

Stent misdeployment and factors associated with failure in endoscopic ultrasound-guided choledochoduodenostomy: analysis of the combined datasets from two randomized trials

Authors

Yen-I Chen¹ , Clara Long¹, Anand V. Sahai², Bertrand Napoleon³ , Gianfranco Donatelli⁴ , Rastislav Kunda^{5,6,7,8}, Myriam Martel¹, Shannon M. Chan⁹ , Paolo G. Arcidiacono¹⁰ , Eric Lam¹¹, Pradermchai Kongkam¹² , Nauzer Forbes¹³ , Alberto Larghi¹⁴, Jeffrey D. Mosko¹⁵, Schalk Van der Merwe¹⁶, Seng Ian Gan¹⁷, Jeremie Jacques¹⁸, Sana Kenshil¹⁹, Thawee Ratanachu-Ek²⁰, Corey Miller²¹, Payal Saxena²², Etienne Desilets²³, Gural Sandha²⁴ , Yousef Alrifae¹, Anthony Y. B. Teoh⁹ , on behalf of the ELEMENT and DRA-MBO working groups

The ELEMENT and DRA-MBO working groups

Sharif Yassin¹, Kevin K. C. NG⁹, Enders K. W. NG⁹, Abdulrahman Qatomah¹, Yidan Lu¹, Alan Barkun¹, Alastair Doreen²⁵, Philip W. Y. Chiu⁹, Davide Maggio²⁶

Institutions

- 1 Division of Gastroenterology and Hepatology, McGill University Health Centre, Montreal, Quebec, Canada
- 2 Service de Gastroentérologie, Centre Hospitalier de l'Université de Montréal, Montréal, Quebec, Canada
- 3 Hôpital Privé Jean Mermoz, Ramsay Santé, Lyon, France
- 4 Unité d'Endoscopie Interventionnelle, Hôpital Privé des Peupliers, Paris, France
- 5 Department of Surgery, Universitair Ziekenhuis Brussel, Vrije Universiteit Brussel, Brussels, Belgium
- 6 Department of Gastroenterology-Hepatology, Universitair Ziekenhuis Brussel, Vrije Universiteit Brussel, Brussels, Belgium
- 7 Department of Advanced Interventional Endoscopy, Universitair Ziekenhuis Brussel, Vrije Universiteit Brussel, Brussels, Belgium
- 8 Department of Surgical Gastroenterology, Aarhus University Hospital, Aarhus, Denmark
- 9 Department of Surgery, Prince of Wales Hospital, The Chinese University of Hong Kong, Hong Kong SAR, China
- 10 Pancreato-Biliary Endoscopy and Endosonography Division, Pancreas Translational and Clinical Research Center, San Raffaele Scientific Institute IRCCS, Vita Salute San Raffaele University, Milan, Italy
- 11 Division of Gastroenterology and Hepatology, St-Paul Hospital, Vancouver, British Columbia, Canada
- 12 Division of Hospital and Ambulatory Medicine and Division of Gastroenterology, Department of Medicine, Faculty of Medicine, Chulalongkorn University and King Chulalongkorn Memorial Hospital, Thai Red Cross Society, Bangkok, Thailand
- 13 Division of Gastroenterology and Hepatology, University of Calgary, Calgary, Alberta, Canada
- 14 Digestive Endoscopy Unit, Fondazione Policlinico Universitario A. Gemelli, IRCCS, Rome, Italy
- 15 Division of Gastroenterology, St-Michael's Hospital, University of Toronto, Toronto, Ontario, Canada

- 16 Department of Gastroenterology and Hepatology, The University of Leuven, Leuven, Belgium
- 17 Division of Gastroenterology and Hepatology, Vancouver General Hospital, Vancouver, British Columbia, Canada
- 18 Gastroenterology Department, Dupuytren University Hospital, Limoges, France
- 19 Division of Gastroenterology and Hepatology, Ottawa Hospital, Ottawa, Ontario, Canada
- 20 Department of Surgery, Rajavithi Hospital, Bangkok, Thailand
- 21 Division of Gastroenterology and Hepatology, Jewish General Hospital, Montreal, Quebec, Canada
- 22 Department of Gastroenterology, Royal Prince Alfred Hospital, Sydney, Australia
- 23 Division of Gastroenterology, Hôpital Charles-Le Moyne, Longueuil, Quebec, Canada
- 24 Division of Gastroenterology and Hepatology, University of Alberta Hospital, Edmonton, Alberta, Canada
- 25 Division of Gastroenterology, Notre-Dame Hospital, Montreal, Quebec, Canada
- 26 Division of Gastroenterology, Santa Cabrini Hospital, Montreal, Quebec, Canada

submitted 22.2.2024

accepted after revision 6.11.2024

accepted manuscript online 6.11.2024

published online 2024

Bibliography

Endoscopy

DOI 10.1055/a-2463-1601

ISSN 0013-726X

© 2024, Thieme. All rights reserved.

Georg Thieme Verlag KG, Oswald-Hesse-Straße 50, 70469 Stuttgart, Germany

 **Supplementary Material**
Supplementary Material is available at
<https://doi.org/10.1055/a-2463-1601>

Corresponding author

Anthony Y. B. Teoh, MD, Department of General Surgery, HK Sanatorium Hospital, The Chinese University of Hong Kong, 2 Village Road, Happy Valley, Hong Kong, China
Anthony.YB.Teoh@hksh.com

ABSTRACT

Background Stent misdeployment (SMD) is a feared and poorly characterized technical challenge of endoscopic ultrasound (EUS)-guided choledochoduodenostomy (CDS) using lumen-apposing stents. We aimed to ascertain the rate of stent misdeployment in EUS-CDS for malignant distal biliary obstruction (MDBO) and describe its outcomes while identifying variables associated with its occurrence.

Method This was a post hoc analysis of two randomized controlled trials comparing EUS-CDS vs. endoscopic retrograde cholangiopancreatography in MDBO. The primary

end point was rate of SMD, classified as misdeployment of the distal flange (type I), proximal flange (type II), contralateral bile duct wall injury (type III), or double mucosal puncture (type IV). Multivariable analysis was performed to identify variables associated with SMD and/or technical failure, and with clinical failure or stent dysfunction.

Results 152 patients were included. Technical success was 93.4%. SMD occurred in 11 patients (7.2%; 95%CI 3.1%–11.4%): 8 type I, 1 type II, and 2 type III. Endoscopic salvage of SMD was successful in 81.8%. Misdeployment led to adverse events in four patients (two mild, two moderate), giving an overall SMD-related adverse event rate of 2.6% (95% CI 0.7%–6.6%). On multivariable analysis, extrahepatic bile duct diameter of ≤ 15 mm was associated with increased odds of SMD and/or technical failure.

Conclusion SMD was relatively common in EUS-CDS and was associated with an extrahepatic bile duct diameter of ≤ 15 mm. The majority of misdeployments could be rescued endoscopically with low risk for adverse events.

Introduction

Endoscopic ultrasound-guided choledochoduodenostomy (EUS-CDS) using a lumen-apposing metal stent (LAMS) is emerging as a first-line alternative to endoscopic retrograde cholangiopancreatography (ERCP) in malignant distal biliary obstruction (MDBO), and is arguably the preferred modality [1] in cases of ERCP failure in this patient population. Indeed, two recent multicenter randomized controlled trials (RCTs) have shown that EUS-CDS with LAMS is associated with comparable clinical outcomes to ERCP, while being more efficient [2, 3]. The advent of LAMS has greatly facilitated the technical application of EUS-CDS [4], which in association with newly available high-quality data, is driving EUS-guided biliary drainage toward widespread clinical adoption.

A unique and potentially serious concern with EUS-CDS using LAMS is the risk of stent misdeployment (SMD) [2]. SMD refers to failure in deploying the distal or proximal flange of the LAMS in the bile duct and duodenum, respectively. Given the transluminal nature of EUS-CDS, SMD effectively leads to either a bile duct injury or a small duodenal perforation. The classification and outcomes of SMD have not yet been described using prospective patient-level data. In addition, factors associated with SMD, technical failure, or clinical failure of EUS-CDS using LAMS are also poorly understood.

Our aim was thus to describe the rate and clinical outcomes of SMD in EUS-CDS using LAMS in patients with MDBO, using a recently proposed classification of SMD [2]. We also identified independent clinical variables associated with SMD and/or technical failure. Secondarily, we aimed to ascertain clinical variables associated with stent dysfunction or clinical failure.

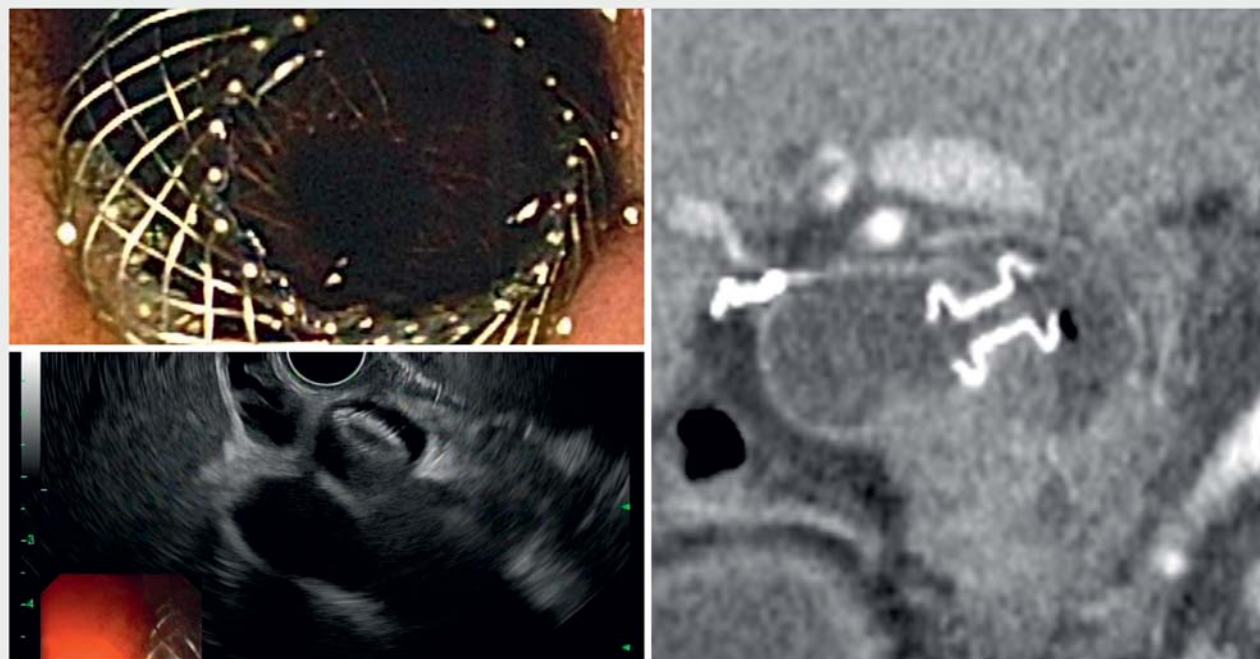
We hypothesized that SMD is relatively common but has no severe adverse consequences.

Methods

We conducted a post hoc analysis of two RCTs comparing EUS-CDS and ERCP in MDBO. The ELEMENT trial was a multicenter RCT coordinated from Montreal, Canada, in which 144 patients were randomized from February 2019 to February 2022 [2]. The DRA-MBO trial was a multicenter RCT coordinated from Hong Kong, China, which randomized 155 patients from January 2017 to February 2021 [3]. Overall, tertiary care centers across four continents were involved in these two studies. Following ethics approval at the coordinating centers, the prospectively acquired data from each trial were used to populate a data collection sheet designed specifically for this post hoc analysis. Only patients who were allocated to EUS-CDS were included in the present study. Patients allocated to ERCP were excluded even if they crossed over to EUS-CDS.

Intervention and participating endoscopists

EUS-CDS was performed using a cautery-assisted 6×8 mm or 8×8 mm LAMS (EC-Axios; Boston Scientific, Marlborough, Massachusetts, USA) (► Fig. 1). The choice of LAMS size was left to the discretion of each individual endoscopist. The LAMS insertion technique was also at the discretion of the operator, and could be done “freehand” or “wire-guided.” The freehand technique entailed direct insertion of the LAMS cautery tip under EUS guidance into the bile duct without initial needle puncture and guidewire insertion. The wire-guided technique involved first a transduodenal puncture of the bile duct using a 19-



► **Fig. 1** Images of endoscopic ultrasound-guided choledochoduodenostomy using a 6×6 mm lumen-apposing metal stent. **a** Endoscopy. **b** Endoscopic ultrasound. **c** Computed tomography.

gauge needle, followed by a contrast cholangiogram and the insertion of a guidewire. In this latter technique, the LAMS was then inserted with cautery assistance over the wire under fluoroscopic and EUS guidance.

Prior to entry into the trials, participating endoscopists had performed a median of 2 EUS-CDS procedures in the ELEMENT study, while in the DRA-MBO trial a minimum of 20 EUS-CDS procedures using LAMS was set as a prerequisite for participation by endoscopists.

Outcomes

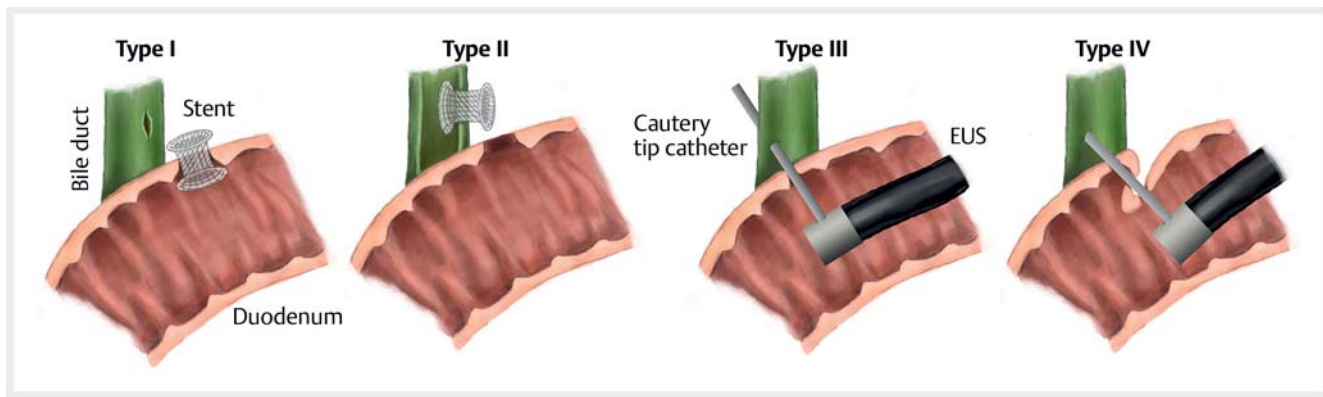
SMD was defined as a failure to achieve an EUS-CDS anastomosis with LAMS on the first attempt during the index procedure. SMDs were classified according to the following classification [2]: type I if the distal flange was deployed in the space between the bile duct and duodenal lumen; type II if the proximal flange of the LAMS was deployed outside of the duodenal lumen; type III if there was inadvertent cautery injury to the contralateral bile duct wall during LAMS catheter advancement; type IV if there was a double mucosal puncture at the level of the duodenal or gastroduodenal wall (► **Fig. 2**).

We also assessed the rates of SMD-related adverse events, technical success, clinical success, and stent dysfunction, and the procedure time from scope insertion to scope withdrawal. SMD-related adverse events were classified according to the American Society for Gastrointestinal Endoscopy lexicon for endoscopic adverse events [5]. Technical success was defined as successfully establishing a choledochoduodenostomy during the index procedure. An SMD that was successfully salvaged with a choledochoduodenostomy (using a second LAMS or tub-

ular stent) was considered to have achieved technical success. Clinical success was defined as a 50% decrease in bilirubin within 2 weeks post-stent insertion or achieving a value of less than 25% of pre-procedure bilirubin levels within 4 weeks post-stent insertion [6–8]. Stent dysfunction was defined by the following criteria: need for endoscopic or radiologic reintervention confirming stent blockage or migration, and at least one of the following: 1) suspected cholangitis (Tokyo consensus definition) [9]; 2) definite cholangitis (Tokyo definition) [9]; 3) ≥50% increase in bilirubin from the lowest level post-index procedure; 4) ≥20% increase in bilirubin from the lowest level post-index procedure as well as evidence of obstruction on imaging [5]. Patients with a bilirubin level that never decreased post-index stenting were classified as clinical failure. Stent dysfunction was assessed until death, surgical resection, or a total of 1-year follow-up.

Statistical analysis

Descriptive statistics are presented using mean (SD) or median (interquartile range) for continuous variables, and proportions (%) for categorical variables. Statistical analyses were performed on variables deemed to be clinically pertinent by the authors for SMD and/or technical failure, including age, sex, American Society of Anesthesiologists (ASA) classification, tumor stage, pre-drainage bilirubin, extrahepatic bile duct diameter on EUS, stent insertion technique, stent size, and endoscopist's experience. Bile duct diameter was determined via EUS immediately prior to LAMS insertion and represents the diameter of the extrahepatic bile duct at the site of intended bile duct puncture.



► **Fig. 2** Classification of stent misdeployment in endoscopic ultrasound-guided choledochoduodenostomy using a lumen-apposing metal stent. Type I: distal flange deployed between the bile duct and duodenal lumen with bile duct injury. Type II: proximal flange deployed outside of the duodenal lumen. Type III: cautery injury to the contralateral bile duct wall. Type IV: double mucosal puncture at the level of the duodenal or gastroduodenal walls.

Endoscopists' experience was dichotomized into two groups: >20 (13 endoscopists) vs. ≤5 (12 endoscopists) EUS-CDS procedures performed prior to participation in the respective trials. Analyses were also performed on variables considered by the authors to be relevant to clinical failure or stent dysfunction, including age, sex, ASA classification, tumor stage, pre-drainage bilirubin, bile duct diameter, stent size, SMD, and the use of coaxial double-pigtail stents. Variables with a *P* value of <0.10 were considered for inclusion in the multivariable analysis. However, recognizing the distinction between prediction and explanatory modeling, we based the final selection of variables on clinical relevance and statistical significance. This approach aligns with the use of an explanatory model, which aims to identify independent factors by controlling for potential confounders [10]. In this context, the inclusion of specific variables reflects both their clinical importance, statistical significance, and their relationship with other factors in the model.

For the multivariable analysis, we used a stepwise logistic regression model to assess the associations between the pre-identified variables and the odds of SMD and/or technical failure, as well as clinical failure or stent dysfunction. Results are presented and interpreted as odds ratios (ORs) with 95% CIs. All analyses were performed using SAS version 9.4 (SAS Institute Inc., Cary, North Carolina, USA).

Results

Patient population

A total of 152 patients who underwent attempted EUS-CDS were included in this post hoc analysis. The mean age of the patients was 74.3 (SD 11.2) years, and 48% of patients were female (► **Table 1**). Pancreatic cancer was the most common etiology (91.5%) of MDBO. Tumor stages were 79.6% unresectable and 20.4% borderline resectable or locally advanced. The mean baseline bilirubin level was 235.3 (SD 130.3) μmol/L. The mean bile duct diameter on EUS was 16.6 (SD 3.7) mm.

► **Table 1** Baseline characteristics of patients undergoing endoscopic ultrasound-guided choledochoduodenostomy.

Patient characteristic	EUS-CDS (n = 152)
Age, mean (SD), years	74.3 (11.2)
Female sex, n (%)	73 (48.0)
ASA class, n (%)	
▪ I–II	▪ 98 (64.5)
▪ III–IV	54 (35.5)
Etiology of MDBO, n (%)	
▪ Pancreatic cancer	▪ 139 (91.5)
▪ Cholangiocarcinoma/gallbladder cancer	▪ 7 (4.6)
▪ Ampullary cancer	▪ 2 (1.3)
▪ Other	4 (2.6)
Tumor stage, n (%)	
▪ Borderline/locally advanced	▪ 31 (20.4)
▪ Unresectable	▪ 121 (79.6)
▪ Baseline bilirubin level, mean (SD), μmol/L	235.3 (130.3)

ASA, American Society of Anesthesiologists; EUS-CDS, endoscopic ultrasound-guided choledochoduodenostomy; MDBO, malignant distal biliary obstruction.

EUS-CDS performance and outcomes

Technical success was achieved in 93.4% of procedures, with a mean procedure time of 16.2 (SD 15.3) minutes. The freehand technique was used in 78.0% of procedures with the remaining 22.0% performed using the wire-guided method. The sizes of LAMS used were 79.3% 6×8 mm, 20.0% 8×8 mm, and 0.7% 15×10 mm (protocol deviation) (► **Table 2**). A coaxial double-pigtail plastic stent was used in 9.2% of the procedures. SMDs occurred in 11 patients (7.2% [95%CI 3.1%–11.4%]), including 8 with type I, 1 with type II, and 2 with type III; there were no

► **Table 2** Endoscopic ultrasound-guided choledochoduodenostomy procedure details.

Procedure details	EUS-CDS (n = 152)
Technical success, n/N (%)	142/152 (93.4)
Clinical success, n/N (%) ¹	128/152 (84.2)
Diameter of bile duct on EUS, mean (SD), mm	16.6 (3.7)
Procedure time, mean (SD), minutes	16.2 (15.3)
Stent size, n/N (%)	
▪ 6 × 8	▪ 115/145 (79.3) ²
▪ 8 × 8	▪ 29/145 (20.0)
▪ 15 × 10	1/145 (0.7)
Coaxial double-pigtail plastic stent, n/N (%)	13/142 (9.2) ³
Freehand technique, n/N (%)	117/150 (78.0)
Procedures by experienced endoscopists, n/N (%) ⁴	89/152 (58.6)

EUS-CDS, endoscopic ultrasound-guided choledochoduodenostomy.

¹ Intention to treat.

² Denominator = cases where a lumen-apposing metal stent was deployed or misdeployed.

³ Denominator = technically successful cases.

⁴ Endoscopists who had performed ≥ 20 EUS-CDS prior to study start.

type IV SMDs (► **Table 3**, ► **Table 4**). By intention-to-treat, clinical success of EUS-CDS was achieved in 84.2% of patients, with stent dysfunction occurring in 7.2%.

Of the 11 patients with SMD, only 4 misdeployments led to a complication, giving an overall SMD-specific adverse event rate of 2.6% (95%CI 0.7%–6.6%). SMD-associated adverse events were rated as mild in two patients and moderate in two patients, with no severe or fatal adverse events noted. The majority (9/11; 81.8% [95%CI 54.6%–100%]) of SMDs were salvaged endoscopically or managed conservatively.

Type I SMDs (deployment of the distal flange between the bile duct and duodenum) was the most common type of misdeployment, occurring in eight patients (72.7% of SMDs) (► **Table 3**). Endoscopic salvage was successfully performed in 87.5% (7/8), which included three cases rescued with application of a second LAMS to create the choledochoduodenostomy, one case rescued with over-the-wire placement of a bridging tubular stent coaxially through the misdeployed LAMS (► **Video 1**; see also **Fig. 1 s A** in the online-only Supplementary material), and three cases of ERCP with insertion of a covered metal stent and duodenal defect closure with through-the-scope clips. Endoscopic salvage failed in one patient. The misdeployed stent was removed without duodenal defect closure and biliary drainage was achieved with PTBD, which led to the only adverse event observed in type I SMD. The event was rated as moderate in severity owing to patient hospitalization beyond 3 days.

Type II SMDs (extraduodenal deployment of the proximal flange) occurred in one patient. Endoscopic salvage was successful with over-the-wire insertion of a tubular self-expanding metal stent placed coaxially through the misdeployed LAMS

► **Table 3** Outcomes of stent misdeployment during endoscopic ultrasound-guided choledochoduodenostomy.

Outcomes	SMD (n = 11)
Overall rate of SMD, n/N (%) [95%CI]	11/152 (7.2) [95%CI 3.1–11.4]
▪ Type I	▪ 8/11 (72.7)
▪ Type II	▪ 1/11 (9.1)
▪ Type III	▪ 2/11 (18.2)
▪ Type IV	0
Endoscopic salvage of SMD, n/N (%)	
▪ Successful endoscopic salvage	▪ 9/11 (81.8)
▪ Type I	▪ 7/8 (87.5) ¹
▪ Type II	▪ 1/1 (100) ²
▪ Type III	1/2 (50) ³
SMD-related adverse events, n/N (%) [95%CI]	4/152 (2.6) [95%CI 0.7–6.6]
▪ Mild	▪ 2/11 (18.2)
▪ Moderate	▪ 2/11 (18.2)
▪ Severe	▪ 0
▪ Fatal	0

SMD, stent misdeployment.

¹ Second lumen-apposing metal stent (LAMS) (n = 3 patients); bridging tubular stent (n = 1); endoscopic retrograde cholangiopancreatography with metal stent (n = 3); percutaneous transhepatic biliary drainage (PTBD) (n = 1).

² Bridging coaxial tubular metal stent (n = 1).

³ Successful LAMS deployment with conservative management of contralateral bile duct wall injury (n = 1); LAMS removal and duodenal defect closure with over-the-scope clip, PTBD (n = 1).

(► **Video 2**, **Fig. 1 s B**). This led to a mild adverse event owing to the need to hospitalize the patient for observation for less than 3 days.

Type III SMDs (contralateral bile duct wall injury) occurred in two patients. One patient had cautery injury of the contralateral bile duct wall with successful LAMS deployment on both the biliary and duodenal side. The patient was admitted for observation and was started on broad-spectrum antibiotics. Computed tomography scan showed a small amount of free air without evidence of a bile leak. The patient recovered uneventfully and was discharged on day 3 post-index procedure without further sequelae from this adverse event. The other patient with type III SMD had cautery injury to the contralateral wall and misdeployment of the distal flange through the contralateral wall. This stent was removed and the duodenal defect was closed with an over-the-scope clip. Attempt at ERCP insertion of a transpapillary metal stent was not successful. No portal vein injury was noted. PTBD was therefore performed with an additional need for percutaneous drainage for a bile leak, which was rated as a moderate adverse event.

► **Table 4** Summary of stent misdeployments.

SMD type	Operator experience	Freehand vs. wire-guided	Bile duct diameter	Stent size	Endoscopic salvage
I	> 20 cases	Wire-guided	15 mm	8 × 8 mm	Misdeployed LAMS removed, salvaged with second LAMS inserted over a wire
I	> 20 cases	Wire-guided	12 mm	6 × 8 mm	Failed endoscopic salvage, LAMS removed, no duodenal closure, PTBD
I	> 20 cases	Wire-guided	15 mm	8 × 8 mm	Misdeployed LAMS removed, salvaged with second LAMS inserted freehand
I	> 20 cases	Wire-guided	13 mm	8 × 8 mm	Misdeployed LAMS removed, salvaged with second LAMS inserted freehand
I	< 5 cases	Freehand	20 mm	6 × 8 mm	ERCP with fully covered metal stent, closure of duodenal defect with through-the-scope clips
I	≤ 5 cases	Freehand	14 mm	15 × 10 mm ¹	Bridging tubular 10 × 60 mm partially covered metal stent
I	≤ 5 cases	Freehand	15 mm	6 × 8 mm	ERCP fully covered metal stent, closure of duodenal defect with through-the-scope clips
I	> 20 cases	Freehand	13 mm	6 × 8 mm	ERCP with fully covered metal stent, closure of duodenal defect with through-the-scope clips
II	≤ 5 cases	Freehand	17 mm	6 × 8 mm	Bridging tubular 10 × 60 mm partially covered metal stent
III	≤ 5 cases	Freehand	14 mm	6 × 8 mm	Conservative management
III	> 20 cases	Freehand	18 mm	8 × 8 mm	Failed endoscopic salvage, LAMS removed, over-the-scope clip closure of duodenal defect, PTBD

ERCP, endoscopic retrograde cholangiopancreatography; LAMS, lumen-apposing metal stent; PTBD, percutaneous transhepatic biliary drainage; SMD, stent misdeployment.

¹ Protocol deviation in terms of stent size used.



► **Video 1** Demonstration of type I stent misdeployment rescued with tubular stent.

Online content viewable at:

<https://doi.org/10.1055/a-2463-1601>



► **Video 2** Demonstration of type II stent misdeployment rescued with tubular stent.

Online content viewable at:

<https://doi.org/10.1055/a-2463-1601>

Univariable and multivariable analyses

► **Table 5** and **Table 1 s** detail the univariable analysis. On multivariable analysis, an extrahepatic bile duct diameter of ≤ 15 mm was independently associated with an increased odds for SMD and/or technical failure (OR 6.25, 95%CI 1.11–33.3) (► **Table 5**). Endoscopist's experience (≥ 20 EUS-CDS vs. ≤ 5 EUS-CDS) was not significantly associated with SMD and/or technical failure. Moreover, no independent variables were found to be significantly associated with clinical failure or stent dysfunction, including the addition of a coaxial double-pigtail stent (**Table 1 s**).

Discussion

The advent of cautery-assisted biliary LAMS has greatly facilitated the technical application of EUS-CDS. One of the major barriers to the adoption of EUS-CDS has been its technical difficulty and lack of dedicated devices [11, 12]. The use of LAMS allows for one-step transluminal bile duct access and stent deployment without the requirement for needle access, wire insertion, and tract dilation, as is the case for tubular stents. The improvements in technical accessibility, together with evidence from recent RCTs showing excellent results of EUS-CDS with LAMS compared with ERCP [2, 3], will likely lead to greater clinical adoption of EUS-CDS. However, one major aspect that is unique to EUS-CDS is the risk of SMD.

In this post hoc analysis of the ELEMENT [2] and DRA-MBO [3] RCTs, we aimed to describe SMDs and their resulting outcomes, while identifying factors associated with SMD/technical failure and clinical success or stent dysfunction. Our post hoc analysis of primary data from these RCTs demonstrated an overall SMD rate of 7.2% (95%CI 3.1%–11.4%). The overall adverse event rate from SMD was 2.6% (95%CI 0.7%–6.6%), with severities rated as mild in two patients and moderate in two patients. On multivariable analysis, a bile duct size of ≤ 15 mm was independently associated with SMD and/or technical failure (OR 6.25, 95%CI 1.11–33.3).

The different types of SMD pose variable challenges for the endoscopist and are likely associated with diverging clinical consequences. Type I SMD, which was the most common in our study, appears to be salvageable in most cases. Indeed, 7/8 (87.5%) type I SMDs were salvaged endoscopically without any adverse events noted. The misdeployed stents were either removed and replaced with another LAMS, bridged with a tubular stent, or removed and salvaged with ERCP. Type II SMD appears to be less common but likely more difficult to rescue endoscopically. In type II SMD, the operator may lose access to the misdeployed LAMS, given that the proximal flange is released outside of the duodenum. The key to salvage is the placement of a wire through the misdeployed LAMS allowing for insertion of a bridging tubular stent. Although not observed in our study, failure to insert a wire through the LAMS in a type II SMD would likely require PTBD and LAMS removal through a percutaneous sheath. Surgical salvage, although unlikely, could also be needed in cases of failure to obtain adequate biliary drainage and/or failure to remove the misdeployed stent. Finally, type III SMD also appears to be rare, occurring in two

► **Table 5** Predictors of stent misdeployment or technical failure.

Variable	OR (95%CI)	
	Univariable	Multivariable
Age (continuous)	0.99 (0.95–1.04)	1.03 (1.00–1.22)
Female	0.51 (0.16–1.56)	
ASA, I–II (vs. III–IV)	1.58 (0.48–5.23)	
Etiology, pancreatic cancer (vs. other)	0.62 (0.13–3.10)	
Unresectable (vs. other)	0.47 (0.15–1.49)	0.17 (0.03–1.11)
Baseline bilirubin (continuous)	1.00 (0.99–1.00)	
Baseline bilirubin, ≤ 250 μ mol/L (vs. > 250 μ mol/L)	1.32 (0.43–4.07)	
Bile duct diameter (continuous)	0.77 (0.61–0.96)	
Bile duct diameter, ≤ 15 mm (vs. > 15 mm)	5.26 (1.39–20.0)	6.25 (1.11–33.3)
LAMS size, 6 $\times$ 8 mm (vs. 8 $\times$ 8 mm)	0.56 (0.14–2.32)	0.19 (0.03–1.22)
Technique, freehand (vs. wire-guided)	1.77 (0.38–8.34)	
Endoscopist experience, ≥ 20 EUS-CDS (vs. ≤ 5)	0.59 (0.20–1.71)	

ASA, American Society of Anesthesiologists; EUS-CDS, endoscopic ultrasound-guided choledochoduodenostomy; LAMS, lumen-apposing metal stent; OR, odds ratio

patients. SMD with contralateral bile duct wall injury appears to be especially problematic, leading to a moderate adverse event, whereas the one case of cautery injury with successful stent deployment was managed conservatively and led to only a mild adverse event. Portal vein injury could also theoretically occur in a type III SMD; however, this was not observed in our study. Finally, type IV SMD with a double mucosal puncture, which can lead to severe bleeding or even perforation if the muscular wall is involved, has been described in the literature [13, 14], but was not observed in our study.

Overall, when rescued endoscopically, SMD did not lead to significant adverse events whereas failure of endoscopic salvage was associated with more significant consequences. The overall proportion of EUS-CDS procedures with failed endoscopic salvage of SMD, however, appears to be low, at 1.3%. An extrahepatic bile duct diameter of ≤ 15 mm was identified as a factor associated with increase odds for SMD and/or technical failure. This is consistent with previous retrospective data suggesting the same threshold [15]. This diameter cutoff can be used when selecting patients for EUS-CDS. This is especially relevant to operators with less experience performing EUS-CDS. In the case of operators with more experience, this cutoff can also be used to ensure other safety measures are available

such as a preloaded guidewire, the procedure being performed in a room with fluoroscopy access to facilitate rescue, and the timely availability of interventional radiology backup. Interestingly, in a study on 491 patients in whom common bile duct size was measured at the EUS-CDS site, a duct diameter >15 mm could be identified in only 51.9% of patients [16]. This result suggests the need for development of stents with different designs to overcome the limitation of bile duct diameter.

Our multivariable analysis did not identify any factors associated with stent dysfunction or clinical failure. Previous data have suggested that the use of coaxially placed double-pigtail plastic stents through the LAMS was associated with improved stent patency [17]. It is important to note, however, that these data originate from a study using large, nonbiliary LAMS measuring 10 mm in diameter. These LAMS are associated with large flanges, which can block the bile duct as the biliary tree collapses onto the stent during initial bile duct decompression. The use of a double-pigtail stent prevents such an occlusion phenomenon. The biliary LAMSs used in both the ELEMENT and DRA-MBO trials had much smaller flanges and appear less likely to block the bile duct during decompression. Notably, however, only 13 patients in this study had coaxial double-pigtail stents placed, therefore larger studies are needed to ascertain the true value of this practice. An RCT comparing coaxial double-pigtail stent placement through the LAMS vs. LAMS alone is ongoing and will probably give a definitive answer to this important procedural aspect [18].

Limitations of our study include the fact that neither RCTs were designed to capture SMD as an end point, putting the current analysis at risk of detection bias. Nevertheless, both studies were diligently designed to ascertain all adverse events. Therefore, although there is a risk of underdetection of SMD without adverse events, any SMD with associated adverse events would have been captured. In addition, given that SMD, technical failure, clinical failure, and stent dysfunction were all rare events in these trials, we may have been underpowered to detect significant factors associated with these outcomes. It is also important to note that neither RCT included patients with malignant gastric outlet obstruction, which is a common indication for EUS-guided biliary drainage owing to the inability of ERCP to access the major papilla. The exclusion of these patients may also explain the excellent clinical success and low rate of CDS stent dysfunction noted in our study.

Strengths of the study include the use of primary prospective patient-level data on EUS-CDS using LAMS in the context of two international RCTs. The broad geographical coverage of participating sites from East to West, as well as variable operator experience in EUS-CDS using LAMS also greatly enhance the generalizability of our data. It is important to note, however, that while we included operators with varying levels of EUS-CDS experience, our study only included large referral centers with direct access to interventional radiology and pancreaticobiliary surgery. Consequently, the excellent clinical outcomes of SMD in our study may not necessarily translate to nontertiary settings, regardless of the operator's experience level.

In conclusion, SMDs are relatively common in EUS-CDS but usually occur without severe consequences, owing to the possi-

bility of endoscopic rescue in the majority of cases. An extrahepatic bile duct diameter >15 mm is associated with lower odds for SMD and/or technical failure, and this cutoff could be used to select patients for EUS-CDS, especially for less experienced operators.

Conflict of Interest

Y.I. Chen is a consultant for Boston Scientific, has received research funding from Boston Scientific, and is the co-founder of Chess Medical Inc. A. Sahai is a consultant for Boston Scientific and Pentax. B. Napoleon has received honoraria for proctoring endoscopy training from Maunea Kea, Boston Scientific, Olympus, and TaeWoong Medical. R. Kunda is a consultant for Boston Scientific, Olympus, M.I.Tech, Omega Medical Imaging, Q3 Medical-AMG International, and EndoGastric Solutions. N. Forbes is a consultant and speaker for Boston Scientific and Pentax Medical, a speaker for AstraZeneca, and has received research funding from Pentax Medical. A.Y.B. Teoh is a consultant for Boston Scientific, Cook, TaeWoong Medical, Microtech, and M.I. Tech. The remaining authors declare that they have no conflict of interest.

Funding Information

Fonds de Recherche du Québec – Santé
<http://dx.doi.org/10.13039/501100000156>
 Institute of Nutrition, Metabolism and Diabetes
<http://dx.doi.org/10.13039/501100000035>

References

- [1] Elmunzer BJ, Maranki JL, Gómez V et al. ACG Clinical Guideline: diagnosis and management of biliary strictures. *Am J Gastroenterol* 2023; 118: 405–426
- [2] Chen Y-I, Sahai A, Donatelli G et al. Endoscopic ultrasound-guided biliary drainage of first intent with a lumen-apposing metal stent vs endoscopic retrograde cholangiopancreatography in malignant distal biliary obstruction: a multicenter randomized controlled study (ELEMENT trial). *Gastroenterology* 2023; 165: 1249–1261.e5
- [3] Yuen A, Napoleon B, Kunda R et al. EUS-guided choledochoduodenostomy using lumen apposing stent versus ERCP with covered metallic stents in patients with unresectable malignant distal biliary obstruction: a multicenter randomized controlled trial (DRA-MBO trial). *Gastroenterology* 2023; 165: 473–482.e2
- [4] Kunda R, Pérez-Miranda M, Will U et al. EUS-guided choledochoduodenostomy for malignant distal biliary obstruction using a lumen-apposing fully covered metal stent after failed ERCP. *Surg Endosc* 2016; 30: 5002–5008
- [5] Cotton PB, Eisen GM, Aabakken L et al. A lexicon for endoscopic adverse events: report of an ASGE workshop. *Gastrointest Endosc* 2010; 71: 446–454
- [6] Bang JY, Navaneethan U, Hasan M et al. Stent placement by EUS or ERCP for primary biliary decompression in pancreatic cancer: a randomized trial (with videos). *Gastrointest Endosc* 2018; 88: 9–17
- [7] Paik WH, Lee TH, Park DH et al. EUS-guided biliary drainage versus ERCP for the primary palliation of malignant biliary obstruction: a multicenter randomized clinical trial. *Am J Gastroenterol* 2018; 113: 987–997

- [8] Almadi MA, Barkun A, Martel M. Plastic vs. self-expandable metal stents for palliation in malignant biliary obstruction: a series of meta-analyses. *Am J Gastroenterol* 2017; 112: 260–273
- [9] Kiriya S, Kozaka K, Takada T et al. Tokyo Guidelines 2018: diagnostic criteria and severity grading of acute cholangitis (with videos). *J Hepatobiliary Pancreat Sci* 2018; 25: 17–30
- [10] Ramspek CL, Steyerberg EW, Riley RD et al. Prediction or causality? A scoping review of their conflation within current observational research. *Eur J Epidemiol* 2021; 36: 889–898
- [11] Holt BA, Hawes R, Hasan M et al. Biliary drainage: role of EUS guidance. *Gastrointest Endosc* 2016; 83: 160–165
- [12] Palmieri V, Barkun A, Forbes N et al. EUS-guided biliary drainage in malignant distal biliary obstruction: an international survey to identify barriers of technology implementation. *Endosc Ultrasound* 2022; 12: 104–110
- [13] Ogura T, Masuda D, Takeuchi T et al. Intraluminal water filling technique to prevent double mucosal puncture during EUS-guided choledochoduodenostomy. *Gastrointest Endosc* 2016; 83: 834–835
- [14] Hara K, Okuno N, Haba S et al. Forward viewing liner echoendoscopy for therapeutic interventions. *Clin Endosc* 2024; 57: 175–180
- [15] Jacques J, Privat J, Pinard F et al. Endoscopic ultrasound-guided choledochoduodenostomy with electrocautery-enhanced lumen-apposing stents: a retrospective analysis. *Endoscopy* 2018; 51: 540–547
- [16] Rimbaş M, Anderloni A, Napoléon B et al. Common bile duct size in malignant distal obstruction and lumen-apposing metal stents: a multicenter prospective study. *Endosc Int Open* 2021; 09: E1801–E1810
- [17] El Chafic AH, Shah JN, Hamerski CM et al. EUS-guided choledochoduodenostomy for distal malignant biliary obstruction using electrocautery-enhanced lumen-apposing metal stents: first US, multicenter experience. *Dig Dis Sci* 2019; 64: 3321–3327
- [18] Garcia-Sumalla A, Loras C, Sanchiz V et al. Multicenter study of lumen-apposing metal stents with or without pigtail in endoscopic ultrasound-guided biliary drainage for malignant obstruction – BAMPI TRIAL: an open-label, randomized controlled trial protocol. *Trials* 2022; 23: 181