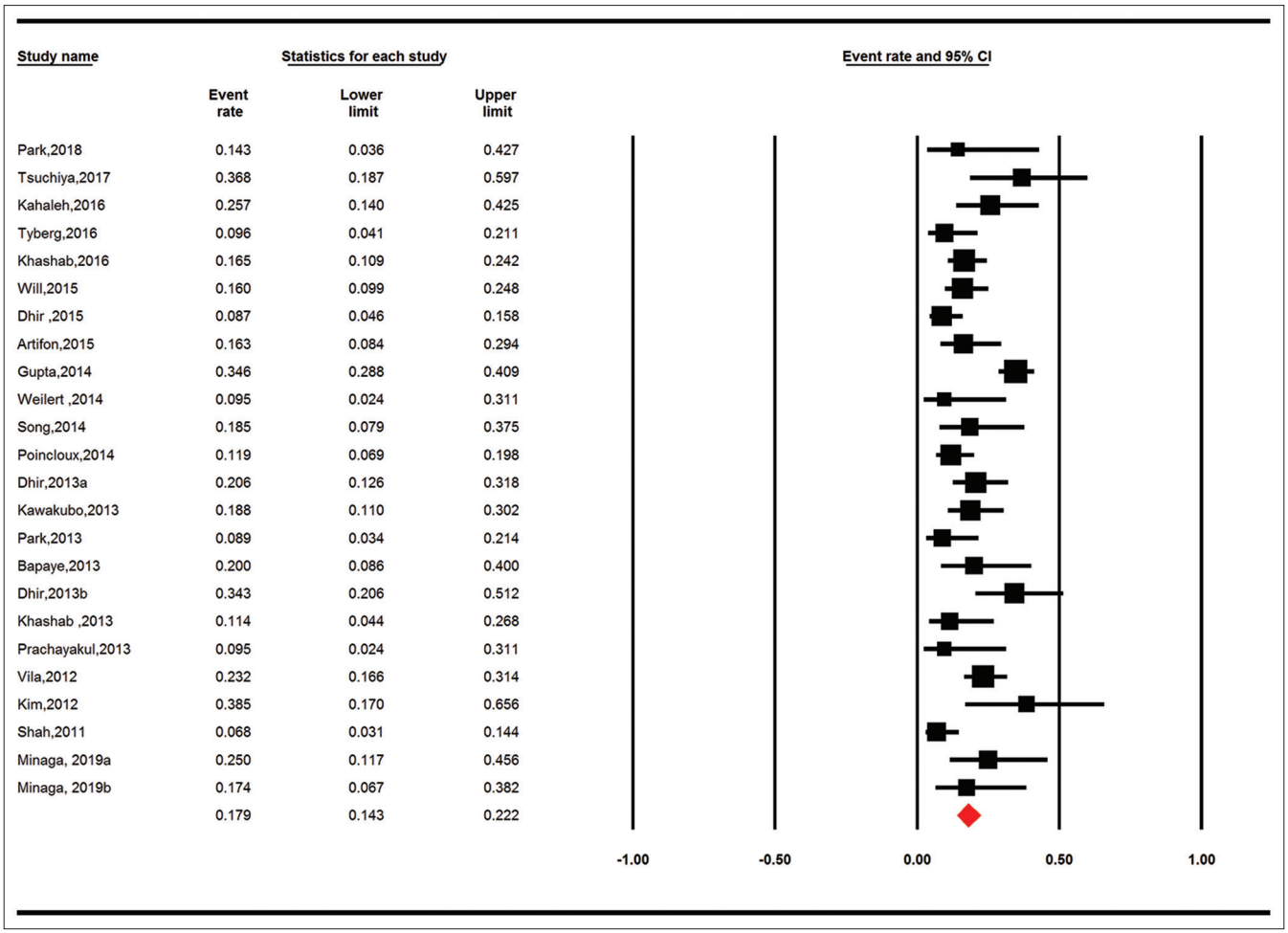

Figure 4. Forest plot – All adverse events

of adverse events, their subcategories, technical success, and clinical success information.

There are limitations to this study. The included studies were not entirely representative of the general population and community practice, with most studies being performed in tertiary-care referral centers. Our pooled rates were limited by heterogeneity. Although our subgroup analysis did not ascertain the cause for the observed heterogeneity, we believe that the most likely reason is the route of access to BD. Patient-related characteristics such as age, smoking, previous attempts and procedures, the stage of malignancy, and performance characteristics could influence the calculated rates. However, this estimate is the best available that summarizes the overall clinical outcomes with EUS-BD that is being rapidly adopted across centers around the world.

CONCLUSION

EUS-BD is a safe alternative option in cases where ERCP fails and in future may become an alternative to ERCP for BD. However, more well-conducted RCTs are needed to establish its role as an alternative to ERCP.

Supplementary materials

Supplementary information is linked to the online version of the article on the *Endoscopic Ultrasound* website.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

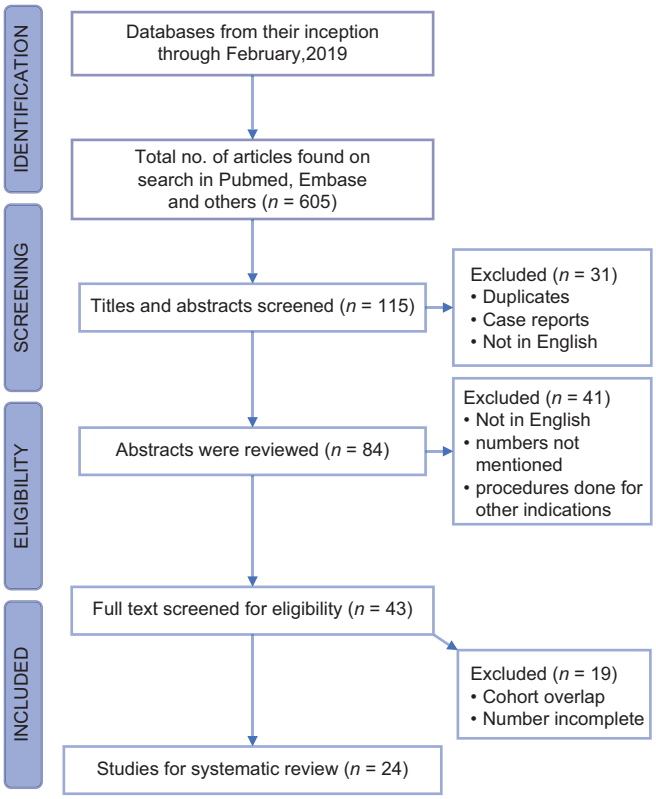
1. Enochsson L, Swahn F, Arnelo U, *et al*. Nationwide, population-based data from 11,074 ERCP procedures from the Swedish registry for gallstone surgery and ERCP. *Gastrointest Endosc* 2010;72:1175-84, 1184.e1-3.
2. Giovannini M, Moutardier V, Pesenti C, *et al*. Endoscopic ultrasound-guided bilioduodenal anastomosis: A new technique for biliary drainage. *Endoscopy* 2001;33:898-900.
3. Stang A. Critical evaluation of the Newcastle-Ottawa scale for the assessment of the quality of nonrandomized studies in meta-analyses. *Eur J Epidemiol* 2010;25:603-5.

4. DerSimonian R, Laird N. Meta-analysis in clinical trials. *Control Clin Trials* 1986;7:177-88.
5. Sutton AJ, Abrams KR, Jones DR, *et al*. Methods for Meta-Analysis in Medical Research. New York: John Wiley and Sons Ltd.; 2000. p. 205-8.
6. Higgins JP, Thompson SG, Deeks JJ, *et al*. Measuring inconsistency in meta-analyses. *BMJ* 2003;327:557-60.
7. Kanwal F, White D. "Systematic reviews and meta-analyses" in clinical gastroenterology and hepatology. *Clin Gastroenterol Hepatol* 2012;10:1184-6.
8. Guyatt GH, Oxman AD, Kunz R, *et al*. GRADE guidelines: 7. rating the quality of evidence-inconsistency. *J Clin Epidemiol* 2011;64:1294-302.
9. Easterbrook PJ, Berlin JA, Gopalan R, *et al*. Publication bias in clinical research. *Lancet* 1991;337:867-72.
10. Duval S, Tweedie R. Trim and fill: A simple funnel-plot-based method of testing and adjusting for publication bias in meta-analysis. *Biometrics* 2000;56:455-63.
11. Rothstein HR, Sutton AJ, Borenstein M. Publication bias in Meta-Analysis: Prevention, Assessment and Adjustments. West Sussex, England: John Wiley & Sons,; 2006.
12. Minaga K, Ogura T, Shiomi H, *et al*. Comparison of the efficacy and safety of endoscopic ultrasound-guided choledochoduodenostomy and hepaticogastrostomy for malignant distal biliary obstruction: Multicenter, randomized, clinical trial. *Dig Endosc* 2019;31:575-82.
13. Park JK, Woo YS, Noh DH, *et al*. Efficacy of EUS-guided and ERCP-guided biliary drainage for malignant biliary obstruction: Prospective randomized controlled study. *Gastrointest Endosc* 2018;88:277-82.
14. Tsuchiya T, Teoh AY, Itoi T, *et al*. Long-term outcomes of EUS-guided choledochoduodenostomy using a lumen-apposing metal stent for malignant distal biliary obstruction: A prospective multicenter study. *Gastrointest Endosc* 2018;87:1138-46.
15. Kahaleh M, Perez-Miranda M, Artifon EL, *et al*. International collaborative study on EUS-guided gallbladder drainage: Are we ready for prime time? Dig Liver Dis 2016;48:1054-7.
16. Tyberg A, Desai AP, Kumta NA, *et al*. EUS-guided biliary drainage after failed ERCP: A novel algorithm individualized based on patient anatomy. *Gastrointest Endosc* 2016;84:941-6.
17. Khashab MA, Messallam AA, Penas I, *et al*. International multicenter comparative trial of transluminal EUS-guided biliary drainage via hepatogastrostomy vs. choledochoduodenostomy approaches. *Endosc Int Open* 2016;4:E175-81.
18. Will U, Fueldner F, Kern C, *et al*. EUS-guided bile duct drainage (EUBD) in 95 patients. *Ultraschall Med* 2015;36:276-83.
19. Dhir V, Itoi T, Khashab MA, *et al*. Multicenter comparative evaluation of endoscopic placement of expandable metal stents for malignant distal common bile duct obstruction by ERCP or EUS-guided approach. *Gastrointest Endosc* 2015;81:913-23.
20. Artifon EL, Marson FP, Gaidhane M, *et al*. Hepaticogastrostomy or choledochoduodenostomy for distal malignant biliary obstruction after failed ERCP: Is there any difference? *Gastrointest Endosc* 2015;81:950-9.
21. Gupta K, Perez-Miranda M, Kahaleh M, *et al*. Endoscopic ultrasound-assisted bile duct access and drainage: Multicenter, long-term analysis of approach, outcomes, and complications of a technique in evolution. *J Clin Gastroenterol* 2014;48:80-7.
22. Weilert F. Prospective evaluation of simplified algorithm for EUS-guided intra-hepatic biliary access and anterograde interventions for failed *ERCP. Surg Endosc* 2014;28:3193-9.
23. Song TJ, Lee SS, Park DH, *et al*. Preliminary report on a new hybrid metal stent for EUS-guided biliary drainage (with videos). *Gastrointest Endosc* 2014;80:707-11.
24. Poincloux L, Rouquette O, Buc E, *et al*. Endoscopic ultrasound-guided biliary drainage after failed ERCP: Cumulative experience of 101 procedures at a single center. *Endoscopy* 2015;47:794-801.
25. Dhir V, Artifon EL, Gupta K, *et al*. Multicenter study on endoscopic ultrasound-guided expandable biliary metal stent placement: Choice of access route, direction of stent insertion, and drainage route. *Dig Endosc* 2014;26:430-5.
26. Kawakubo K, Isayama H, Kato H, *et al*. Multicenter retrospective study of endoscopic ultrasound-guided biliary drainage for malignant biliary obstruction in Japan. *J Hepatobiliary Pancreat Sci* 2014;21:328-34.
27. Park DH, Jeong SU, Lee BU, *et al*. Prospective evaluation of a treatment algorithm with enhanced guidewire manipulation protocol for EUS-guided biliary drainage after failed ERCP (with video). *Gastrointest Endosc* 2013;78:91-101.
28. Bapaye A, Dubale N, Aher A. Comparison of endosonography-guided vs. percutaneous biliary stenting when papilla is inaccessible for ERCP. United *European Gastroenterol J* 2013;1:285-93.
29. Dhir V, Bhandari S, Bapat M, *et al*. Comparison of transhepatic and extrahepatic routes for EUS-guided rendezvous procedure for distal CBD obstruction. *United European Gastroenterol J* 2013;1:103-8.
30. Khashab MA, Valeshabad AK, Modayil R, *et al*. EUS-guided biliary drainage by using a standardized approach for malignant biliary obstruction: Rendezvous versus direct transluminal techniques (with videos). *Gastrointest Endosc* 2013;78:734-41.
31. Prachayakul V, Aswakul P. A novel technique for endoscopic ultrasound-guided biliary drainage. *World J Gastroenterol* 2013;19:4758-63.
32. Vila JJ, Pérez-Miranda M, Vazquez-Sequeiros E, *et al*. Initial experience with EUS-guided cholangiopancreatography for biliary and pancreatic duct drainage: A Spanish national survey. *Gastrointest Endosc* 2012;76:1133-41.
33. Kim TH, Kim SH, Oh HJ, *et al*. Endoscopic ultrasound-guided biliary drainage with placement of a fully covered metal stent for malignant biliary obstruction. *World J Gastroenterol* 2012;18:2526-32.
34. Shah JN, Marson F, Weilert F, *et al*. Single-operator, single-session EUS-guided anterograde cholangiopancreatography in failed ERCP or inaccessible papilla. *Gastrointest Endosc* 2012;75:56-64.
35. Mohan BP, Shakhatreh M, Garg R, *et al*. Efficacy and Safety of endoscopic ultrasound-guided choledochoduodenostomy: A systematic review and meta-analysis. J Clin Gastroenterol 2019;53:243-50.

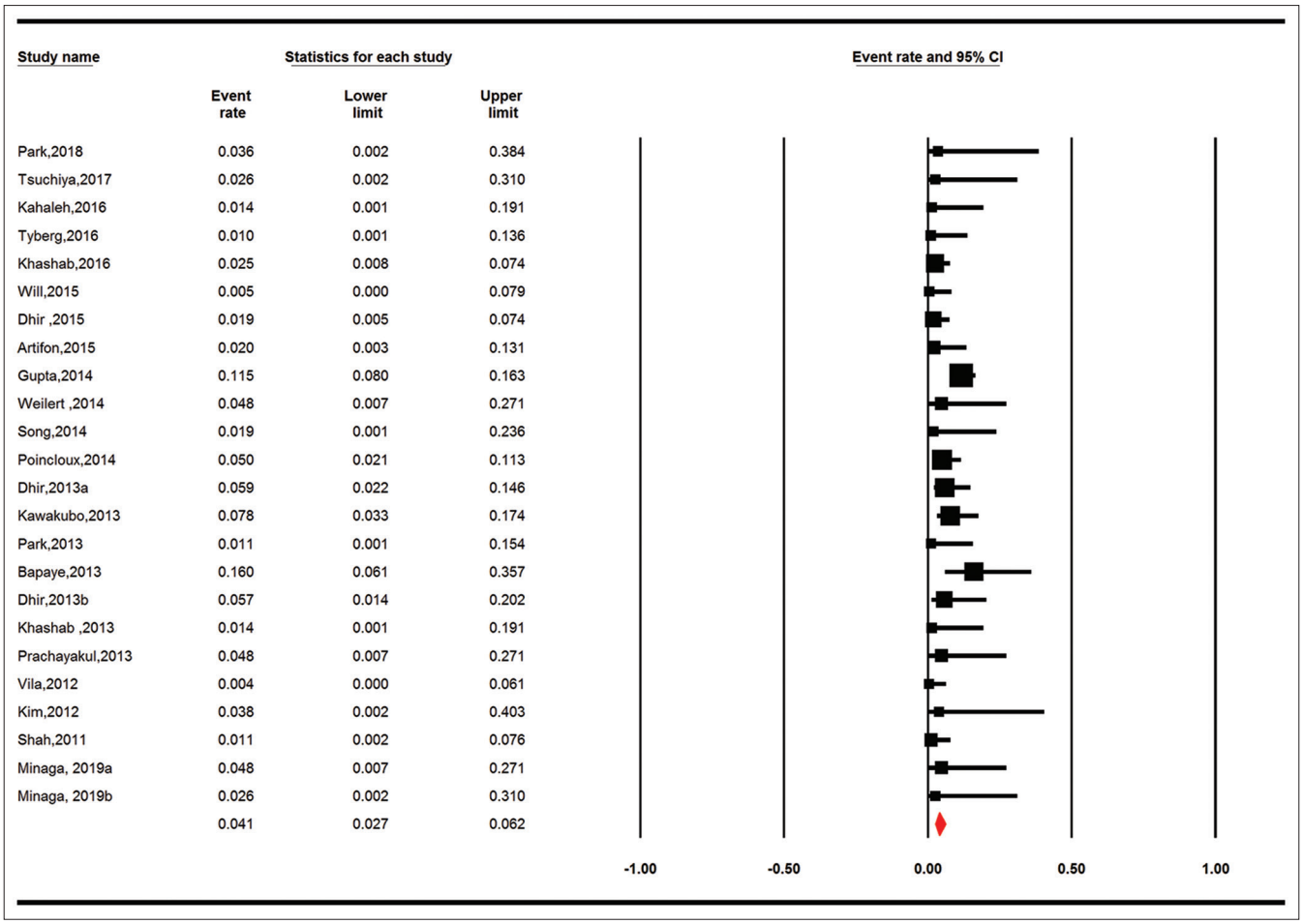
Supplementary Table 1. Study quality assessment

Author	Study type	Cohort case-control	Year	Number of patients	Newcastle-Ottawa Scale		
					Selection	Comparability	Outcome
Tsuchiya	Prospective	Cohort	2017	19	***	**	***
Kahaleh	Retrospective	Cohort	2016	35	***	**	***
Tyberg	Prospective	Cohort	2016	52	**	*	***
Khashab	Retrospective	Cohort	2016	121	***	**	***
Will	Prospective	Cohort	2015	94	***	**	***
Dhir	Retrospective	Cohort	2015	104	***	**	***
Gupta	Retrospective	Cohort	2014	234	***	**	**
Weilert	Prospective	Cohort	2014	21	***	**	**
Song	Prospective	Cohort	2014	27	**	**	**
Poincloux	Retrospective	Cohort	2014	101	***	**	***
Dhir	Retrospective	Cohort	2013	68	***	**	**
Kawakubo	Retrospective	Cohort	2013	64	***	**	***
Park	Prospective	Cohort	2013	45	***	**	***
Bapaye	Retrospective	Cohort	2013	25	***	*	**
Dhir	Retrospective	Cohort	2013	35	***	**	**
Khashab	Retrospective	Cohort	2013	35	***	**	***
Prachayakul	Retrospective	Cohort	2013	21	***	**	***
Vila	Retrospective	Cohort	2012	125	***	*	**
Kim	Retrospective	Cohort	2012	13	***	*	**
Shah	Retrospective	Cohort	2011	66	**	*	**
			Jadad-Oxford score for RCT				
Minaga	Prospective	RCT	2019	47	2	1	1
Park	Prospective	RCT	2018	14	2	0	1
Artifon	Prospective	RCT	2015	49	2	0	1

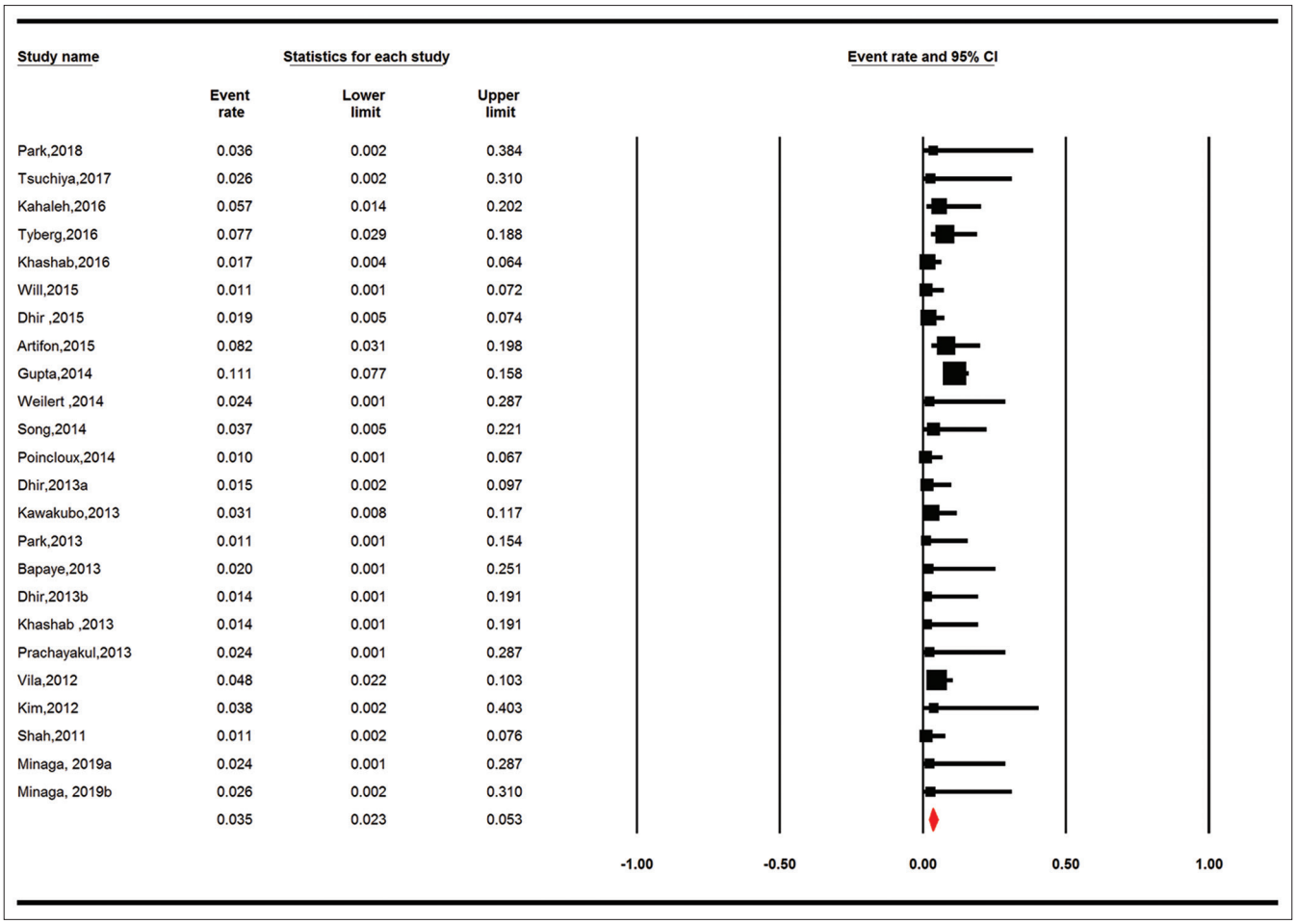
*meaning: number of stars awarded to each criteria based on the quality of bias. RCT: Randomized controlled trial



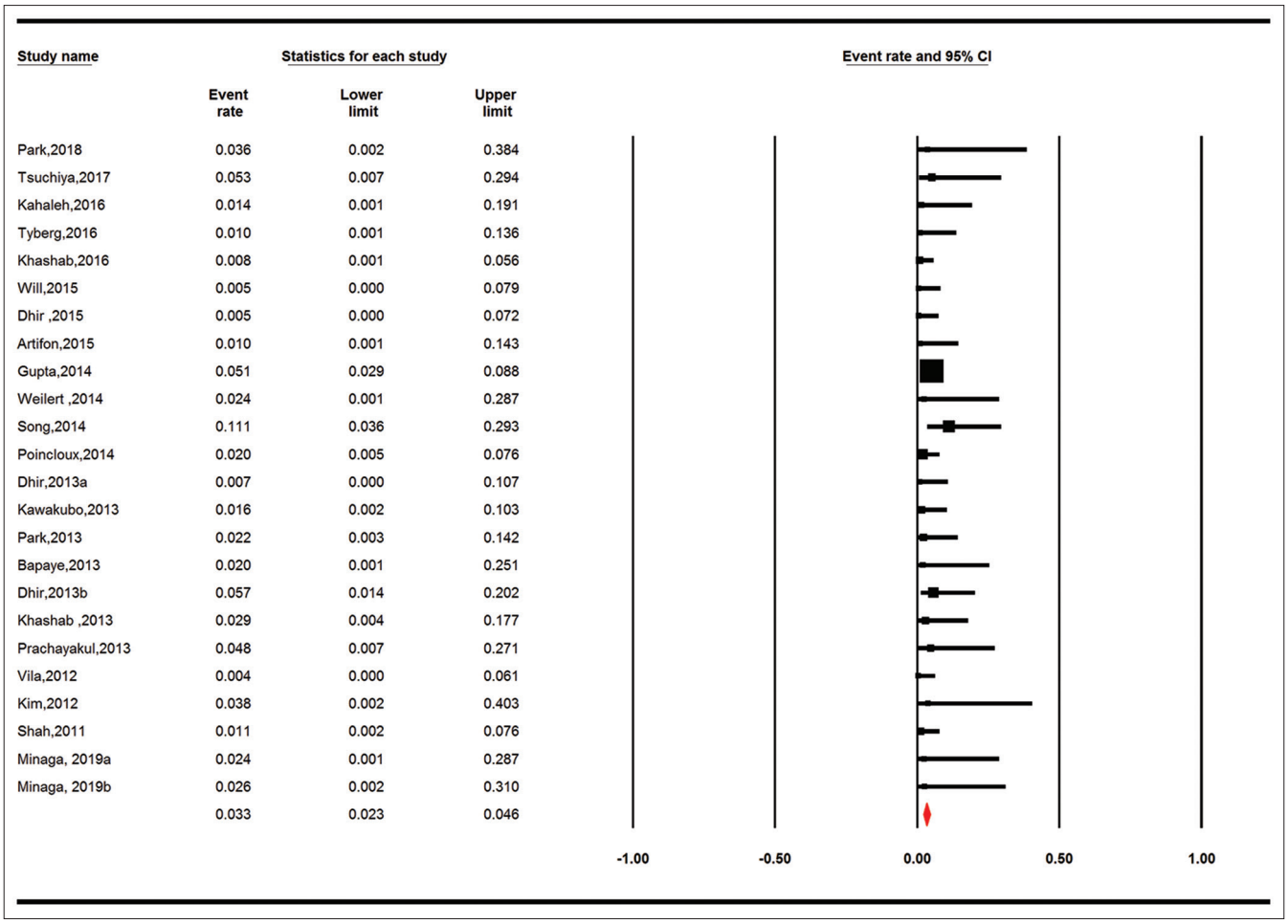
Supplementary Figure 1. Preferred Reporting items for Systematic Reviews and Meta-Analyses flow diagram of the study selection



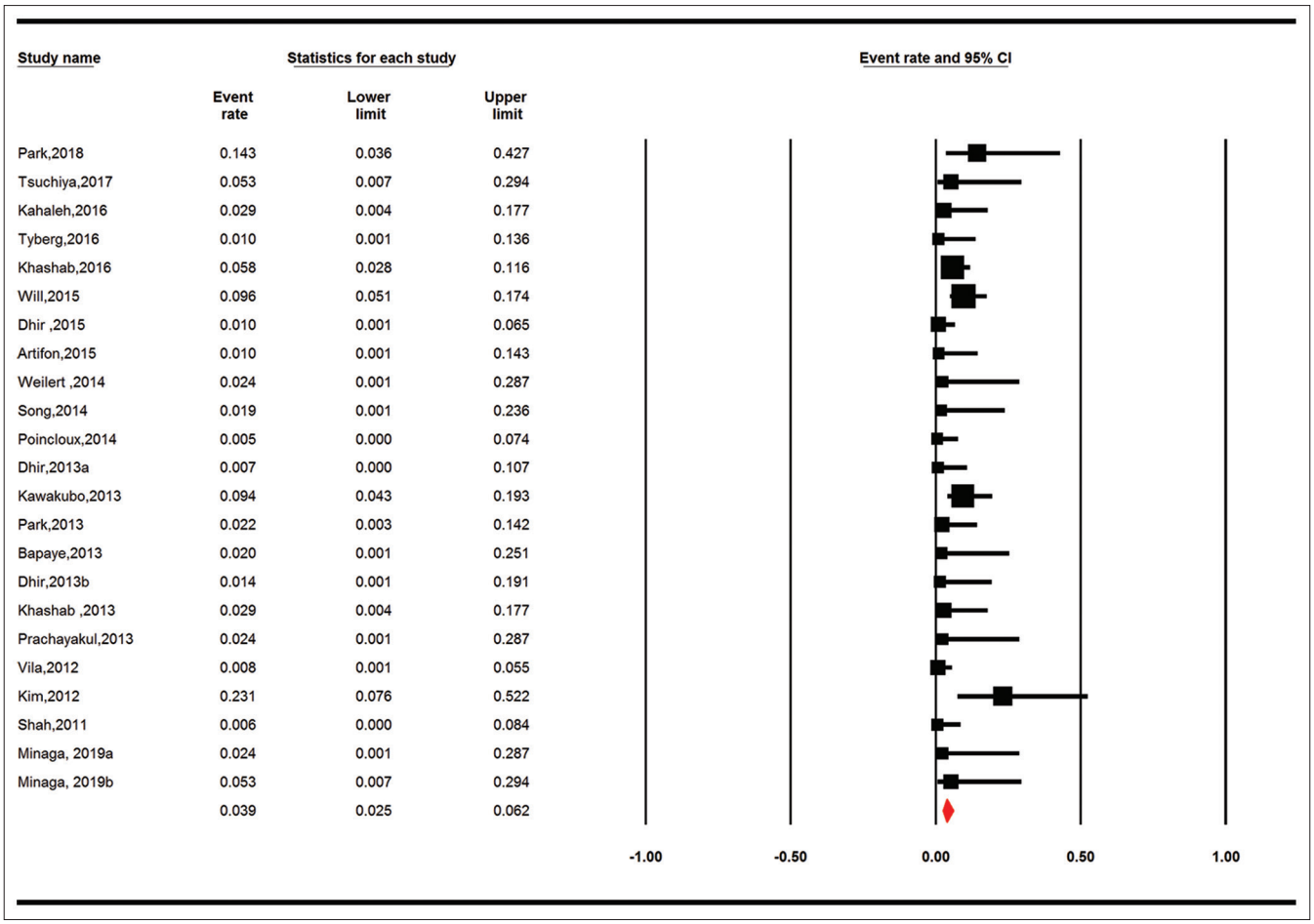
Supplementary Figure 2. Bile leak



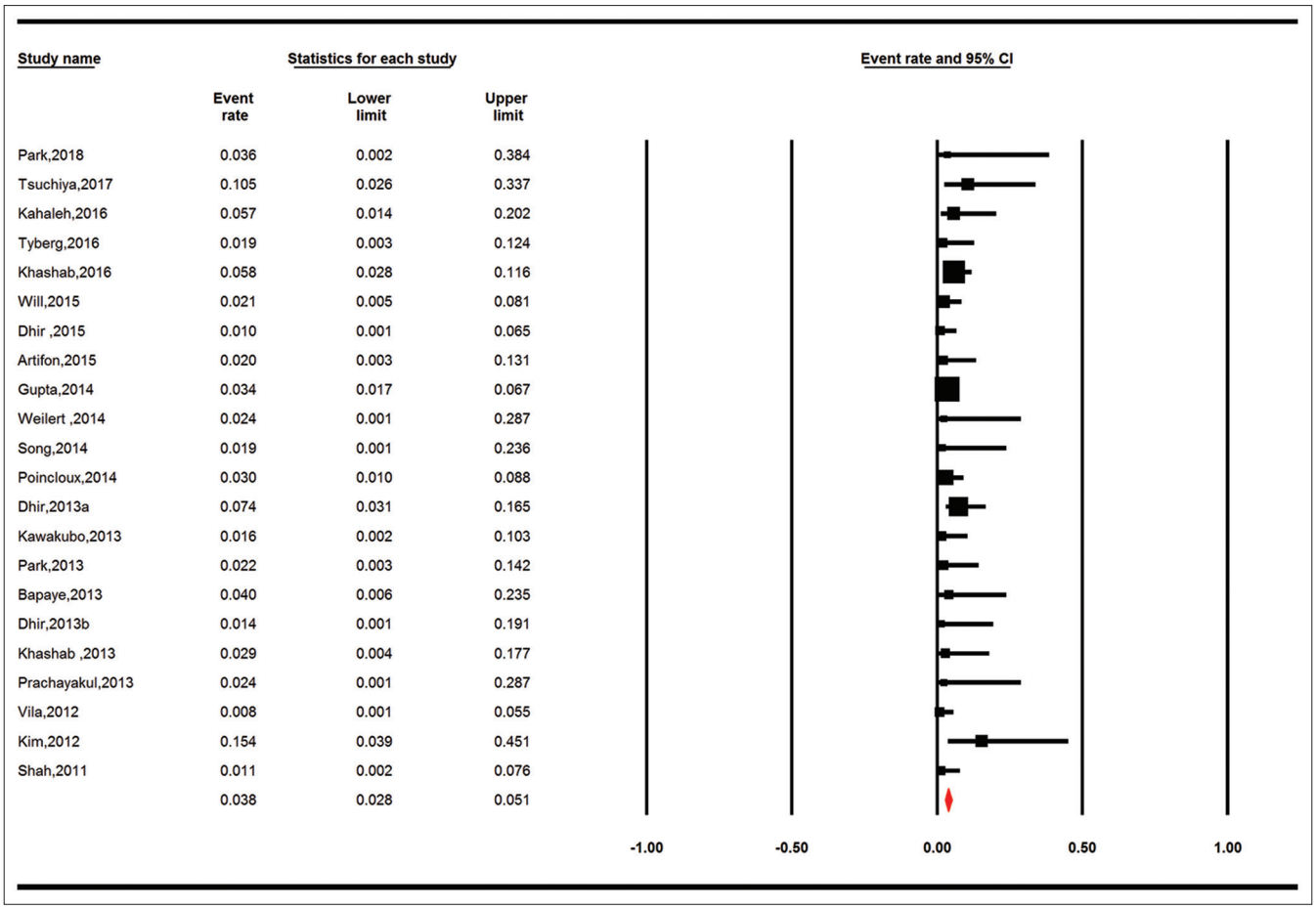
Supplementary Figure 3. Bleeding



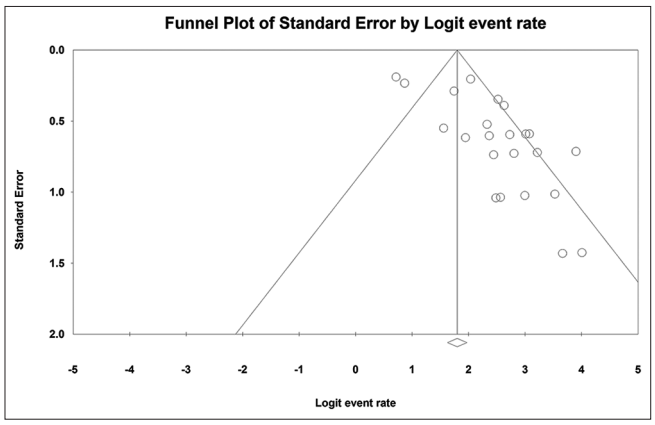
Supplementary Figure 4. Pneumoperitoneum



Supplementary Figure 5. Stent migration



Supplementary Figure 6. Infection



Supplementary Figure 7. Funnel plot