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Comparison of 4 first-line endoscopic biliary drainage modalities in distal malignant biliary obstruction: A systematic review and network meta-analysis

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ABSTRACT

Background and objectives: EUS-guided biliary drainage is a potential alternative to endoscopic retrograde cholangiopancreatography (ERCP) for distal malignant biliary obstruction (DMBO). However, its role as a primary intervention remains uncertain. This study compares the clinical outcomes of 4 primary endoscopic drainage modalities: ERCP, EUS-hepaticogastrostomy (HGS), EUS-choledochoduodenostomy (CDS) with lumen-apposing metal stent (LAMS), and EUS-CDS with self-expandable metal stents (SEMSs).

Methods: The literature was searched up until July 2024. A network meta-analysis of 5 randomized controlled trials and 3 comparative studies, including 796 patients (444 ERCP, 180 EUS-CDS-LAMS, 116 EUS-CDS-SEMS, 56 EUS-HGS), was conducted. Outcomes assessed included clinical success, technical success, procedural time, adverse events, reintervention rates, and stent patency.

Results: Clinical success was comparable across all modalities. EUS-CDS-LAMS demonstrated higher technical success compared with ERCP (odds ratio [OR], 3.95; 95% confidence interval [CI], 1.54–10.12) and EUS-CDS-SEMS (OR, 4.37; 95% CI, 1.03–18.55). EUS-CDS-LAMS also had a shorter procedural time compared with ERCP (standardized mean difference, −11.67; 95% CI, −15.66 to −7.68), EUS-CDS-SEMS, and EUS-HGS. Adverse event rates were similar across all groups. EUS-HGS had fewer reinterventions compared with ERCP (OR, 0.20; 95% CI, 0.08–0.52) and EUS-CDS-LAMS (OR, 0.22; 95% CI, 0.07–0.74). At 6 months, stent patency rates were 88.7% for EUS-HGS, 84.5% for EUS-CDS-SEMS, 73.1% for EUS-CDS-LAMS, and 64.8% for ERCP.

Conclusions: Clinical success and adverse event rates were comparable among modalities. EUS-CDS-LAMS showed superior technical success and shorter procedural time. In contrast, EUS-HGS showed fewer reinterventions and better stent patency than ERCP.

Keywords: Distal malignant biliary obstruction; Endoscopic retrograde cholangiopancreatography; EUS; Lumen apposing metal stent

Introduction

The management of distal malignant biliary obstruction (DMBO) has significantly evolved with advancements in endoscopic techniques. Endoscopic retrograde cholangiopancreatography (ERCP) has been the mainstay of DMBO therapy; however, ERCP may not always be successful or feasible, and percutaneous transhepatic biliary drainage (BD) has been used after ERCP failure. Recently, EUS-guided biliary drainage (EUS-BD) has emerged as an alternative to percutaneous transhepatic BD after failure of ERCP owing to the reduced reintervention rate and fewer adverse events.[1–6] Furthermore, EUS-BD has been proposed as the primary technique of BD of DMBO instead of ERCP because the former may offer a lower rate of procedure-related pancreatitis, better stent patency, and lower reintervention rate due to the stent placement away from the tumor. However, previous randomized controlled trials (RCTs) have reported conflicting clinical outcomes owing to the heterogeneous use of conventional or dedicated tubular metal stents.[7–9] Recently, the development of luminal-apposing metal stents (LAMSs) with an enhanced electrocautery system has rendered interventional EUS easier and safer.[10–18] Specifically, EUS-guided choledochoduodenostomy (EUS-CDS) using electrocautery-enhanced LAMS presents a potential primary modality for BD.

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Recent meta-analyses comparing primary EUS-BD and ERCP have demonstrated comparable rates of technical success, clinical success, adverse events, and reintervention, with EUS-BD showing a statistically significant lower reintervention rate compared with ERCP.[19–21] However, EUS-BD encompasses various techniques, including EUS-guided hepaticogastrostomy (EUS-HGS), EUS-CDS with LAMS, and EUS-CDS with tubular self-expandable metal stent (SEMS). Moreover, there is a lack of data on the long-term outcomes concerning stent patency for these modalities. In this study, we aimed to utilize current evidence from randomized trials and nonrandomized comparative studies to compare the outcomes of these 4 modalities, with the goal of potentially redefining first-line treatment strategies for DMBO.

Materials and methods

Search strategy

Two researchers (G.H. and W.-M.C.) conducted a systematic literature search using PubMed, EMBASE, and Cochrane Library database, following the Preferred Reporting Items for Systematic reviews and Meta-analysis (PRISMA) guidelines. All discrepancies were resolved through discussion and agreement. Detailed search strategies for each database are provided in Supplementary Table 1, http://links.lww.com/ENUS/A375.

Study selection, data extraction, and quality assessment

The database searches included full-text articles published in English. Inclusion criteria were as follows: (1) patient population: malignant biliary obstruction; (2) treatment: ERCP-assisted transpapillary stenting *versus* EUS-guided transmural stenting; (3) study design: comparative studies; (4) outcome: clinical success, technical success, procedural times, adverse events rates, reintervention rates, and stent patency; and (5) studies published between 2010 and July 2024. Exclusion criteria included (1) case reports, conference abstracts, editorials, letters, meta-analyses, and reviews; (2) animal studies; (3) inappropriate comparisons (e.g., percutaneous approaches, EUS-guided rendezvous, antegrade or transpapillary stenting, or historical controls); (4) EUS-guided transmural stenting as a second-line treatment after failed ERCP in the same session; (5) heterogeneous EUS-guided transmural stenting techniques lacking separate outcome data (e.g., CDS and HGS); and (7) studies on other medical conditions.

Data were independently extracted by 2 independent researchers (G.H. and W.-M.C.) using a predefined electronic spreadsheet. These data included (1) author names and publication year; (2) data source and country of origin; (3) number of patients; (4) patient characteristics; (5) type of stents for ERCP and EUS-BD; and (6) outcomes, including clinical success, technical success, procedural times, adverse events rates, reintervention rates, and stent patency. Clinical success was defined as a reduction in total serum bilirubin levels by up to one-half within 2 weeks or a decrease to one-quarter of the pretreatment level or normalization within 4 weeks.[11,22] Although there were minor discrepancies in the degree of bilirubin reduction and the time point for assessment across individual studies, this definition encompassed and unified the clinical success definitions used in all included studies, aligning with standard clinical criteria. Technical success was defined as the successful placement of a stent (either transpapillary in ERCP or transmural in EUS-HGS and EUS-CDS) during the endoscopic session, and this definition was consistently applied across the studies. Procedure time was defined as the duration from the positioning of the endoscope to the completion of stent placement, including the time from EUS puncture or biliary cannulation to the end of the procedure, with minimal variations in definition across the studies potentially leading to difference in measurement.[9,22,23] Procedure-related adverse events were evaluated according to the severity grading system of the ASGE lexicon.[24] Reintervention was defined as the need for an additional endoscopic or percutaneous procedure due to cholangitis and/or jaundice. Stent patency was defined as the time between stent placement and stent dysfunction.[10] Regarding long-term outcome assessments, we used the intention-to-treat approach, meaning that the outcome was based on all cases, regardless of initial clinical success. The risk of bias in each RCT was evaluated using the Cochrane risk-of-bias tool (version 2).[25] Non-RCTs were assessed using the Newcastle-Ottawa scale.[26] We assessed the effect of assignment to intervention (the intention-treat effect). Two review authors (G.H., W.-M.C.) independently assessed the risk of bias. If they were unable to reach a consensus, the third review author (D.H.P.) made the final decision.

Data analysis

We pooled the effect with traditional pairwise meta-analysis and network meta-analysis to aggregate the treatment effect estimates by pooling the results of the included studies. We used the random-effects model within frequentist methods for network meta-analysis considering the heterogeneity between the studies (including RCTs, prospective observational study, and retrospective studies).[27] ERCP was considered as the reference in the network meta-analysis models because it was the most frequent comparison and had the largest number of participants.

Treatment effect estimates were presented using pooled odds ratios (ORs) with corresponding 95% confidence intervals (CIs) for dichotomous outcomes. For continuous outcomes, standardized mean differences (SMDs) with 95% CIs were calculated. In cases where the mean and/or SD were unavailable, but median, standard error, or CI data were reported, a conversion method was used to estimate the standard mean and sample SD.[28]

Forest plots were used to visualize the primary and secondary outcomes. Time-to-event data were analyzed by digitizing Kaplan-Meier curves from each study using Engauge Digitizer software (version 12.0), and survival curves were synthesized using a multivariate, mixed-effects model.[29,30]

Heterogeneity between studies was assessed with Higgins' I^2 statistic, where an I^2 value of ≥50% indicates substantial heterogeneity, and ≥75% indicates considerable heterogeneity. Intervention methods were ranked using the *P* score, with higher scores (closer to 1.00) indicating better outcomes (e.g., higher success rates, shorter procedure times, fewer adverse events and reinterventions, and longer stent patency). When significant inconsistency in pooled analysis was identified, random-effects model and *P* score ranking analysis were excluded.[31] Publication bias was assessed using a comparison-adjusted funnel plot and linear regression for funnel plot asymmetry. The GRADE framework was used to assess the certainty of evidence (high, moderate, low, or very low).[32] All statistical analyses were performed using R statistical software (version 4.3.2; R Software for Statistical Computing, Vienna, Austria), with 2-tailed tests and statistical significance set at $P < 0.05$. The study protocol was approved by the institutional review board of the Asan Medical Center (2025-0047).

Results

Study results and risk of bias

The initial bibliographical search strategy identified 3929 studies. A total of 3288 studies remained after removing duplicates, and 3112 studies were excluded based on the title or abstract screening. A total of 176 articles were assessed for meta-analysis eligibility, and 168 studies were excluded. Finally, 8 studies including 796 patients (444 ERCP, 180 EUS-CDS with LAMS, 116 EUS-CDS with SEMS, and 56 EUS-HGS) were included in this network meta-analysis.[7–11,22,23,33] The characteristics of the included studies are shown in Table 1, with individual study outcomes shown in Supplementary Table 2, http://links.lww.com/ENUS/A375. The search strategy is detailed in Figure 1. Risk-of-bias traffic light plots and summary plots for 5 randomized studies are shown in Supplementary Figures 1, 2, http://links.lww.com/ENUS/A375. Newcastle-Ottawa scales for 3 nonrandomized studies are presented in Supplementary Table 3, http://links.lww.com/ENUS/A375. The certainty of evidence using GRADE framework is shown in Supplementary Table 4, http://links.lww.com/ENUS/A375. The networks of included studies with direct comparisons between endoscopic interventions for primary BD are presented in Figure 2 and Supplementary Figure 3, http://links.lww.com/ENUS/A375.

Primary outcomes: Clinical success

In the network meta-analysis, no inconsistency was observed between the results of direct and indirect comparisons ($P = 0.753$). As detailed in Supplementary Table 4, http://links.lww.com/ENUS/A375, no significant differences were observed between ERCP, EUS-HGS, EUS-CDS with LAMS, and EUS-CDS with SEMS. None of the treatments were superior to ERCP (OR, 1.71; 95% CI, 0.80–3.68 for EUS-CDS with LAMS; OR, 1.41; 95% CI, 0.51–3.85 for EUS-CDS with SEMS; OR, 0.95; 95% CI, 0.30–3.03 for EUS-HGS; Supplementary Table 4, http://links.lww.com/ENUS/A375 and Figure 3A]. In the network ranking estimate comparing the 4 procedures, clinical success was most favorable for EUS-CDS with LAMS (P score = 0.7777) and EUS-CDS with SEMS (0.6149), with EUS-HGS (0.3168) and ERCP (0.2905) showing less effectiveness [Figure 4].

Technical success and procedure time

In the network meta-analysis, no inconsistency was observed between direct and indirect comparisons for technical success and procedure time ($P = 0.790$ and $P = 0.369$, respectively). EUS-CDS with LAMS showed superior technical success compared with ERCP (OR, 3.95; 95% CI, 1.54–10.12; $P = 0.004$) and EUS-CDS with SEMS (OR, 4.37; 95% CI, 1.03–18.55; $P = 0.046$) (Supplementary Table 4, http://links.lww.com/ENUS/A375, Figure 3B]. The ranking analysis revealed that EUS-CDS with LAMS had the highest technical success (P score = 0.8476), followed by EUS-HGS (0.7097), with ERCP (0.2440) and EUS-CDS with SEMS (0.1987) performing less effectively [Figure 4].

EUS-CDS with LAMS also showed significantly shorter procedure times compared with ERCP (SMD, –11.67; 95% CI, –15.66 to –7.68; $P < 0.001$), EUS-CDS with SEMS (SMD, –11.46; 95% CI, –16.46 to –6.47; $P < 0.001$), and EUS-HGS (SMD, –5.26; 95% CI, –10.31 to –0.21; $P = 0.041$). EUS-HGS also had a significantly shorter procedure time compared with ERCP (SMD, –6.41; 95% CI, –9.51 to –3.3; $P < 0.001$) (Supplementary Table 4, http://links.lww.com/ENUS/A375, Figure 3C]. In the ranking analysis, EUS-CDS with LAMS ranked highest for procedure time (P score = 0.9931), indicating superior efficiency, followed by EUS-HGS (0.6734). EUS-CDS with SEMS (0.1848) and ERCP (0.1486), was less efficient [Figure 4].

Adverse events

No inconsistency was observed between direct and indirect comparisons regarding adverse events ($P = 0.090$). No significant differences were observed in the comparison of adverse event rates between the 4 modalities (Supplementary Table 4, http://links.lww.com/ENUS/A375, Figure 3D]. In the ranking analysis, EUS-HGS had the best safety profile (P score = 0.9120), followed by EUS-CDS with LAMS (0.5811). ERCP (0.3137) and EUS-CDS with SEMS (0.1931) were associated with higher rates of adverse events [Figure 4].

Reintervention and stent patency

No inconsistency was observed between direct and indirect comparisons for reintervention rates ($P = 0.497$). EUS-HGS showed significantly lower reintervention rates compared with ERCP (OR, 0.20; 95% CI, 0.08–0.52) and EUS-CDS with LAMS (OR, 0.22; 95% CI, 0.07–0.74) (Supplementary Table 4, http://links.lww.com/ENUS/A375, Figure 3E]. In the ranking analysis, EUS-HGS had the lowest reintervention rate (P score = 0.9567). EUS-CDS with SEMS (0.6781) performed moderately, whereas EUS-CDS with LAMS (0.2310) and ERCP (0.1341) required more frequent reinterventions.

Significant inconsistency was observed between direct and indirect comparisons for stent patency ($P < 0.001$, data not shown). Therefore, the results of random-effects model and P score ranking analysis for stent patency are not presented. Kaplan-Meier curves for stent patency were available in 6 studies (5 RCTs and 1 propensity score–matching study). In these studies, fully covered, partially covered, or uncovered SEMSs were used for ERCP-guided transpapillary stenting, whereas fully covered or partially covered SEMSs were used for EUS-guided transmural stenting. Kaplan-Meier estimates of stent patency at 6 months showed pooled rates of 88.7% for EUS-HGS, 84.5% for EUS-CDS with SEMS, 73.1% for EUS-CDS with LAMS, and 64.8% for ERCP [Figure 5]. EUS-CDS with SEMS had significantly higher pooled stent patency compared with ERCP ($P = 0.004$), with significant interaction effects between time and group ($P < 0.001$) and time[2] and group ($P < 0.001$).

Small-study effects, network coherence, and certainty of evidence

No significant imprecision, inconsistency, or publication bias was identified for any of the comparisons in the network meta-analysis. Confidence intervals for all network estimates were narrow and precise, and there was no evidence of incoherence between direct and indirect comparisons. Funnel plot analyses also revealed no significant small-study effects (Supplementary Figure 4, http://links.lww.com/ENUS/A375). The certainty of evidence was assessed using GRADE framework. Supplementary Table 4, http://links.lww.com/ENUS/A375, showed detailed certainty of evidence for both direct and indirect comparisons of each modality.

The certainty of evidence was downgraded primarily for indirectness and risk of bias. For clinical success, technical success, and procedure time, high-quality evidence supported the use of EUS-CDS-LAMS over ERCP and EUS-CDS-SEMS. In contrast, the evidence supporting EUS-HGS compared with other interventions was rated as low to moderate quality, mainly due to variability in study designs, procedural techniques, and small sample sizes, introducing indirectness and imprecision. Reintervention rates favored EUS-HGS, indicating fewer secondary procedures; however, the evidence was rated as moderate to low quality due to indirectness

Table 1

Summary of baseline characteristics.

Study (year)	Design	No. of patients	Specific technique and stent	Age (y), mean ± SD	Sex, male, %	Etiology (*n*)	Duodenal invasion, *n* (%)	Follow-up
Paik et al.[7] (2018)	RCT, multicenter (*n* = 4), South Korea	EUS-BD: 64	HGS with tubular SEMS	62.0 (range 43–88)	68.8	Pancreatic cancer (18) Others (14)	9 (28.1)	Until death or at least 6 mo
			CDS with tubular SEMS	67.6 (range, 40–90)	59.4	Pancreatic cancer (20) Others (12)	9 (28.1)	Until death or at least 6 mo
		ERCP: 61	FCSEMS or UCSEMS	68.4 (range, 46–88)	42.6	Pancreatic cancer (40) Others (21)	15 (24.6)	Until death or at least 6 mo
Park et al.[8] (2018)	RCT, single center (*n* = 1), South Korea	EUS-BD: 14	CDS with tubular SEMS	66.8 ± 8.0	64.3	Pancreatic cancer (14)	NR	Until death or at least 6 mo
		ERCP: 14	FCSEMS	65.4 ± 9.3	57.1	Pancreatic cancer (12) Others (2)	NR	Until death or at least 6 mo
Bang et al.[9] (2018)	RCT, single center (*n* = 1), United States	EUS-BD: 33	CDS with tubular SEMS	69.4 ± 12.6	51.5	Pancreatic cancer (33)	NR	Until death or at least 6 mo
		ERCP: 34	FCSEMS	69.2 ± 11.6	67.6	Pancreatic cancer (31) Others (3)	NR	Until death or at least 6 mo
Teoh et al.[10] (2023)	RCT, multicenter (*n* = 10), multinational*	EUS-BD: 79	CDS with electrocautery-enhanced LAMS	75.1 ± 11.9	40.5	Pancreatic cancer (76) Others (3)	6 (7.6)†	Until death or up to 1 yr
		ERCP: 76	PCSEMS	72.1 ± 12.4	53.9	Pancreatic cancer (73) Others (3)	7 (9.2)†	Until death or up to 1 yr
Chen et al.[11] (2023)	RCT, multicenter (*n* = 11), Canada and France	EUS-BD: 73	CDS with electrocautery-enhanced LAMS	72.0 ± 10.9	67.4	Pancreatic cancer (63) Others (10)	15 (20.5)	Until death or up to 1 yr
		ERCP: 71	PCSEMS or UCSEMS	73.3 ± 10.4	64.4	Pancreatic cancer (67) Others (4)	22 (31.0)	Until death or up to 1 yr
Janet et al.[33] (2023)	Retrospective study, multicenter (*n* = 9), France	EUS-CDS: 28	CDS with electrocautery-enhanced LAMS	73 (IQR, 60.7–76)	71.4	Pancreatic cancer (18) Others (10)	NR	NA‡
		ERCP: 128	FCSEMS or plastic stent	69 (IQR, 61.7–76)	57.0	Pancreatic cancer (66) Others (62)	NR	NA‡
Ogura et al.[22] (2024)	Propensity score matching study, multicenter (*n* = 7), Japan	EUS-HGS: 24	HGS	70.5 (IQR, 62.75–80.5)	44.4	Pancreatic cancer (13) Others (11)	NR	NR
		ERCP: 24	FCSEMS	71.5 (IQR, 63.75–80.5)	54.2	Pancreatic cancer (14) Others (10)	NR	NR
Ghoneem et al.[23] (2024)	Prospective multicenter (*n* = 3) nonrandomized study, Egypt	EUS-CDS: 37	CDS with tubular SEMS	65 (range, 55–69)	73.0	Pancreatic cancer (34) Others (3)	NR	Until death or at least 3 mo
		ERCP: 36	PCSEMS or half-covered SEMS	62.5 (range, 58–67)	69.4	Pancreatic cancer (28) Others (8)	NR	Until death or at least 3 mo

*China, France, Belgium, Denmark, Italy, Thailand, and Australia.

†Cuodenal obstruction.

‡Preoperative stenting.

CDS, choledochoduodenostomy; EUS-BD, EUS-guided biliary drainage; FCSEMS, fully covered SEMS; HGS, hepaticogastrostomy; LAMS, lumen-apposing metal stent; NA, not applicable; NR, not reported; RCT, randomized controlled trial; SEMS, self-expanding metal stent; UCSEMS, uncovered SEMS.

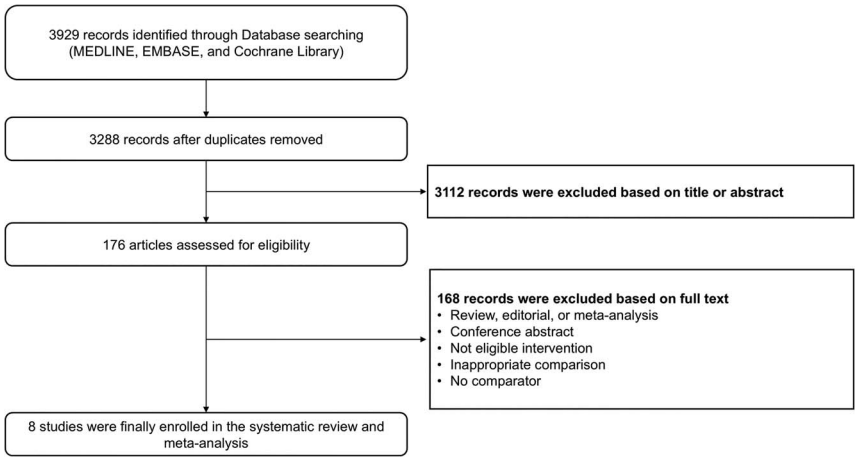

Figure 1. Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) flowchart for the inclusion of studies in the meta-analysis.

and imprecision, particularly for less frequently studied modalities (Supplementary Table 4, http://links.lww.com/ENUS/A375).

Discussion

In this systematic review and network meta-analysis, we found no statistically significant differences among the 4 modalities (i.e., ERCP, EUS-HGS, EUS-CDS with LAMS, and EUS-CDS with SEMS) in clinical success and adverse events. EUS-CDS with LAMS demonstrated superior technical success and shorter procedure time compared with ERCP and EUS-CDS with SEMS. EUS-HGS showed a lower reintervention rate compared with ERCP and EUS-CDS with LAMS while exhibiting favorable stent patency in Kaplan-Meier curve estimates. Recent meta-analyses have reported no significant difference in clinical success between EUS-BD and ERCP.[19–21] One meta-analysis, through subgroup analysis based on stent type, showed that the clinical success rate of EUS-CDS with SEMS was comparable to that of ERCP (relative risk [RR], 1.03 [0.94–1.12]) and similarly for EUS-CDS with LAMS compared with ERCP (RR, 1.02 [0.94–1.10]).[21] However, a recent network meta-analysis indicated a higher clinical success rate for EUS-CDS with LAMS compared with ERCP (RR, 1.12 [1.01–1.25]).[34] In our study, clinical success was similar across all modalities, although the *P* score was highest for EUS-CDS with LAMS (*P* score = 0.7097) and lowest for ERCP (0.2905).

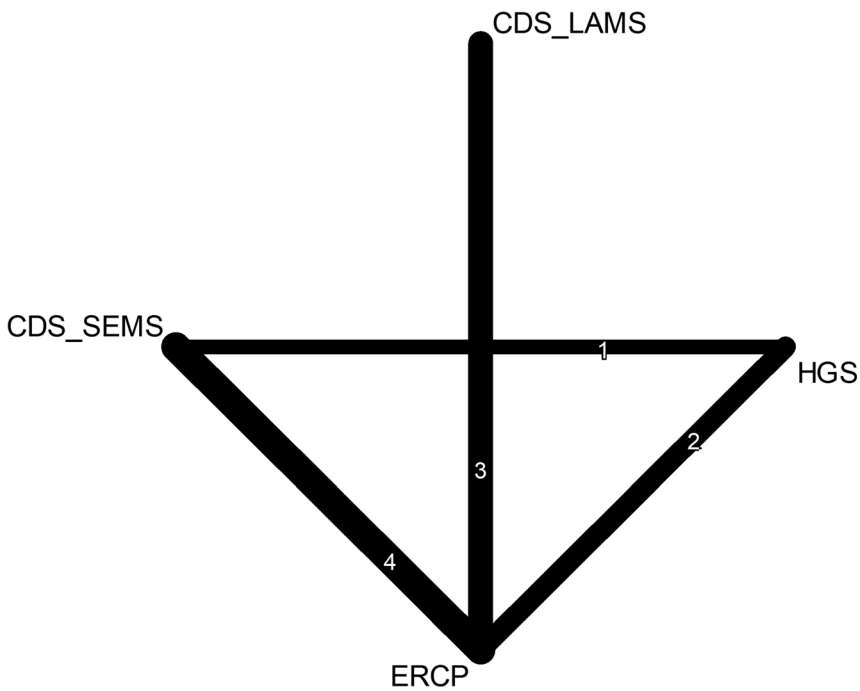

Figure 2. Network of included studies with the available direct comparisons between endoscopic interventions for primary biliary drainage in terms of clinical success.

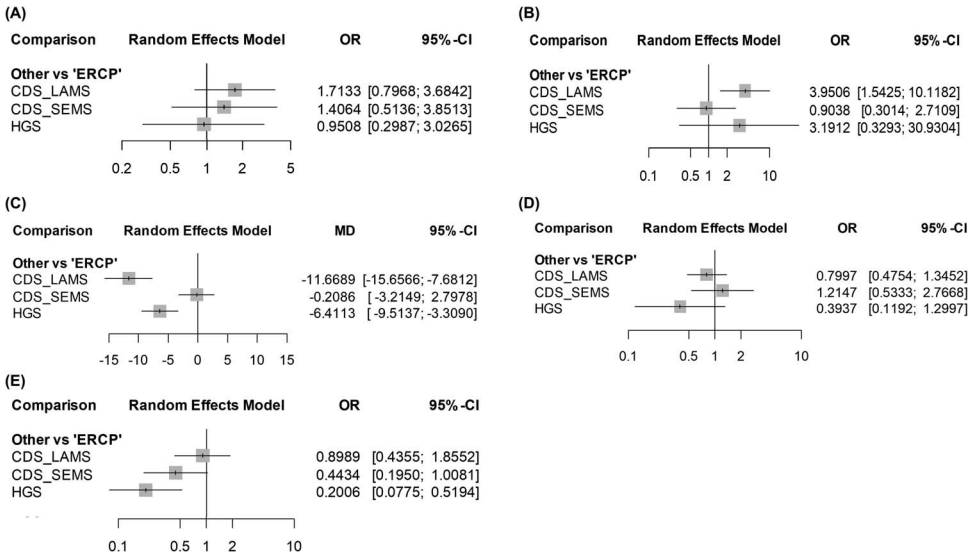

Figure 3. Forest plots reporting estimates derived from network meta-analysis assessing (A) clinical success, (B) technical success, (C) procedure time, (D) adverse events, and (E) reintervention. CDS_LAMS, EUS-guided choledochoduodenostomy with luminal-apposing metal stents; CDS_SEMS, EUS-guided choledochoduodenostomy with self-expanding metal stents; ERCP, endoscopic retrograde cholangiopancreatography.

The inconsistent results may be attributed to heterogeneity among studies and relatively small sample sizes, limiting the ability to detect subtle differences.

In terms of technical success, EUS-CDS with LAMS outperformed both ERCP and EUS-CDS with SEMS. Additionally, EUS-CDS with LAMS had the shortest procedure times among all modalities. Ranking analyses for technical success and procedure times placed EUS-CDS with LAMS at the top, followed by EUS-HGS. Notably, EUS-CDS with LAMS, especially those equipped with an electrocautery-enhanced system, facilitates the procedure by eliminating the need for fistula tract dilation, resulting in shorter procedure times and better technical success compared with ERCP. This reduced procedure time in EUS-CDS may have clinical implications, such as improved radiation safety and the facilitation of same-session tissue diagnosis via EUS-guided core biopsy, without requiring a change of duodenoscope to achieve biliary decompression.

However, caution is warranted when interpreting these results. Recruitment in prior ERCP studies typically occurs after cannulation is achieved, which would result in a technical success rate of approximately 100% in transpapillary stenting. However, in 2 recent RCTs comparing EUS-CDS with LAMS to ERCP, a substantial portion (9%–31%) of patients in the ERCP group had duodenal invasion [Table 1], leading to lower technical success (76.3%–83.1%) due to factors such as edema, friability, and duodenal

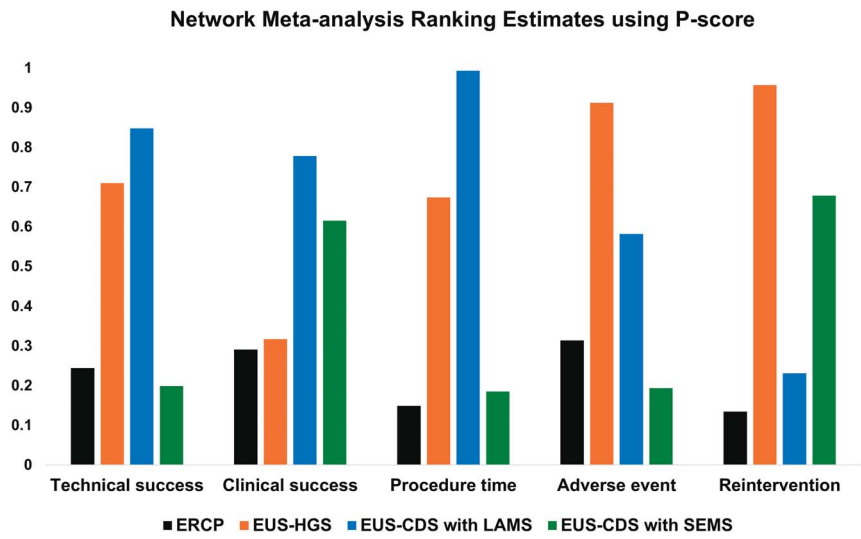

Figure 4. Network meta-analysis ranking estimates using the *P* score.

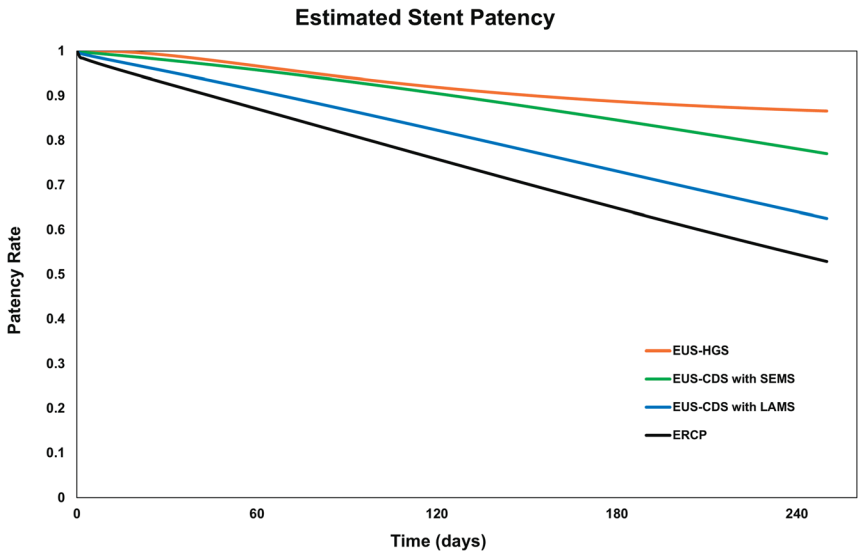

Figure 5. Pooled estimated stent patency rate according to endoscopic interventions by Kaplan-Meier estimates.

narrowing. In detail, technical failures (18 cases of 76) in the ERCP arm were due to failed cannulation (n = 10), inability to access the ampulla of Vater because of duodenal obstruction (n = 7), and 1 case of endoscope-related perforation (n = 1) in the DRA-MBO trial.[10] Similarly, in the ELEMENT trial,[11] technical failures (12 cases of 71) in the ERCP group were attributed to failed deep cannulation (n = 8), inability to reach the papilla due to duodenal tumor involvement (n = 2), and intolerance to conscious sedation (n = 2).

Regarding long-term outcomes, EUS-HGS demonstrated significantly lower reintervention rates compared with ERCP and EUS-CDS with LAMS. Kaplan-Meier analysis revealed favorable stent patency for EUS-HGS compared with other EUS-BD techniques and ERCP, but only the comparison between EUS-CDS with SEMS and ERCP showed a significant difference.

EUS-HGS has theoretical advantages in that the stent is placed away from the tumor in patients with DMBO, thereby minimizing the risk of tumor ingrowth or overgrowth. However, in EUS-CDS with LAMS, this benefit seemed to be compromised by frequent LAMS dysfunction associated with food impaction and ascending cholangitis, particularly in patients with duodenal invasion.[35] This is largely attributed to the anatomical position of the LAMS in the duodenal bulb, along with its short saddle length, especially when oriented toward the pylorus, which facilitates the influx of food into the stent and biliary system, leading to food impaction.[36] Additionally, unlike ERCP with endobiliary retrograde BD, which typically drains the entire biliary system, EUS-CDS may not effectively drain the distal part of the common bile duct, resulting in bile stasis, sludge and food accumulation, and bacterial overgrowth, further contributing to sump syndrome. In this context, EUS-CDS with a dedicated tubular metal stent may provide more favorable long-term stent patency by reducing the risk of food reflux due to the longer length of the stent, although direct comparative data between tubular SEMS and LAMS are limited.[7] A retrospective study suggested that tubular SEMS with stent direction toward the anal side may have lower rates of stent dysfunction compared with those directed orally, likely due to reduced food reflux.[37] Additionally, a recent proof-of-concept study reported a low rate of stent dysfunction (10%) after placing a coaxial SEMS through the LAMS in EUS-CDS during 6-month follow-up periods.[38] Meanwhile, the use of coaxial double pigtail plastic stents across LAMS has been proposed as a strategy to prevent stent occlusion due to food impaction. This approach is widely used as a salvage strategy for LAMS dysfunction, although its routine use during the index procedure remains debated, pending results from an ongoing RCT.[39,40] Further RCTs comparing EUS-HGS and EUS-CDS with LAMS, along with additional coaxial plastic stents or dedicated tubular SEMS for the primary management of DMBO, are warranted.

This study had several limitations that should be acknowledged. First, the included studies exhibited variability in procedural protocols, stent types, and patient populations, although all random-effects models showed low heterogeneity based on the I^2 statistic. Differences in operator experience and institutional expertise across studies could have also contributed to outcome variability. Future studies with standardized protocols and outcome definitions are warranted. The P scores provided robust comparative insights despite this heterogeneity. Additionally, the Cochrane risk-of-bias tool was applied to ensure methodological rigor in evaluating study quality.

Second, the small sample sizes for patients undergoing EUS-CDS with SEMS and EUS-HGS (116 and 56 patients, respectively) limited statistical power for subgroup analyses, particularly for secondary outcomes. Wider CIs observed in certain comparisons highlight the need for caution when interpreting results, as small sample sizes may reduce generalizability. Within the robust GRADE framework, the evidence supporting lower reintervention of EUS-HGS was rated as low level of evidence, primarily due to small sample sizes, variability in study designs, and indirectness.

These challenges highlight the importance of conducting further high-quality, well-designed studies to comprehensively evaluate the clinical outcomes and safety of EUS-HGS. Finally, although this study provides a comprehensive comparison of different primary endoscopic drainage modalities for DMBO, its applicability may be limited by regional variations in endoscopic practice patterns. Specifically, EUS-HGS and EUS-CDS using dedicated SEMSs are more commonly performed and studied in Asia,[41–49] whereas in Western centers, EUS-CDS with LAMSs has gained broader acceptance. Furthermore, in the current LAMS era, EUS-CDS with conventional SEMS is rarely used as a first-line approach except in salvage settings for maldeployed LAMS, raising questions about its long-term adoption. Given these differences, additional studies are needed to assess the real-world adoption of EUS-HGS and EUS-CDS–dedicated SEMS in Western practice and determine their feasibility outside of high-volume expert centers. Future research should evaluate how institutional expertise and regional practice patterns influence the clinical outcomes and technical feasibility of these procedures.

Despite these limitations, our study underscores the distinctive strengths of the 4 modalities in the primary drainage of DMBO. Although all modalities demonstrated similar clinical success rates and adverse event rates, EUS-CDS with LAMS outperformed both ERCP and EUS-CDS with SEMS in terms of technical success and exhibited the shortest procedure time, suggesting reduced procedural burden. In terms of long-term outcomes, EUS-HGS showed lower reintervention rates and favorable stent patency compared with EUS-CDS with LAMS and ERCP.

In conclusion, EUS-BD has the potential to redefine the primary endoscopic management of DMBO, offering tailored approaches based on patient-specific needs and clinical priorities.

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Ethical approval

The study protocol was approved by the Institutional Review Board of the Asan Medical Center (IRB no. 2025-0047).

Informed Consent

Not applicable.

Conflict of Interest

John J. Vargo is consultant for Steris Medical and Olympus, Inc., and received a research grant from Olympus, Inc. The other authors declare that they have no financial conflict of interest with regard to the content of this report.

Author Contributions

Gunn Huh and Ce Hwan Park did the conceptualization and design. Gunn Huh, Won-Mook Choi, Jung Bok Lee, and Ce Hwan Park did the analysis and interpretation of the data. Gunn Huh and Ce Hwan Park drafted the article. Gunn Huh, Won-Mook Choi, Jung Bok Lee, John J. Vargo, Sunguk Jang, Taehyung Lee, Ce Hwan Park, and Steven A. Edmundowicz did the critical revision of the article for important intellectual content and final approval of the article.

Data Availability Statement

Data described in the manuscript, code book, and analytic code will be made available upon reasonable request.

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