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Efficacy and safety of endoscopic duodenal stent versus endoscopic or surgical gastrojejunostomy to treat malignant gastric outlet obstruction: systematic review and meta-analysis

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ABSTRACT

Background and study aims Malignant disease accounts for up to 80 % of gastric outlet obstruction (GOO) cases, which may be treated with duodenal self-expanding metal stents (SEMS), surgical gastrojejunostomy (GJ), and more recently endoscopic-ultrasound-guided gastroenterostomy (EUS-GE). These three treatments have not been compared head-to-head in a randomized trial.

Methods We searched the Embase and MEDLINE databases for studies published January 2015–February 2021 assessing treatment of malignant GOO using duodenal SEMS, endoscopic (EUS-GE) or surgical (laparoscopic or open) GJ. Efficacy outcomes assessed included technical and clinical success rates, GOO recurrence and reintervention. Safety outcomes included procedure-related bleeding or perforation, and stent-related events for the duodenal SEMS and EUS-GE arms.

Results EUS-GE had a lower rate of technical success (95.3%) than duodenal SEMS (99.4 %) or surgical GJ (99.9%) ($P=0.0048$). For duodenal SEMS vs. EUS-GE vs. surgical GJ, rates of clinical success (88.9 % vs. 89.0 % vs. 92.3 % respectively, $P=0.49$) were similar. EUS-GE had a lower rate of GOO recurrence based on limited data ($P=0.0036$), while duodenal SEMS had a higher rate of reintervention ($P=0.041$). Overall procedural complications were similar (duodenal SEMS 18.7 % vs. EUS-GE 21.9 % vs. surgical GJ 23.8 %, $P=0.32$), but estimated bleeding rate was lowest ($P=0.0048$) and stent occlusion rate was highest ($P=0.0002$) for duodenal SEMS.

Conclusions Duodenal SEMS, EUS-GE, and surgical GJ showed similar clinical efficacy for the treatment of malignant GOO. Duodenal SEMS had a lower procedure-related bleeding rate but higher rate of reintervention.

Introduction

Malignant disease accounts for an estimated 50 % to 80 % of cases of gastric outlet obstruction (GOO), with pancreatic cancer being the most common associated malignancy (15 %–20 %) [1]. Patients with GOO may experience progressively worsening nausea, vomiting, weight loss, abdominal pain and severe dehydration [2]. Because patients with GOO secondary to an un-

▶ Table 1 Publications and extracted data.

First author	Year	Country	Study design	Treatment	Treatment subgroup	No. of Cases	Age [mean± SD]	Males (x/n)
Chiu [32]	2015	UK	Retrospective	SEMS	Uncovered	18	70 median (range 46–85)	8/18
JW Kim [33]	2015	South Korea	Retrospective	SEMS	Uncovered	38	68.9 ± 10.2	18/38
				SEMS	Covered	29	68.5 ± 11.2	11/29
SH Kim [34]	2015	South Korea	Retrospective	SEMS	27 Covered stents, 29 uncovered	56	69 mean (range 52–91)	36/56
H Lee [35]	2015	South Korea	Prospective randomized; WAVE partially covered SEMS vs uncovered SEMS	SEMS	Partially covered	51	57.9 ± 12.5	34/51
				SEMS	Uncovered	51	58.7 ± 10.8	36/51
JE Lee [23]	2015	South Korea	Retrospective	SEMS	60 Uncovered, 7 partially covered	67	61.2 ± 12.7	41/67
				SEMS	80 Uncovered; eight partially covered	88	64.4 ± 12.8	61/88
D Oh [36]	2015	South Korea	Retrospective	SEMS	Partially covered	20	64.5 median (range 39–85)	11/20
SY Oh [37]	2015	USA	Retrospective	SEMS	NS	196	65.4 median (IQR 59.4–74.2)	102/196
				SEMS	NS	96	70.4 median (IQR 61.0–79.2)	55/96
Park [24]	2015	South Korea	Retrospective	SEMS	Mixed (141 uncovered, 76 covered)	217	60.7 ± 13.3	162/217
				Surgical	Mixed	39	61.7 ± 13.3	34/39
Sato [38]	2015	Japan	Retrospective	SEMS	Uncovered	61	64.0 ± 10.3	35/61
Trotter [39]	2015	UK	Retrospective	SEMS	NS	29		
Fiori [40]	2016	Italy	Prospective, not randomized	SEMS (arm excluded for overlap)[1]	Mixed covered and uncovered[1]	72[1]	71[1]	46/70[1]
				Surgical	Open	30	70	19/30
Grunwald [41]	2016	USA	Retrospective	SEMS	NS	100	69.7	43/100
Itoi [42]	2016	Japan, India, USA	Prospective	EUS-GJ (EPASS) with LAMS	EUS-GJ	20		
Jung [43]	2016	South Korea	Retrospective	SEMS	Fully covered			
				SEMS	Partially covered			
				SEMS	Uncovered			
				SEMS	Mixed	220	63 median (IQR 15–90)	125/220

▶ **Table 1** (Continuation)

First author	Year	Country	Study design	Treatment	Treatment subgroup	No. of Cases	Age [mean± SD]	Males (x/n)
Kato [44]	2016	Japan	Retrospective	SEMS	Uncovered	46		
				SEMS	Uncovered	79		
				SEMS	Uncovered	125	70.2 mean (range 38–97)	71/125
Khan [45]	2016	China	Prospective	SEMS	Uncovered	30	65 mean (range 40–90)	18/30
Kobayashi [46]	2016	Japan	Retrospective	SEMS	Uncovered	71	67.6 (range: 31–92)	43/71
Lye [47]	2016	Singa-pore	Retrospective	SEMS	Uncovered	24	79.5 median (range 49–92)	11/24
				Surgical	Open	30		
Okuwaki [48]	2016	Japan	Retrospective	SEMS	Uncovered	14	72 median (IQR 69–79)	9/14
				SEMS	Uncovered	17	71 median (IQR 66–75)	8/17
J-H Park (1) [49]	2016	South Korea	Retrospective	SEMS	Partially cov-ered	125	61 mean (range 25–89)	81/125
				SEMS	Partially cov-ered	68	62 mean (range 36–91)	48/68
J-H Park (2) [50]	2016	South Korea	Retrospective pro-pensity score-matched	SEMS	Dual stent con-sisting of outer partially cov-ered stent and inner bare stent	74	62.1 ± 13.8	57/74
				Surgical	Mixed	74	61.1 ± 12.1	55/74
Radema-cher [51]	2016	Germa-ny	Retrospective	SEMS	NS	62	70.5 median (range 63–81)	35/62
Sasaki [52]	2016	Japan	Prospective	SEMS	Uncovered	39	69.2 ± 13.3	25/39
Shin [53]	2016	South Korea	Retrospective	SEMS	Mixed	124	71.8 median (range 42–97)	70/122
Tsauo [54]	2016	South Korea	Retrospective	SEMS	Partial	75	61.7 ± 10.9	45/75
				Surgical	Mixed	32	63.4 ± 9.6	21/32
Yamao [55]	2016	Japan	Retrospective	SEMS	Mixed covered and uncovered	278	71.7 ± 11.4	163/278
Bulut [56]	2017	Turkey	Retrospective	SEMS	Uncovered	53	58.7 ± 15.07	33/53
Chen [30]	2017	USA, Japan (EUS-GJ) USA (SEMS)	Retrospective	SEMS	NS	52	64 ± 13.2	32/52
				EUS-GJ	EUS-GJ	30	70 ± 13.3	17/30
Hori [57]	2017	Japan	Retrospective	SEMS	Uncovered	126	74 median (range 39–101)	160/252
				SEMS	Covered	126		
Jang [58]	2017	South Korea	Retrospective	SEMS	NS	99	58.8 ± 13.2	67/99
				Surgical	Mixed	45	58.9 ± 11.4	36/45

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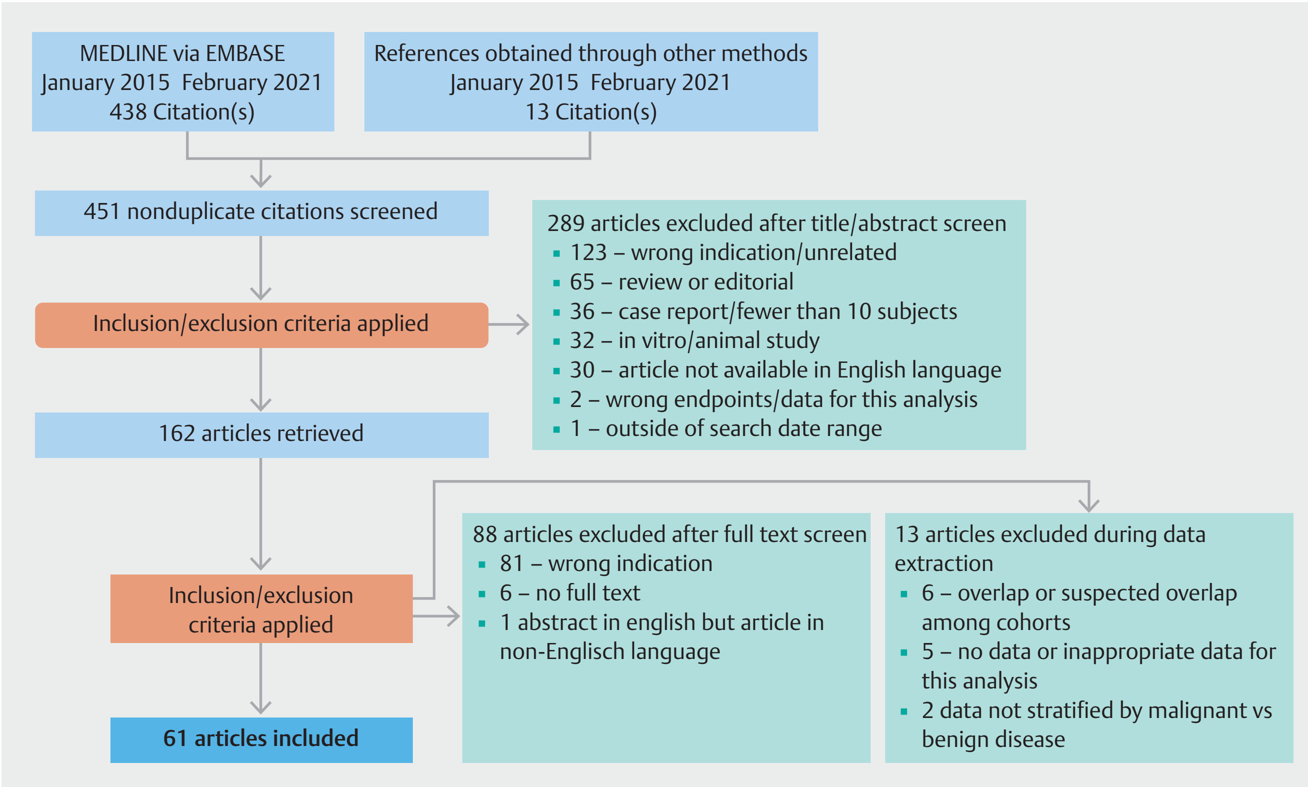
▶ **Table 1** (Continuation)

First author	Year	Country	Study design	Treatment	Treatment subgroup	No. of Cases	Age [mean± SD]	Males (x/n)
Khashab [59]	2017	USA, Japan	Retrospective	EUS-GJ (arm excluded for overlap)[1]		30[1]	70 ± 13.3[1]	17/30[1]
				Surgical	Open	63	68 ± 9.6	32/63
Kim [60]	2017	South Korea	Retrospective	SEMS	Partially covered	18	71.2 ± 10.0	9/18
Ojima [61]	2017	Japan	Retrospective	Surgical	Open	23	67 median (range 45–85)	15/23
				Surgical	Lap	30	71 median (range 52–85)	20/30
Perez-Miranda [62]	2017	USA, Spain, France	Retrospective	EUS-GJ[1]	EUS-GJ[1]	25[1]	63.9[1]	11/25[1]
				Surgical	Lap, with conversion to open at surgeon's discretion	29	75.8	22/29
Takahara [63]	2017	Japan	Retrospective	SEMS	Partially covered	41	67 median (range 35–89)	26/41
Tanaka [64]	2017	Japan	Retrospective	Surgical	lap	43	67 median (range 43–83)	29/43
Tsauo [65]	2017	South Korea	Retrospective	SEMS	Dual stent consisting of outer partially covered stent and inner bare stent	40	56.8 ± 10.6	23/40
Ye [66]	2017	Taiwan	Retrospective	SEMS	Uncovered	87	71.1 ± 14.6	58/87
Yoshida [67]	2017	Japan	Retrospective	SEMS	Uncovered	23	70 (range 48–87)	15/23
				Surgical	Mixed (28 open, 2 lap)	30	63.5 (range 46–72)	16/30
				SEMS	Uncovered	23	70 (range 48–87)	15/23
Bekheet [68]	2018	South Korea	Retrospective	SEMS	Covered	55	60.6 (range 38–89)	35/55
Choi [69]	2018	South Korea	Retrospective	SEMS (Bonastent Wing)	Partially covered	63	65.0 (range 58.5–75.0)	44/63
Leiyuan [70]	2018	China	Retrospective	SEMS	NS	29	64.6 ± 14.2	19/29
				Surgical	Lap	34	59.8 ± 15.5	21/34
Uemura [71]	2018	Japan	Retrospective	SEMS	Uncovered	64	72 (range 43–90)	32/64
				Surgical	Open	35	68 (range 47–87)	12/35
Yukimoto [72]	2018	Japan	Retrospective	SEMS	Uncovered	38	73.0 median (IQR 65.0–79.0)	23/38
				Surgical	Open	27	75.0 median (IQR 66.0–81.5)	18/27

▶ **Table 1** (Continuation)

First author	Year	Country	Study design	Treatment	Treatment subgroup	No. of Cases	Age [mean± SD]	Males (x/n)
Ge [22]	2019	USA	Prospective	SEMS	Uncovered	78	65.7 ± 12.6	47/78
				EUS-GJ	EUS-GJ	22	66.4 ± 9.2	9/22
Jang [73]	2019	USA	Retrospective	SEMS	Uncovered	183	66.2 ± 14.3	90/183
				Surgical	Mixed	127	67.5 ± 11.1	80/127
Kerdsiri-chairat [74]	2019	USA	Retrospective	EUS-GJ	malignant	48	65 median for all	28/57 for all
				EUS-GJ[1]	Benign[1]	9[1]		
Kumar [75]	2019	India	Retrospective	SEMS	NS	90	56.4 ± 11.7	43/90
				SEMS	NS	24	56.9 ± 11.6	12/24
Ramos [76]	2019	Brazil	Retrospective	Surgical	Gastric partitioning	30	67.5 ± 13.4	22/30
				Surgical	Conventional GJ	30	64.3 ± 12.7	19/30
Ratone [77]	2019	France	Retrospective	SEMS	Uncovered	220	67.2 ± 13.9	123/220
Sterpetti [78]	2019	Italy	Prospective	SEMS		87	71	57/87
Alcala-Gonzalez [79]	2020	Spain	Retrospective	SEMS	Uncovered	36	68 median (IQR 53–83)	20/36
Kastelijn [5]	2020	The Netherlands, Germany, Spain, Italy	Retrospective	EUS-GJ	EUS-GJ	45	69.9 ± 12.3	22/45
Miwa [80]	2020	Japan	Prospective	SEMS	Uncovered	31	70 median (range 52–90)	19/31
Mo [81]	2020	South Korea	Retrospective	SEMS	61 Uncovered, 29 covered initially	90	72.1 (range 31–96)	59/90
Wu [82]	2020	Taiwan	Retrospective	SEMS	Uncovered	71	63 ± 16	36/71
				SEMS	Uncovered	32	62 ± 12	17/30
Xu [83]	2020	China	Retrospective	EUS-GJ	EUS-GE	36	69.0 ± 12.8	17/36
Yildirim [84]	2020	Turkey	Retrospective	Surgical	Open	37	68.7 ± 14.4	25/37
				Surgical	Mixed (2 lap, 14 open)	16	62.7 ± 10.2	11/16
Hindryckx [85]	2021	Belgium	Retrospective	EUS-GJ	EUS-GJ	6		
Kouanda [86]	2021	USA	Retrospective	EUS-GJ	EUS-GJ	36	70.4 ± 11.8	20/36
				Surgical	Open	14	71.5 ± 15.6	8/14
Yamao [87]	2021	Japan	Prospective randomized	SEMS	Covered	182	73.5 median (range 35–97)	98/182
				SEMS	Uncovered	184	72 median (range 43–96)	107/184

SEMS, self-expanding metal stent; EUS-GJ, endoscopic ultrasound-guided gastrojejunostomy.
[1] Trial arms were excluded due to overlap with one or more other studies.



▶ **Fig. 1** Flow diagram of literature search and study selection.

resectable malignancy have limited life expectancy, palliative treatment prioritizes symptom resolution (especially relief of vomiting and return to oral intake) and minimization of hospital stays, complications and reinterventions [1].

Palliative interventions for GOO include open or laparoscopic surgical gastrojejunostomy (GJ), duodenal stenting using self-expanding metal stents (SEMS), and endoscopic gastroenterostomy (EUS-GE). Surgical GJ and SEMS are the two most common palliative treatment options for patients with malignant GOO [2]. A 2019 meta-analysis of data from 27 studies including 2354 patients with malignant GOO found similar technical and clinical success rates for surgical GJ and duodenal stenting, with shorter mean time to resumption of oral intake for patients who received stenting [2]. However, because stenting was associated with shorter survival time (mean difference 43 days) and higher rates of stent-related complications, reobstruction and reintervention compared to surgical GJ, the authors concluded that surgical GJ was preferable for patients with a long life expectancy and good performance status [2]. A 2018 meta-analysis of the same treatments analyzed only three randomized controlled trials (RCTs) including 84 patients after exclusion of many studies for low-quality data [1]. This analysis confirmed that compared to surgical GJ, patients receiving duodenal stenting had a faster return to oral intake, shorter mean hospital stay, increased recurrence of symptoms and increased reintervention rate, while quality of life and survival could not be analyzed due to insufficient adequate-quality data [1].

Since 2015 [3], endoscopic ultrasound-guided gastroenterostomy (EUS-GE) has been studied for the management of GOO. A meta-analysis of 12 studies published through 2018 including 285 patients concluded that EUS-GE is effective and safe for patients with malignant GOO, estimating 92 % technical success, clinical success in 90 % of patients, symptom recurrence or unplanned reintervention in 9 % and adverse events (AEs) in 12 % [4]. Subsequently, a 2020 multicenter study of 45 patients showed lower technical (86.7 %) and clinical (73.3 %) success rates with AEs in 12 patients (26.7 %), including five fatal AEs that occurred at one center [5].

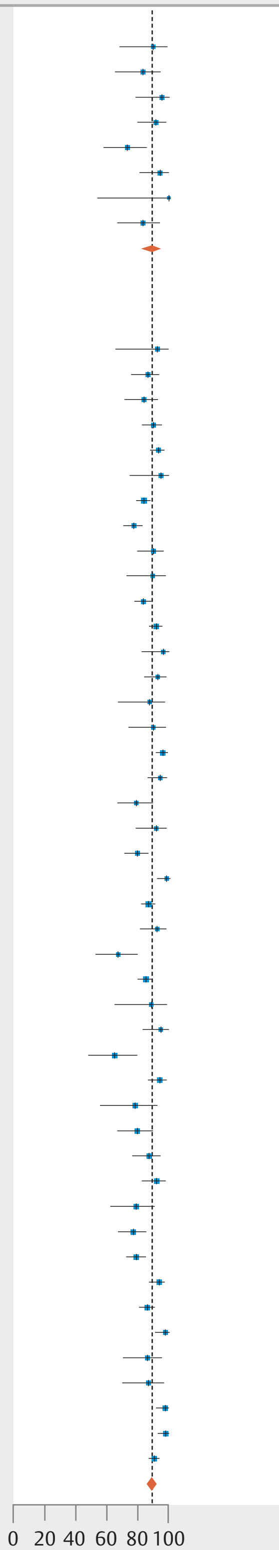
The above treatments have been studied in observational studies and 2-arm randomized trials. No clinical trials have included all three treatments in a head-to-head comparison. To address this evidence gap, we conducted a systematic review and meta-analysis comparing the efficacy and safety of duodenal SEMS versus EUS-GJ versus surgical GJ in observational studies.

Methods

Search strategy

An expert librarian conducted searches of the Embase and MEDLINE databases (via Embase.com) to identify studies published in English between January 2015 and February 2021 (**eTable 1**). January 2015 was chosen as the search start date because EUS-GE (newest of the three treatments) was first documented for the management of GOO in human patients

Study	# Clinical Success	Total	% Clinical Success	95% CI	Weight
EUS-GE					
Itoi (2016)	18	30	90.0	(68.3, 98.8)	1.0 %
Chen (2017)	25	30	83.3	(65.3, 94.4)	1.2 %
Ge (2019)	23	24	95.8	(78.9, 99.9)	1.1 %
Kerdsirichairat (2019)	44	48	91.7	(80.0, 97.7)	1.5 %
Kastelijin (2020)	33	45	73.3	(58.3, 85.4)	1.5 %
Xu (2020)	34	36	94.4	(81.3, 99.3)	1.3 %
Hindryckx (2021)	6	6	100.0	(54.1, 100.0)	0.4 %
Kouanda (2021)	30	36	83.3	(67.2, 93.6)	1.3 %
Pooled EUS-GE	**213**	**245**	**89.0**	**(82.3, 94.3)**	**9.5 %**
Heterogeneity: *P* = 0.031					
Duodenal SEMS					
Chiu (2015)	13	14	92.9	(66.1, 99.8)	0.8 %
JW Kim (2015)	58	67	86.6	(76.0, 93.7)	1.6 %
SH Kim (2015)	47	56	83.9	(71.7, 92.4)	1.6 %
H Lee (2015)	92	102	90.2	(82.7, 95.2)	1.8 %
JE Lee (2015)	145	155	93.5	(88.5, 96.9)	1.9 %
D Oh (2015)	19	20	95.0	(75.1, 99.9)	1.0 %
SY Oh (2015)	245	292	83.9	(79.2, 87.9)	2.1 %
Park (2015)	168	217	77.4	(71.3, 82.8)	2.0 %
Sato (2015)	55	61	90.2	(79.8, 96.3)	1.6 %
Trotter (2015)	26	29	89.7	(78.1, 97.8)	1.2 %
Jung (2015)	184	220	83.6	(78.1, 88.3)	2.0 %
Kato (2016)	230	250	92.0	(87.9, 95.0)	2.0 %
Khan (2016)	29	30	96.7	(82.8, 99.9)	1.2 %
Kobayashi (2016)	66	71	93.0	(84.3, 97.7)	1.7 %
Lye (2016)	21	24	87.5	(67.6, 97.3)	1.1 %
Okuwaki (2016)	28	31	90.3	(74.2, 98.0)	1.3 %
J-H Park (1) (2016)	182	189	96.3	(92.5, 98.5)	2.0 %
J-H Park (2) (2016)	70	74	94.6	(86.7, 98.5)	1.7 %
Rademacher (2016)	49	62	79.0	(66.8, 88.3)	1.6 %
Sasaki (2016)	36	39	92.3	(79.1, 98.4)	1.4 %
Shin (2016)	99	124	79.8	(71.8, 86.5)	1.9 %
Tsauo (2016)	74	75	98.7	(92.8, 100.0)	1.7 %
Yamao (2016)	242	278	87.1	(82.5, 90.8)	2.1 %
Bulut (2017)	49	53	92.5	(81.8, 97.9)	1.5 %
Chen (2017)	35	52	67.3	(52.9, 79.7)	1.5 %
Hori (2017)	215	252	85.3	(80.3, 89.4)	2.0 %
Kim (2017)	16	18	88.9	(65.3, 98.6)	1.0 %
Takahara (2017)	39	41	95.1	(83.5, 99.4)	1.4 %
Tsauo (2017)	26	40	65.0	(48.3, 79.4)	1.4 %
Ye (2017)	82	87	94.3	(87.1, 98.1)	1.7 %
Yoshida (2017)	18	23	78.3	(56.3, 92.5)	1.1 %
Bekheet (2018)	44	55	80.0	(67.0, 89.6)	1.6 %
Choi (2018)	55	63	87.2	(76.5, 94.4)	1.6 %
Uemura (2018)	59	64	92.2	(82.7, 97.4)	1.6 %
Yukimoto (2018)	30	38	78.9	(62.7, 90.4)	1.4 %
Ge (2019)	75	97	77.3	(67.7, 85.2)	1.8 %
Jang (2019)	145	183	79.2	(72.6, 84.9)	2.0 %
Kumar (2019)	107	114	93.9	(87.8, 97.5)	1.8 %
Ratone (2019)	190	220	86.4	(81.1, 90.6)	2.0 %
Sterpetti (2019)	82	84	97.6	(91.7, 99.7)	1.7 %
Alcala-Gonzalez (2020)	31	36	86.1	(70.5, 95.3)	1.3 %
Miwa (2020)	27	31	87.1	(70.2, 96.4)	1.3 %
Mo (2020)	88	90	97.8	(92.2, 99.7)	1.8 %
Wu (2020)	101	103	98.1	(93.2, 99.8)	1.8 %
Yamao (2021)	332	366	90.7	(87.3, 93.5)	2.1 %
Pooled Duodenal SEMS	**4024**	**4590**	**88.9**	**(86.7, 90.9)**	**72.8 %**
Heterogeneity: *P* <0.001					



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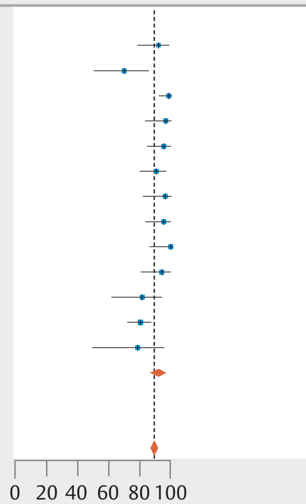
► **Fig. 2a** Analysis of efficacy outcomes. Outcomes for clinical success.

Study	# Clinical Success	Total	% Clinical Success	95% CI	Weight
Surgical GJ					
Park (2015)	36	39	92.3	(79.1, 98.4)	1.4 %
Lye (2016)	21	30	70.0	(50.6, 85.3)	1.2 %
J-H Park (2) (2016)	73	74	98.6	(92.7, 100.0)	1.7 %
Tsauo (2016)	31	32	96.9	(83.8, 99.9)	1.3 %
Jang (2017)	43	45	95.6	(84.9, 99.5)	1.5 %
Khashab (2017)	57	63	90.5	(80.4, 96.4)	1.6 %
Perez-Miranda (2017)	28	29	96.6	(82.2, 99.9)	1.2 %
Tanaka (2017)	41	43	95.3	(84.2, 99.4)	1.4 %
Yoshida (2017)	30	30	100.0	(88.4, 100.0)	1.2 %
Uemura (2018)	33	35	94.3	(80.8, 99.3)	1.3 %
Yukimoto (2018)	22	27	51.5	(61.9, 93.7)	1.2 %
Jang (2019)	102	127	80.3	(72.6, 86.8)	1.9 %
Kouanda (2021)	11	14	78.6	(49.2, 95.3)	0.8 %
Pooled Surgical GJ	**528**	**588**	**92.3**	**(86.9, 96.3)**	**17.8 %**
Heterogeneity: *P* = 0.001					
Pooled all treatments	**4765**	**5423**	**89.6**	**(87.7, 91.3)**	**100.0 %**
Heterogeneity: *P* < 0.001					



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▶ **Fig. 2a** Analysis of efficacy outcomes. Outcomes for clinical success. *(Continuation)*

in 2015 [3]. RCTs, retrospective and prospective cohort studies, case-control studies, and case series that assessed endoscopic duodenal stenting or endoscopic or surgical GJ for malignant GOO were included. We excluded in vitro or animal studies, reviews or editorials, and publications that reported on < 10 patients, had article text in a non-English language, or had study populations that were clearly overlapping or had suspected overlap based on common authors and study sites with overlapping enrollment dates. In cases of overlap, we retained the study/studies with the most comprehensive data on the outcomes of interest that were mutually exclusive with all other included studies. If some but not all arms of a comparative study showed overlap with another publication, the arm(s) with overlap were excluded but the arm(s) without overlap were retained for the analysis.

Data extraction and assessment for risk of bias

For all manuscripts identified by the literature search, two authors (RK, SB) independently reviewed studies for eligibility and/or extracted data from selected publications for preidentified efficacy and safety endpoints. Discrepancies were resolved after review by a third author (PB) and consensus decision after discussion among the entire author group. Baseline information consisted of study characteristics (year published, country of origin, study design, sample size), patient characteristics (age, sex), treatment and treatment subgroup (e. g., type of stent, subcategory of surgery). Reasons for study exclusion were documented.

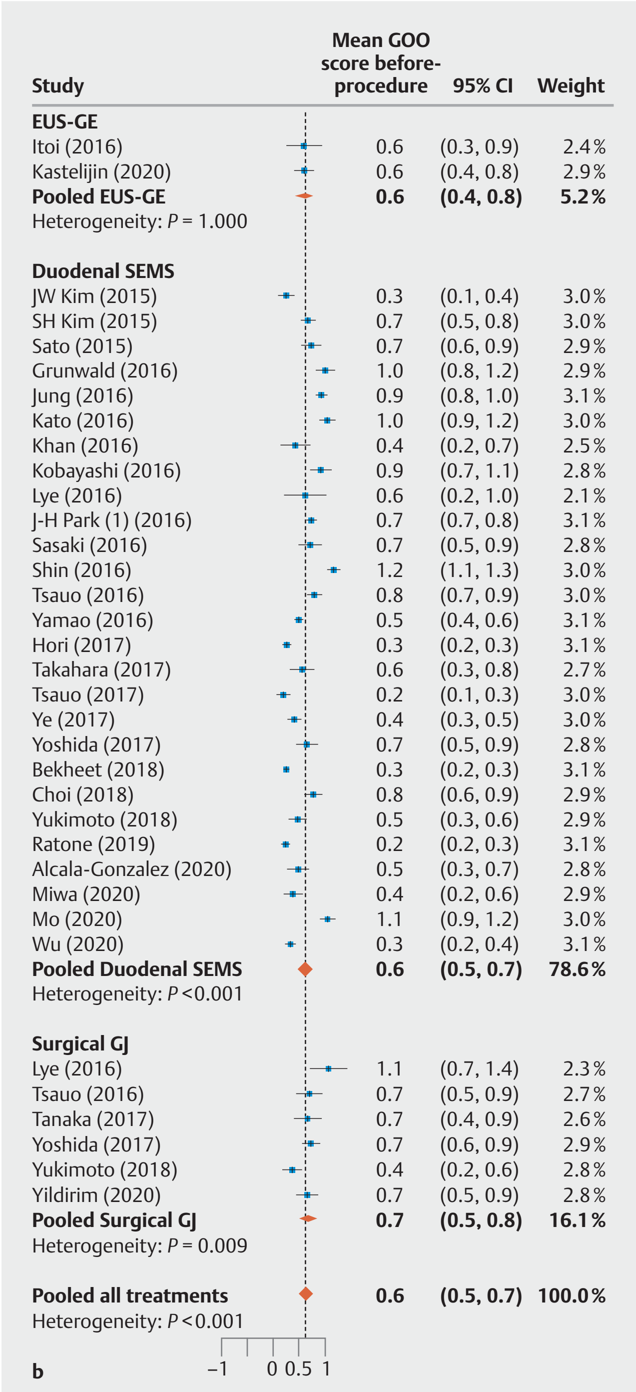
The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used to conduct this analysis [6]. The Newcastle-Ottawa Scale (NOS) was employed (author SB) to review the methodologic quality of non-randomized studies and assess for bias. An adapted NOS was used that assessed the selection and representativeness of the study population (**eTable 2**) and the ascertainment of outcomes and exposures. Items from the NOS that made comparative assessments (e. g. exposed vs. non-exposed cohorts) were removed, as they did not apply to single-arm studies. This adaptation of the NOS has been used previously [7–9], and for the purposes of this study, one question ("Were other important diagnoses excluded?") was replaced by another question ("Was follow-up long enough for outcomes to occur? Reported adequate follow-up time") to make it more appropriate for this systematic review. Yes/no responses were required for each of five questions, and the quality of each study was ranked as good (5 yes responses), moderate (4 yes responses), or poor (≤ 3 yes responses).

Endpoint assessment and definition

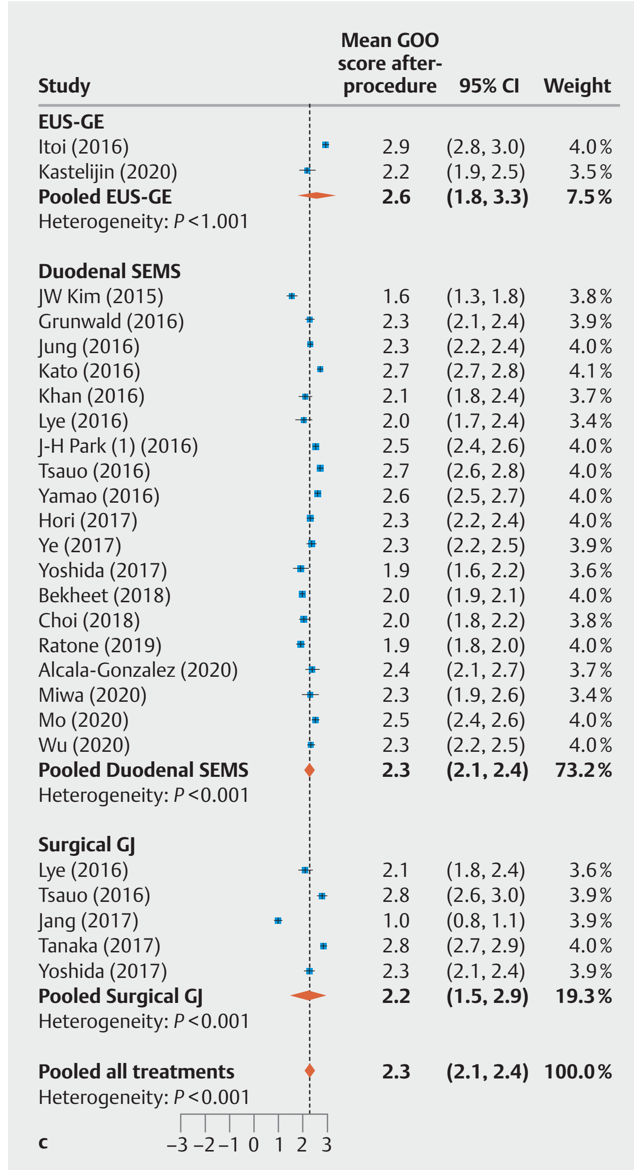
Efficacy outcomes assessed were "technical success" and "clinical success" as defined by the reporting authors, pre- and post-procedural Gastric Outlet Obstruction Scoring System (GOOSS) score [10] (no oral intake = 0, liquids only = 1, soft solids = 2, low-residue or full diet = 3), recurrence of GOO, and reintervention (for any reason) during the study period.

Safety outcomes assessed were overall adverse event rate, procedure-related bleeding and perforation, and for the duodenal stent and EUS-GE arms: stent migration, patency, occlusion, ingrowth and overgrowth. In many cases, procedure-related deaths were not distinguished from all-cause deaths, and some studies were designed to follow all patients until death. Therefore, as a surrogate of procedure-related deaths, we only extracted deaths described in the AEs section since this location in the paper suggested the authors thought the death could be procedure-related.

In some articles, some outcomes were only reported for technically successful cases. To avoid inflated estimates (e. g. clinical success only reported for technically successful cases) or exclusion of AEs in failed cases, all reported events were ex-



▶ **Fig. 2b** Analysis of efficacy outcomes. Outcomes for preprocedural GOOSS score.



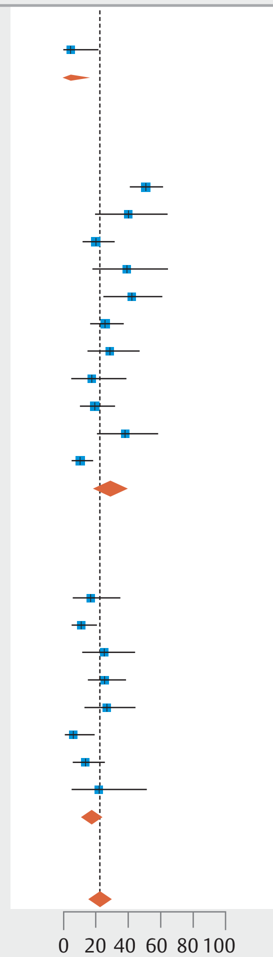
▶ **Fig. 2c** Analysis of efficacy outcomes. Outcomes for postprocedural GOOSS score.

tracted, using denominators reflecting the entire study population.

Statistical methods

Efficacy and safety outcomes were assessed using a random-effects meta-analysis to estimate the proportion of patients with the measure or mean of the measure. Since the number of comparative studies was small and those studies were retrospective, both arms from all comparative studies were treated as independent studies and combined with non-comparative studies. The arcsine transformation was used to compute weighted pooled random-effects estimates for all endpoints. For endpoints with three treatment groups, pairwise comparisons between treatments were done with a Bonferroni adjustment. A sensitivity analysis was performed including only studies with "good" quality ratings. Heterogeneity was assessed across studies using the I^2 statistic [11]. Funnel plots were created to assess for publication bias across studies. The Begg and Mazumdar rank correlation test of funnel plot asymmetry and Egger's linear regression test of funnel plot asymmetry were also used to assess publication bias [12, 13]. All meta-analyses were performed using R (version 3.6.1); SAS (version 9.4, SAS Inc.,

Study	# Recurrence of GOO	Total	% Recurrence of GOO	95% CI	Weight
EUS-GE					
Chen (2017)	1	25	4.0	(0.1, 20.4)	4.5 %
Pooled EUS-GE	**1**	**25**	**4.0**	**(0.0, 15.0)**	**4.5 %**
Heterogeneity: not applicable					
Duodenal SEMS					
JE Lee (2015)	55	108	50.9	(41.1, 60.7)	5.9 %
D Oh (2015)	8	20	40.0	(19.1, 63.9)	4.2 %
Kobayashi (2016)	14	71	19.7	(11.2, 30.9)	5.6 %
Lye (2016)	7	18	38.9	(17.3, 64.3)	4.0 %
Okuwaki (2016)	13	31	41.9	(24.5, 60.9)	4.8 %
J-H Park (2) (2016)	19	74	25.7	(16.2, 37.2)	5.7 %
Chen (2017)	10	35	28.6	(14.6, 46.3)	4.9 %
Yoshida (2017)	4	23	17.4	(5.0, 38.8)	4.4 %
Choi (2018)	12	63	19.0	(10.2, 30.9)	5.5 %
Leiyuan (2018)	11	29	37.9	(20.7, 57.7)	4.7 %
Wu (2020)	10	101	9.9	(4.9, 17.5)	5.9 %
Pooled Duodenal SEMS	**163**	**573**	**28.7**	**(19.7, 38.6)**	**55.7 %**
Heterogeneity: *P* < 0.001					
Surgical GJ					
Lye (2016)	5	30	16.7	(5.6, 34.7)	4.8 %
J-H Park (2) (2016)	8	74	10.8	(4.8, 20.2)	5.7 %
Tsauo (2016)	8	32	25.0	(11.5, 43.4)	4.8 %
Khashab (2017)	16	63	25.4	(15.3, 37.9)	5.5 %
Leiyuan (2018)	9	34	26.5	(12.9, 44.4)	4.9 %
Uemura (2018)	2	35	5.7	(0.7, 19.2)	4.9 %
Ramos (2019)	8	60	13.3	(5.9, 24.6)	5.5 %
Kouanda (2021)	3	14	21.7	(4.7, 50.8)	3.6 %
Pooled Surgical GJ	**59**	**342**	**16.9**	**(11.6, 23.0)**	**39.8 %**
Heterogeneity: *P* = 0.058					
Pooled all treatments	**223**	**940**	**22.5**	**(16.5, 29.0)**	**100.0 %**
Heterogeneity: *P* < 0.001					



d

▶ **Fig. 2d** Analysis of efficacy outcomes. Outcomes for recurrence of GOO.

Cary, North Carolina, United States) was used for plotting and all other analyses.

Results

Study selection and patient characteristics

Study and patient characteristics are summarized in ▶ **Table 1**. The systematic literature search identified 451 unique articles, of which 61 studies representing 5772 subjects met the inclusion criteria (▶ **Fig. 1**). In total, 390 articles were excluded (▶ **Fig. 1**), most often for the wrong indication (including benign GOO) or being unrelated to the search objectives (n = 211), or because they were a review article or editorial (n = 65), case report or had < 10 patients (36), in vitro or animal study (32) or not available in English language (31). Fifty-two eligible studies were retrospective; and nine were prospective, including two randomized studies comparing covered SEMS to uncovered SEMS.

Patients who were treated with EUS-GJ were significantly older than patients who were treated with duodenal SEMS or surgical GJ (mean age 69.1 for EUS-GJ, 64.2 for duodenal SEMS, 64.3 years for surgical GJ, *P* = 0.0004) The EUS-GJ treatment group had a lower proportion of males than the surgical GJ group (50.3 % vs. 65.6 %, *P* = 0.0042 for pairwise comparison). The preprocedural GOOSS scores were similar among groups (0.62 for duodenal SEMS vs. 0.60 for EUS-GJ vs. 0.68 for surgical GJ, *P* = 0.7783).

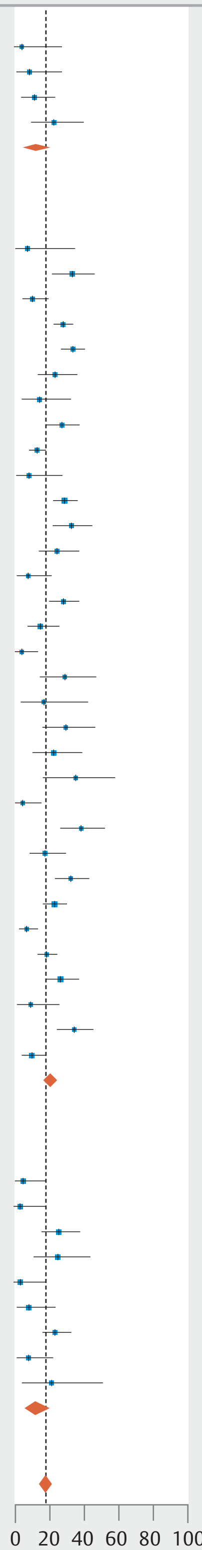
Study quality

All 61 publications were assessed for quality with the modified NOS. Thirty-eight studies were judged to have good quality, 17 moderate quality, and six poor quality (**eTable 2**).

Assessment of heterogeneity

Heterogeneity was found in the analyses endpoints (**eTable 3**). There was heterogeneity in the EUS-GE and SEMS groups for technical success, stent migration, and death reported in AE section, in the Surgical GJ and SEMS groups for clinical success, reintervention, procedure-related complications, and pre- and postprocedural GOOSS score, and for the SEMS group only for

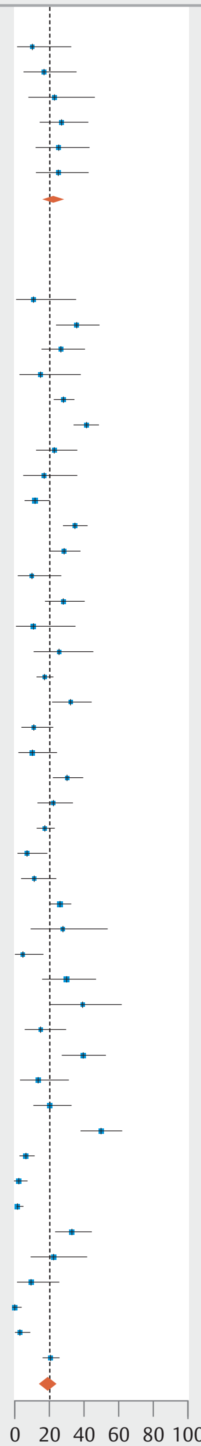
Study	# Re-Intervention	Total	% Re-Intervention	95% CI	Weight
EUS-GE					
Chen (2017)	1	25	4.0	(0.1, 20.4)	1.7 %
Ge (2019)	2	24	8.3	(1.0, 27.0)	1.7 %
Kerdsirichairat (2019)	5	44	11.4	(3.8, 24.6)	2.1 %
Kouanda (2021)	8	36	22.2	(10.1, 39.2)	2.0 %
Pooled EUS-GE	**16**	**129**	**11.2**	**(4.2, 19.6)**	**7.4 %**
Heterogeneity: *P* = 0.146					
Duodenal SEMS					
Chiu (2015)	1	14	7.1	(0.2, 33.9)	1.3 %
JW Kim (2015)	22	67	32.8	(21.8, 45.4)	2.3 %
H Lee (2015)	8	79	10.1	(4.5, 19.0)	2.4 %
SY Oh (2015)	81	292	27.7	(22.7, 33.3)	2.8 %
Park (2015)	72	217	33.2	(27.0, 39.9)	2.7 %
Sato (2015)	14	61	23.0	(13.2, 35.5)	2.3 %
Trotter (2015)	4	29	13.8	(3.9, 31.7)	1.8 %
Grunwald (2016)	27	100	27.0	(18.6, 36.8)	2.5 %
Jung (2015)	27	213	12.7	(8.5, 17.9)	2.7 %
Lye (2016)	2	24	8.3	(1.0, 27.0)	1.7 %
J-H Park (1) (2016)	54	189	28.6	(22.2, 35.6)	2.7 %
J-H Park (2) (2016)	24	74	32.4	(22.0, 44.3)	2.4 %
Rademacher (2016)	15	62	24.2	(14.2, 36.7)	2.3 %
Sasaki (2016)	3	39	7.7	(1.6, 20.9)	2.0 %
Shin (2016)	34	122	27.9	(20.1, 36.7)	2.6 %
Tsauo (2016)	11	75	14.7	(7.6, 24.7)	2.4 %
Bulut (2017)	2	53	3.8	(0.5, 13.0)	2.2 %
Chen (2017)	10	35	28.6	(14.6, 46.3)	1.9 %
Kim (2017)	3	18	16.7	(3.6, 41.4)	1.5 %
Takahara (2017)	12	41	29.3	(16.1, 45.5)	2.0 %
Tsauo (2017)	9	40	22.5	(10.8, 38.5)	2.0 %
Yoshida (2017)	8	23	34.8	(16.4, 57.3)	1.6 %
Bekheet (2018)	2	46	4.3	(0.5, 14.8)	2.1 %
Choi (2018)	24	63	38.1	(26.1, 51.2)	2.3 %
Uemura (2018)	11	64	17.2	(8.9, 28.7)	2.3 %
Ge (2019)	31	97	32.0	(22.9, 42.2)	2.5 %
Jang (2019)	42	183	23.0	(17.1, 29.7)	2.7 %
Kumar (2019)	8	114	7.0	(3.1, 13.4)	2.6 %
Ratone (2019)	41	220	18.6	(13.7, 24.4)	2.7 %
Sterpetti (2019)	23	87	26.4	(17.6, 37.0)	2.5 %
Alcala-Gonzalez (2020)	3	31	9.7	(2.0, 25.8)	1.9 %
Mo (2020)	31	90	34.4	(24.7, 45.2)	2.5 %
Wu (2020)	10	101	9.9	(4.9, 17.5)	2.5 %
Pooled Duodenal SEMS	**669**	**2963**	**20.3**	**(16.9, 23.9)**	**74.8 %**
Heterogeneity: *P* <0.001					
Surgical GJ					
Park (2015)	2	39	5.1	(0.6, 17.3)	2.0 %
Fiori (2016)	1	30	3.3	(0.1, 17.2)	1.8 %
J-H Park (2) (2016)	19	74	25.7	(16.2, 37.2)	2.4 %
Tsauo (2016)	8	32	25.0	(11.5, 43.4)	1.9 %
Yoshida (2017)	1	30	3.3	(0.1, 17.2)	1.8 %
Uemura (2018)	3	35	8.6	(1.8, 23.1)	1.9 %
Jang (2019)	30	127	23.6	(16.5, 32.0)	2.6 %
Yildirim (2020)	3	37	8.1	(1.7, 21.9)	2.0 %
Kouanda (2021)	3	14	21.4	(4.7, 50.8)	1.3 %
Pooled Surgical GJ	**70**	**418**	**12.6**	**(6.6, 20.1)**	**17.8 %**
Heterogeneity: *P* = 0.001					
Pooled all treatments	**755**	**3510**	**18.1**	**(15.1, 21.2)**	**100.0 %**
Heterogeneity: *P* <0.001					



e

▶ **Fig. 2e** Analysis of efficacy outcomes. Outcomes for reintervention.

Study	# Complications	Total	% Complications	95% CI	Weight
EUS-GE					
Itoi (2016)	2	20	10.0	(1.2, 31.7)	1.2 %
Chen (2017)	5	30	16.7	(5.6, 34.7)	1.4 %
Ge (2019)	5	22	22.7	(7.8, 45.4)	1.3 %
Kastelijin (2020)	12	45	26.7	(14.6, 41.9)	1.5 %
Xu (2020)	9	36	25.0	(12.1, 42.2)	1.5 %
Kouanda (2021)	9	36	25.0	(12.1, 42.2)	1.5 %
Pooled EUS-GE	**42**	**189**	**21.9**	**(16.3, 28.1)**	**8.3 %**
Heterogeneity: *P* = 0.598					
Duodenal SEMS					
Chiu (2015)	2	18	11.1	(1.4, 34.7)	1.2 %
JW Kim (2015)	24	67	35.8	(24.5, 48.5)	1.6 %
SH Kim (2015)	15	56	26.8	(15.8, 40.3)	1.6 %
D Oh (2015)	3	20	15.0	(3.2, 37.9)	1.2 %
SY Oh (2015)	83	292	28.4	(23.3, 34.0)	1.8 %
Park (2015)	90	217	41.5	(34.8, 48.3)	1.8 %
Sato (2015)	14	61	23.0	(13.2, 35.5)	1.6 %
Trotter (2015)	5	29	17.2	(5.8, 35.8)	1.4 %
Grunwald (2016)	12	100	12.0	(6.4, 20.0)	1.7 %
Jung (2015)	74	213	34.7	(28.4, 41.5)	1.8 %
Kato (2016)	36	125	28.8	(21.1, 37.6)	1.7 %
Khan (2016)	3	30	10.0	(2.1, 26.5)	1.4 %
Kobayashi (2016)	20	71	28.2	(18.1, 40.1)	1.6 %
Lye (2016)	2	18	11.1	(1.4, 34.7)	1.2 %
Okuwaki (2016)	8	31	25.8	(11.9, 44.6)	1.4 %
J-H Park (1) (2016)	53	306	17.3	(13.3, 22.0)	1.8 %
J-H Park (2) (2016)	24	74	32.4	(22.0, 44.3)	1.6 %
Rademacher (2016)	7	62	11.3	(4.7, 21,9)	1.6 %
Sasaki (2016)	4	39	10.3	(2.9, 24.2)	1.5 %
Shin (2016)	37	122	30.3	(22.3, 39.3)	1.7 %
Tsauo (2016)	17	75	22.7	(13.8, 33.8)	1.6 %
Yamao (2016)	49	278	17.6	(13.3, 22.6)	1.8 %
Bulut (2017)	4	53	7.5	(2.1, 18.2)	1.6 %
Chen (2017)	6	52	11.5	(4.4, 23.4)	1.6 %
Hori (2017)	66	252	26.2	(20.9, 32.1)	1.8 %
Kim (2017)	5	18	27.8	(9.7, 53.5)	1.2 %
Takahara (2017)	2	41	4.9	(0.6, 16.5)	1.5 %
Tsauo (2017)	12	40	30.0	(16.6, 46.5)	1.5 %
Yoshida (2017)	9	23	39.1	(19.7, 61.5)	1.3 %
Bekheet (2018)	7	46	15.2	(6.3, 28.9)	1.5 %
Choi (2018)	25	63	39.7	(27.6, 52.8)	1.6 %
Leiyuan (2018)	4	29	13.8	(3.9, 31.7)	1.4 %
Uemura (2018)	13	64	20.3	(11.3, 32.2)	1.6 %
Ge (2019)	39	78	50.0	(38.5, 61.5)	1.7 %
Jang (2019)	12	183	6.6	(3.4, 11.2)	1.8 %
Kumar (2019)	3	114	2.6	(0.5, 7.5)	1.7 %
Ratone (2019)	4	219	1.8	(0.5, 4.6)	1.8 %
Sterpetti (2019)	29	87	33.3	(23.6, 44.3)	1.7 %
Alcala-Gonzalez (2020)	7	31	22.6	(9.6, 41.1)	1.4 %
Miwa (2020)	3	31	9.7	(2.0, 25.8)	1.4 %
Mo (2020)	0	90	0.0	(0.0, 4.0)	1.7 %
Wu (2020)	3	101	3.0	(0.6, 8.4)	1.7 %
Yamao (2021)	76	366	20.8	(16.7, 25.3)	1.8 %
Pooled Duodenal SEMS	**911**	**4285**	**18.7**	**(14.7, 23.1)**	**68.0 %**
Heterogeneity: *P* <0.001					



a

▶ **Fig. 3a** Analysis of safety outcomes. Outcomes for any procedure-related adverse event.

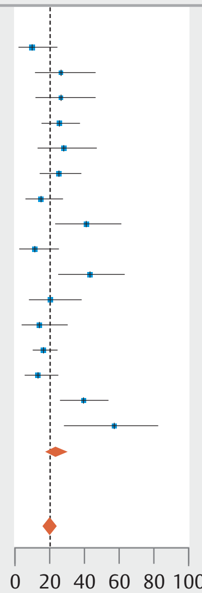
bleeding, recurrence of GOO, stent occlusion, ingrowth, and overgrowth. No heterogeneity was found in the analyses of perforation and patency for any group.

Efficacy outcomes

Technical success

Forty-four of 61 (72.1 %) studies reported rates of procedural technical success. Consistent with its more recent development, EUS-GE was reported to have a significantly lower rate

Study	# Complications	Total	% Complications	95% CI	Weight
Surgical GJ					
Park (2015)	4	39	10.3	(2.9, 24.2)	1.5 %
Fiori (2016)	8	30	26.7	(12.3, 45.9)	1.4 %
Lye (2016)	8	30	26.7	(12.3, 45.9)	1.4 %
J-H Park (2) (2016)	19	74	25.7	(16.2, 37.2)	1.6 %
Tsauo (2016)	9	32	28.1	(13.7, 46.7)	1.4 %
Khashab (2017)	16	63	25.4	(15.3, 37.9)	1.6 %
Ojima (2017)	8	53	15.1	(6.7, 27.6)	1.6 %
Perez-Miranda (2017)	12	29	41.4	(23.5, 61.1)	1.4 %
Tanaka (2017)	5	43	11.6	(3.9, 25.1)	1.5 %
Yoshida (2017)	13	30	43.3	(25.5, 62.6)	1.4 %
Leiyuan (2018)	7	34	20.6	(8.7, 37.9)	1.4 %
Uemura (2018)	5	35	14.3	(4.8, 30.3)	1.4 %
Jang (2019)	21	127	16.5	(10.5, 24.2)	1.7 %
Ramos (2019)	8	60	13.3	(5.9, 24.6)	1.6 %
Yildirim (2020)	21	53	39.6	(26.5, 54.0)	1.6 %
Kouanda (2021)	8	14	57.1	(28.9, 82.3)	1.1 %
Pooled Surgical GJ	**172**	**746**	**23.8**	**(18.6, 29.5)**	**23.7 %**
Heterogeneity: *P* = 0.001					
Pooled all treatments	**1125**	**5220**	**20.2**	**(16.9, 23.6)**	**100.0 %**
Heterogeneity: *P* < 0.001					



a

▶ **Fig. 3a** Analysis of safety outcomes. Outcomes for any procedure-related adverse event. *(Continuation)*

of technical success than the other two treatments (pooled rates 95.3 % for EUS-GE vs. 99.4 % for duodenal SEMS [*P* = 0.0495 for pairwise comparison] and 95.3 % for EUS-GE vs. 99.9 % for surgical GJ [*P* = 0.0060 for pairwise comparison]) (▶ **Table 2**).

Clinical success

Five distinct definitions of "clinical success" were documented among 51 of 61 (83.6 %) studies that reported this endpoint. The most common definition was improved clinical symptoms (especially obstructive symptoms and vomiting) and/or improved oral intake or GOOSS score (19 studies), followed by change in GOOSS score (18), followed by improved oral intake (12), improved oral intake and hospital discharge (1), and resolution of GOO symptoms (intractable vomiting necessitating gastric drainage) the day after stent implantation (1). Pooled rates of "clinical success" were similar among the three treatments, with 88.9 % for duodenal SEMS, 89.0 % for EUS-GE, and 92.3 % for surgical GJ (*P* = 0.49) (▶ **Fig. 2a**, ▶ **Table 2**). Among studies reporting outcomes for laparoscopic GJ alone, open surgical GJ alone, or mixed laparoscopic or surgical GJ, rates of clinical success were similar (96.6 % vs. 85.9 % vs. 93.8 % respectively, *P* = 0.2903).

Pre-procedure and post-procedure GOOSS score

Pooled estimates of mean preprocedural GOOSS score 0.62 for duodenal SEMS, 0.60 for EUS-GE, and 0.68 for surgical GJ, reflecting minimal oral intake before treatment (▶ **Fig. 2b**, ▶ **Table 2**). Estimated mean postprocedural GOOSS scores exceeded two for all three treatments (2.27 for duodenal SEMS, 2.57 for EUS-GE, and 2.20 for surgical GJ), suggesting that most patients were able to eat solid food after treatment (▶ **Fig. 2c**, ▶ **Table 2**).

Recurrence of GOO

Recurrence of GOO in the EUS-GE group (4.0 %, 95 % CI 0.0 % to 15.0 %) was significantly lower than for duodenal SEMS (28.7 %, 95 % CI 19.7 % to 38.6 %; *P* = 0.0040 for pairwise comparison) and similar to surgical GJ (16.9 %, 95 % CI 11.6 % to 23.0 %; *P* = 0.11 for pairwise comparison) (▶ **Fig. 2d**, ▶ **Table 2**). Only one EUS-GE study (N = 25 patients) was included in this comparison, while 11 studies of duodenal SEMS (573 patients) and eight studies of surgical GJ (342 patients) were represented.

Reintervention

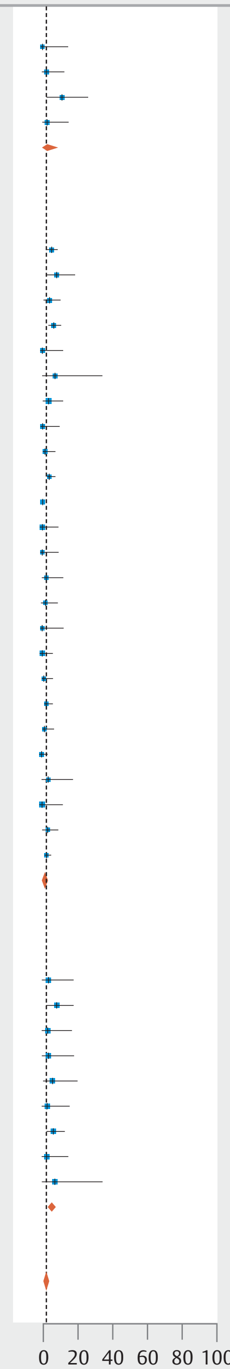
Rates of reintervention (for any reason) during the study period were lower for EUS-GE (11.2 % among 129 patients in four studies) and surgical GJ (12.6 % among 418 patients in nine studies) than for duodenal SEMS (20.3 % among 2963 patients in 33 studies) (*P* = 0.041 for comparison of all three treatments, pairwise comparisons did not show significant differences) (▶ **Fig. 2e**, ▶ **Table 2**).

Safety outcomes

Any procedure-related serious adverse event

The pooled rate of any procedure-related serious adverse event was similar among the three treatments, i. e. 18.7 %, 95 % CI 14.7 % to 23.1 % for SEMS vs. 21.9 %, 95 % CI 16.3 % to 28.1 % for EUS-GE vs. 23.8 %, 95 % CI 18.6 % to 29.5 % for surgical GJ (*P* = 0.32) (▶ **Fig. 3a**, ▶ **Table 2**). Among studies reporting outcomes for laparoscopic GJ alone, open surgical GJ alone, or mixed laparoscopic or open surgical GJ, rates of procedure-related complications were similar (17.6 % vs. 26.9 % vs. 19.3 % respectively, *P* = 0.1340).

Study	# Bleeding	Total	% Bleeding	95% CI	Weight
EUS-GE					
Ge (2019)	0	24	0.0	(0.0, 14.2)	1.5 %
Kastelijin (2020)	1	45	2.2	(0.1, 11.8)	2.3 %
Xu (2020)	4	36	11.1	(3.1, 26.1)	2.0 %
Kouanda (2021)	1	36	2.8	(0.1, 14.5)	2.0 %
Pooled EUS-GE	**6**	**141**	**2.9**	**(0.2, 8.6)**	**7.7 %**
Heterogeneity: *P* = 0.073					
Duodenal SEMS					
SY Oh (2015)	15	292	5.1	(2.9, 8.3)	4.4 %
Sato (2015)	5	61	8.2	(2.7, 18.1)	2.7 %
Grunwald (2016)	4	100	4.0	(1.1, 9.9)	3.3 %
Kato (2016)	16	250	6.4	(3.7, 10.2)	4.3 %
Khan (2016)	0	30	0.0	(0.0, 11.6)	1.7 %
Okuwaki (2016)	1	14	7.1	(0.2, 33.9)	1.0 %
Rademacher (2016)	2	62	3.2	(0.4, 11.2)	2.7 %
Sasaki (2016)	0	39	0.0	(0.0, 9.0)	2.1 %
Tsauo (2016)	1	75	1.3	(0.0, 7.2)	2.9 %
Yamao (2016)	11	278	4.0	(2.0, 7.0)	4.4 %
Hori (2017)	1	252	0.4	(0.0, 2.2)	4.3 %
Takahara (2017)	0	41	0.0	(0.0, 8.6)	2.1 %
Tsauo (2017)	0	40	0.0	(0.0, 8.8)	2.1 %
Bekheet (2018)	1	46	2.2	(0.1, 11.5)	2.3 %
Choi (2018)	1	63	1.6	(0.0, 8.5)	2.7 %
Leiyuan (2018)	0	29	0.0	(0.0, 11.9)	1.7 %
Uemura (2018)	0	64	0.0	(0.0, 5.6)	2.7 %
Ge (2019)	1	97	1.0	(0.0, 5.6)	3.3 %
Jang (2019)	4	183	2.2	(0.6, 5.5)	4.0 %
Kumar (2019)	1	90	1.1	(0.0, 6.0)	3.2 %
Ratone (2019)	1	219	0.5	(0.0, 2.5)	4.2 %
Alcala-Gonzalez (2020)	1	31	3.2	(0.1, 16.7)	1.8 %
Miwa (2020)	0	31	0.0	(0.0, 11.2)	1.8 %
Wu (2020)	3	101	3.0	(0.6, 8.4)	3.3 %
Yamao (2021)	9	366	2.5	(1.1, 4.6)	4.6 %
Pooled Duodenal SEMS	**78**	**2854**	**1.7**	**(0.9, 2.7)**	**73.7 %**
Heterogeneity: *P* < 0.001					
Surgical GJ					
Fiori (2016)	1	30	3.3	(0.1, 17.2)	1.7 %
J-H Park (2) (2016)	6	74	8.1	(3.0, 16.8)	2.9 %
Tsauo (2016)	1	32	3.1	(0.1, 16.2)	1.8 %
Perez-Miranda (2017)	1	29	3.4	(0.1, 17.8)	1.7 %
Leiyuan (2018)	2	34	5.9	(0.7, 19.7)	1.9 %
Uemura (2018)	1	35	2.9	(0.1, 14.9)	1.9 %
Jang (2019)	8	127	6.3	(2.8, 12.0)	3.6 %
Yildirim (2020)	1	37	2.7	(0.1, 14.2)	2.0 %
Kouanda (2021)	1	14	7.1	(0.2, 33.9)	1.0 %
Pooled Surgical GJ	**22**	**412**	**5.2**	**(3.2, 7.5)**	**18.6 %**
Heterogeneity: *P* = 0.908					
Pooled all treatments	**106**	**3407**	**2.3**	**(1.5, 3.2)**	**100.0 %**
Heterogeneity: *P* < 0.001					



b

▶ **Fig. 3b** Analysis of safety outcomes. Outcomes for bleeding.

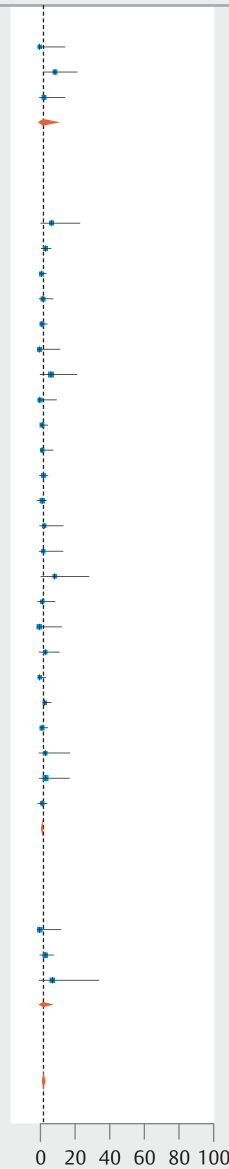
Bleeding

The bleeding rate associated with duodenal SEMS (1.7 %, 95 % CI 0.9 % to 2.7 %) was similar to the rate for EUS-GE (2.9 %, 95 % CI 0.2 % to 8.6 %; *P* = 0.999 for pairwise comparison) and lower than the rate for surgical GJ (5.2 %, 95 % CI 3.2 % to 7.5 %; *P* = 0.0033 for pairwise comparison) (▶ **Fig. 3b**, ▶ **Table 2**).

Perforation

Perforation rates were similar among the three treatments, with 1.6 % for duodenal SEMS, 2.8 % for EUS-GE, and 2.0 % for surgical GJ (*P* = 0.88) (▶ **Fig. 3c**, ▶ **Table 2**).

Study	# Perforation	Total	% Perforation	95% CI	Weight
EUS-GE					
Ge (2019)	0	24	0.0	(0.0, 14.2)	1.2 %
Kastelijin (2020)	4	45	8.9	(2.5, 21.2)	2.0 %
Kouanda (2021)	1	36	2.8	(0.1, 14.5)	1.7 %
Pooled EUS-GE	**5**	**105**	**2.8**	**(0.0, 10.7)**	**4.9 %**
Heterogeneity: *P* = 0.054					
Duodenal SEMS					
JW Kim (2015)	2	29	6.9	(0.8, 22.8)	1.4 %
SY Oh (2015)	10	292	3.4	(1.7, 6.2)	7.2 %
Park (2015)	2	217	0.9	(0.1, 3.3)	6.2 %
Grunwald (2016)	2	100	2.0	(0.2, 7.0)	3.8 %
Kato (2016)	2	171	1.2	(0.1, 4.2)	5.5 %
Khan (2016)	0	30	0.0	(0.0, 11.6)	1.4 %
Okuwaki (2016)	2	31	6.5	(0.8, 21.4)	1.5 %
Sasaki (2016)	0	39	0.0	(0.0, 9.0)	1.8 %
Shin (2016)	1	122	0.8	(0.0, 4.5)	4.4 %
Tsauo (2016)	1	75	1.3	(0.0, 7.2)	3.1 %
Yamao (2016)	6	278	2.2	(0.8, 4.6)	7.1 %
Hori (2017)	3	252	1.2	(0.2, 3.4)	6.7 %
Takahara (2017)	1	41	2.4	(0.1, 12.9)	1.9 %
Tsauo (2017)	1	40	2.5	(0.1, 13.2)	1.8 %
Yoshida (2017)	2	23	8.7	(1.1, 28.0)	1.1 %
Choi (2018)	1	63	1.6	(0.0, 8.5)	2.7 %
Leiyuan (2018)	0	29	0.0	(0.0, 11.9)	1.4 %
Uemura (2018)	2	64	3.1	(0.4, 10.8)	2.7 %
Ge (2019)	0	97	0.0	(0.0, 3.7)	3.7 %
Jang (2019)	5	183	2.7	(0.9, 6.3)	5.7 %
Ratone (2019)	3	219	1.4	(0.3, 4.0)	6.3 %
Alcala-Gonzalez (2020)	1	31	3.2	(0.1, 16.7)	1.5 %
Miwa (2020)	1	31	3.2	(0.1, 16.7)	1.5 %
Yamao (2021)	6	366	1.6	(0.6, 3.5)	8.0 %
Pooled Duodenal SEMS	**54**	**2823**	**1.6**	**(1.1, 2.3)**	**88.5 %**
Heterogeneity: *P* <0.001					
Surgical GJ					
Leiyuan (2018)	0	29	0.0	(0.0, 11.9)	1.4 %
Jang (2019)	4	127	3.1	(0.9, 7.9)	4.5 %
Kouanda (2021)	1	14	7.1	(0.2, 33.9)	0.7 %
Pooled Surgical GJ	**5**	**170**	**2.0**	**(0.0, 7.3)**	**6.6 %**
Heterogeneity: *P* = 0.149					
Pooled all treatments	**64**	**3098**	**1.7**	**(1.2, 2.4)**	**100.0 %**
Heterogeneity: *P* = 0.076					



c

▶ **Fig. 3c** Analysis of safety outcomes. Outcomes for perforation.

Stent-related outcomes

Duodenal SEMS and EUS-GE were reported to have similar rates of stent migration (4.8 % vs. 2.4 % respectively, $P = 0.45$) (▶ **Fig. 3d**, ▶ **Table 2**) and tissue ingrowth (10.9 % vs. 4.2 % [based on one study of EUS-GE], $P = 0.22$) (▶ **Fig. 3e**, ▶ **Table 2**), while stent occlusion was significantly higher for duodenal SEMS (12.9 % vs. 0.5 % respectively, $P = 0.0002$) (▶ **Fig. 3f**, ▶ **Table 2**).

Stent patency (85.9 %) (▶ **Fig. 3g**, ▶ **Table 2**) and tissue overgrowth (5.5 %) (▶ **Fig. 3h**, ▶ **Table 2**) were adequately reported for duodenal SEMS but not for EUS-GE.

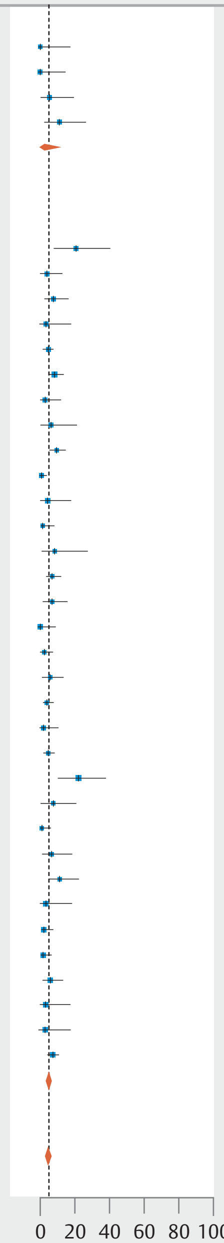
Deaths reported in adverse events section

Using deaths reported in the AEs section of the articles as a surrogate of procedure-related deaths, all three interventions were associated with a similar risk (EUS-GE [1.7 %], vs. duodenal SEMS [0.8 %], and surgical GJ [0.9 %] [$P = 0.89$]) (▶ **Fig. 3i**, ▶ **Table 2**).

Sensitivity analysis

In a sensitivity analysis including 43 studies (33 SEMS, 6 EUS-GE, four surgical GJ) rated as good quality, statistically significant differences from the main analysis included: no significant difference in technical success (99.4 % vs. 95.2 % vs. 99.6 %, $P = 0.097$) and reintervention (18.9 % vs. 11.2 % vs. 23.4 %, $P = 0.082$), and a significant difference in preprocedural GOOSS

Study	# Migration	Total	% Migration	95% CI	Weight
EUS-GE					
Itoi (2016)	0	20	0.0	(0.0, 16.8)	1.3 %
Ge (2019)	0	24	0.0	(0.0, 14.2)	1.5 %
Xu (2020)	2	36	5.6	(0.7, 18.7)	1.9 %
Kouanda (2021)	4	36	11.1	(3.1, 26.1)	1.9 %
Pooled EUS-GE	**6**	**116**	**2.4**	**(0.0, 10.1)**	**6.7 %**
Heterogeneity: *P* = 0.020					
Duodenal SEMS					
JW Kim (2015)	6	29	20.7	(8.0, 39.7)	1.7 %
SH Kim (2015)	2	56	3.6	(0.4, 12.3)	2.5 %
H Lee (2015)	6	79	7.6	(2.8, 15.8)	2.9 %
JE Lee (2015)	1	29	3.4	(0.1, 17.8)	1.7 %
SY Oh (2015)	13	292	4.5	(2.4, 7.5)	4.3 %
Park (2015)	19	217	8.8	(5.4, 13.3)	4.1 %
Sato (2015)	2	61	3.3	(0.4, 11.3)	2.6 %
Trotter (2016)	2	32	6.2	(0.8, 20.8)	1.8 %
Jung (2016)	20	213	9.4	(5.8, 14.1)	4.1 %
Kato (2016)	2	204	1.0	(0.1, 3.5)	4.0 %
Khan (2016)	1	30	3.3	(0.1, 17.2)	1.7 %
Kobayashi (2016)	1	71	1.4	(0.0, 7.6)	2.8 %
Lye (2016)	2	24	8.3	(1.0, 27.0)	1.5 %
J-H Park (1) (2016)	13	189	6.9	(3.7, 11.5)	3.9 %
J-H Park (2) (2016)	5	74	6.8	(2.2 15.1)	2.9 %
Sasaki (2016)	0	39	0.0	(0.0, 9.0)	2.0 %
Shin (2016)	3	122	2.5	(0.5, 7.0)	3.5 %
Tsauo (2016)	4	75	5.3	(1.5, 13.1)	2.9 %
Yamao (2016)	11	278	4.0	(2.0, 7.0)	4.3 %
Bulut (2017)	1	53	1.9	(0.0, 10.1)	2.4 %
Hori (2017)	12	252	4.8	(2.5, 8.2)	4.2 %
Takahara (2017)	9	41	22.0	(10.6, 37.6)	2.1 %
Tsauo (2017)	3	40	7.5	(1.6, 20.4)	2.1 %
Ye (2017)	1	87	1.1	(0.0, 6.2)	3.1 %
Bekheet (2018)	3	46	6.5	(1.4, 17.9)	2.3 %
Choi (2018)	7	63	11.1	(4.6, 21.6)	2.7 %
Leiyuan (2018)	1	29	3.4	(0.1, 17.8)	1.7 %
Ge (2019)	2	97	2.1	(0.3, 7.3)	3.2 %
Kumar (2019)	2	114	1.8	(0.2, 6.2)	3.4 %
Sterpetti (2019)	5	87	5.7	(1.9, 12.9)	3.1 %
Alcala-Gonzalez (2020)	1	31	3.2	(0.1, 16.7)	1.8 %
Miwa (2020)	1	31	3.2	(0.1, 16.7)	1.8 %
Yamao (2021)	26	366	7.1	(4.7, 10.2)	4.5 %
Pooled Duodenal SEMS	**187**	**3451**	**4.8**	**(3.6, 6.1)**	**93.3 %**
Heterogeneity: *P* <0.001					
Pooled all treatments	**193**	**3567**	**4.6**	**(3.5, 5.9)**	**100.0 %**
Heterogeneity: *P* <0.001					



d

▶ **Fig. 3d** Analysis of safety outcomes. Outcomes for stent migration.

score (0.59 vs. 0.60 vs. 1.07, $P = 0.037$) among the SEMS, EUS-GJ and surgical GJ arms respectively.

Publication bias

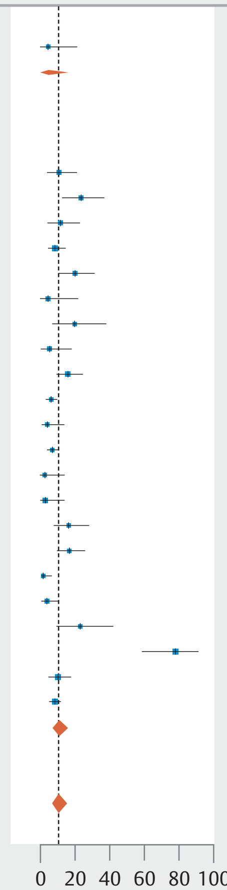
Publication bias was suggested by a significant Begg and Mazumdar test ($p \leq 0.10$) with continuity correction for technical success in duodenal SEMS and surgical GJ, procedure-related complications for EUS-GE and surgical GJ, and overgrowth for duodenal SEMS (**eTable 4**). The Egger test showed a lack of symmetry of the funnel plots (**eFigures 1A–1M**) for technical success (surgical GJ), reintervention (surgical GJ), procedure-related complications (EUS-GE and surgical GJ), bleeding (duodenal SEMS), perforation (EUS-GE), migration (EUS-GJ), overgrowth (duodenal SEMS), and preprocedural and postprocedural GOOSS score (duodenal SEMS for both measures).

Discussion

In this systematic review and meta-analysis of 61 studies including 5772 patients with malignant GOO, duodenal SEMS, EUS-GE and surgical GJ were found to achieve similar rates of clinical success and similar improvement in dietary intake. EUS-GE was reported to have the lowest rate of technical success and (based on one study) lowest recurrence of GOO, while

Study	# Ingrowth	Total	% Ingrowth	95% CI	Weight
EUS-GE					
Ge (2019)	1	24	4.2	(0.1, 21.2)	3.3 %
Pooled EUS-GE	**1**	**24**	**4.2**	**(0.0, 15.6)**	**3.3 %**
Heterogeneity: not applicable					
Duodenal SEMS					
JW Kim (2015)	7	67	10.4	(4.3, 20.3)	4.5 %
SH Kim (2015)	13	56	23.2	(13.0, 36.4)	4.3 %
Sato (2015)	7	61	11.5	(4.7, 22.2)	4.4 %
Kato (2016)	14	171	8.2	(4.5, 13.4)	5.0 %
Kobayashi (2016)	14	71	19.7	(11.2, 30.9)	4.5 %
Lye (2016)	1	24	4.2	(0.1, 21.1)	3.3 %
Okuwaki (2016)	6	31	19.4	(7.5, 37.5)	3.6 %
Sasaki (2016)	2	39	5.1	(0.6, 17.3)	3.9 %
Shin (2016)	19	122	15.6	(9.6, 23.2)	4.9 %
Yamao (2016)	16	278	5.8	(3.3, 9.2)	5.2 %
Bulut (2017)	2	53	3.8	(0.5, 13.0)	4.2 %
Hori (2017)	17	252	6.7	(4.0, 10.6)	5.2 %
Takahara (2017)	1	41	2.4	(0.1, 12.9)	4.0 %
Tsauo (2017)	1	40	2.5	(0.1, 13.2)	3.9 %
Choi (2018)	10	63	15.9	(7.9, 27.3)	4.4 %
Ge (2019)	16	97	16.5	(9.7, 25.4)	4.7 %
Kumar (2019)	1	90	1.1	(0.0, 6.0)	4.7 %
Sterpetti (2019)	3	87	3.4	(0.7, 9.7)	4.7 %
Miwa (2020)	7	31	22.6	(9.6, 41.1)	3.6 %
Mo (2020)	24	31	77.4	(58.9, 90.4)	3.6 %
Wu (2020)	10	101	9.9	(4.9, 17.5)	4.8 %
Yamao (2021)	29	366	7.9	(5.4, 11.2)	5.3 %
Pooled Duodenal SEMS	**220**	**2172**	**10.9**	**(7.5, 14.8)**	**96.7 %**
Heterogeneity: *P* <0.001					
Pooled all treatments	**221**	**2196**	**10.6**	**(7.3, 14.4)**	**100.0 %**
Heterogeneity: *P* <0.001					

e



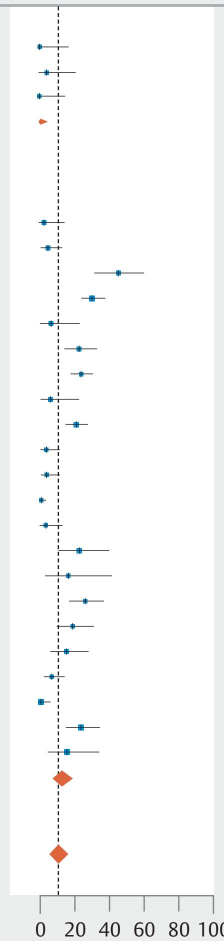
▶ **Fig. 3e** Analysis of safety outcomes. Outcomes for **e** tissue ingrowth.

duodenal SEMS had the highest rate of reintervention. Overall procedure-related AEs were similar among the treatments, but duodenal SEMS had a lower bleeding rate than the other two treatments and a higher rate of stent occlusion than EUS-GE.

Surgical GJ for GOO evolved from an open procedure performed for a patient with a duodenal ulcer in 1884 [14], to the introduction of laparoscopic GJ in 1992 [15]. Laparoscopic GJ has shown improved morbidity and mortality rates compared with the open surgical approach [16], for which delayed gastric emptying rates of 20 % or more and overall complication rates of 25 % to 35 % have been reported [1]. Endoscopic duodenal stenting using SEMS was described in the early 1990 s as a minimally invasive treatment for malignant GOO [17]. While periprocedural outcomes for duodenal stenting are favorable, high reocclusion rates increase the risk of obstruction and need for reintervention over time [18]. A 2020 multicenter prospective study of EUS-GE reported a high rate of AEs including five fatalities [5]. However, because the deaths were reported at one center, these results might be more reflective of an early phase of procedural training than of long-term expected outcomes at centers with endoscopists who are familiar with the technique [19].

Our findings are consistent with the 2021 American Gastroenterology Association Clinical Practice Update on the Optimal Management of the Malignant Alimentary Tract Obstruction [20]. This expert review advised that for surgical candidates with GOO having life expectancy greater than 2 months and good functional status, surgical GJ should be considered, preferably using a laparoscopic approach [20]. EUS-GE was considered an acceptable alternative to surgical GJ depending on the endoscopist's experience, while patients who are not candidates for surgical or endoscopic GE should be considered for an enteral stent [20]. Similarly, the European Society of Gastrointestinal Endoscopy (ESGE) currently recommends EUS-GE performed in an expert setting for malignant GOO, as an alternative to enteral stenting or surgery [21]. EUS-GE is a newer procedure requiring advanced endoscopist expertise; therefore should currently be limited to specialized endoscopy centers with high procedural volume and endoscopists trained in this advanced therapeutic EUS approach. Our results reflect the early stage of EUS-GE procedural development, including its significantly lower reported rate of technical success and higher (but not significantly) rate of deaths reported in the AEs sections of eligible articles. After wider dissemination and increas-

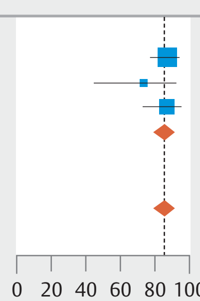
Study	# Stent occlusion	Total	% Stent occlusion	95% CI	Weight
EUS-GE					
Itoi (2016)	0	20	0.0	(0.0, 16.8)	3.4 %
Chen (2017)	1	25	4.0	(0.1, 20.4)	3.6 %
Ge (2019)	0	24	0.0	(0.0, 14.2)	3.5 %
Pooled EUS-GE	**1**	**69**	**0.5**	**(0.0, 4.2)**	**10.4 %**
Heterogeneity: *P* = 0.275					
Duodenal SEMS					
JW Kim (2015)	1	38	2.6	(0.1, 13.8)	3.8 %
H Lee (2015)	4	79	5.1	(1.4, 12.5)	4.2 %
KE Lee (2015)	25	55	45.5	(32.0, 59.4)	4.0 %
Park (2015)	66	217	30.4	(24.4, 37.0)	4.4 %
Trotter (2015)	2	29	6.9	(0.8, 22.8)	3.7 %
Grunwald (2016)	21	91	23.1	(14.9, 33.1)	4.2 %
Jung (2016)	51	213	23.9	(18.4, 30.3)	4.4 %
Khan (2016)	2	30	6.7	(0.8, 22.1)	3.7 %
J-H Park (1) (2016)	40	189	21.2	(15.6, 27.7)	4.4 %
J-H Park (2) (2016)	3	74	4.1	(0.8, 11.4)	4.2 %
Tsauo (2016)	3	75	4.0	(0.8, 11.2)	4.2 %
Yamao (2016)	3	278	1.1	(0.2, 3.1)	4.4 %
Bulut (2017)	2	53	3.8	(0.5, 13.0)	4.0 %
Chen (2017)	8	35	22.9	(10.4, 40.1)	3.8 %
Kim (2017)	3	18	16.7	(3.6, 41.4)	3.3 %
Ye (2017)	23	87	26.4	(17.6, 37.0)	4.2 %
Choi (2018)	12	63	19.0	(10.2, 30.9)	4.1 %
Uemura (2018)	10	64	15.6	(7.8, 26.9)	4.1 %
Ge (2019)	7	97	7.2	(3.0, 14.3)	4.2 %
Kumar (2019)	1	90	1.1	(0.0, 6.0)	4.2 %
Sterpetti (2019)	21	87	24.1	(15.6, 34.5)	4.2 %
Alcala-Gonzalez (2020)	5	31	16.1	(5.5, 33.7)	3.7 %
Pooled Duodenal SEMS	**313**	**1993**	**12.9**	**(7.9, 18.8)**	**89.6 %**
Heterogeneity: *P* < 0.001					
Pooled all treatments	**314**	**2062**	**10.9**	**(6.5, 16.2)**	**100.0 %**
Heterogeneity: *P* < 0.001					



f

▶ **Fig. 3f** Analysis of safety outcomes. Outcomes for stent occlusion.

Study	# Stent patency	Total	% Stent patency	95% CI	Weight
Duodenal SEMS					
H Lee (2015)	69	79	87.3	(78.0, 93.8)	56.4 %
D Oh (2015)	11	15	73.3	(44.9, 92.2)	10.7 %
Bekheet (2018)	40	46	87.0	(73.7, 95.1)	32.9 %
Pooled Duodenal SEMS	**120**	**140**	**85.9**	**(79.7, 91.2)**	**100.0 %**
Heterogeneity: *P* = 0.432					
Pooled all treatments	**120**	**140**	**85.9**	**(79.7, 91.2)**	**100.0 %**
Heterogeneity: *P* = 0.432					



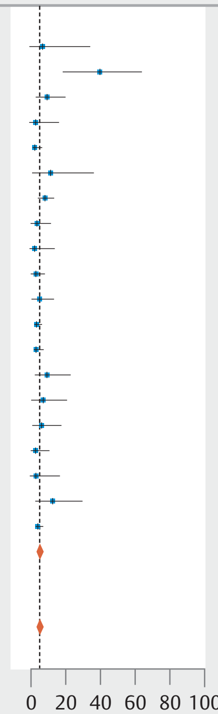
g

▶ **Fig. 3g** Analysis of safety outcomes. Outcomes for stent patency.

ing familiarity among endoscopists, EUS-GE could potentially be used more frequently as a less invasive approach compared to surgery.

There are several considerations that go into selection of what treatment approach is chosen for an individual patient with malignant GOO. Reviewing the cross-sectional imaging (ideally a CT scan) to evaluate for proximity of the small bowel to the stomach, and quantity of intervening ascites (which, should give pause at least with early use of EUS-GE) [22]. Carcinomatosis with ascites predicts unfavorable long-term clinical outcomes in patients undergoing SEMS placement for malignant GOO [23, 24], and a large amount of ascites is currently

Study	# Overgrowth	Total	% Overgrowth	95% CI	Weight
Duodenal SEMS					
Chiu (2015)	1	14	7.1	(0.2, 33.9)	1.5 %
D Oh (2015)	8	20	40.0	(19.1, 63.9)	2.0 %
Sato (2015)	6	61	9.8	(3.7, 20.2)	4.7 %
Trotter (2015)	1	32	3.1	(0.1, 16.2)	2.9 %
Kato (2016)	5	171	2.9	(1.0, 6.7)	8.0 %
Okuwaki (2016)	2	17	11.8	(1.5, 36.4)	1.7 %
J-H Park (1) (2016)	16	189	8.5	(4.9, 13.4)	8.3 %
J-H Park (2) (2016)	3	74	4.1	(0.8, 11.4)	5.3 %
Sasaki (2016)	1	39	2.6	(0.1, 13.5)	3.4 %
Shin (2016)	4	122	3.3	(0.9, 8.2)	6.9 %
Tsauo (2016)	4	75	5.3	(1.5, 13.1)	5.3 %
Yamao (2016)	11	278	4.0	(2.0, 7.0)	9.4 %
Hori (2017)	10	252	4.0	(1.9, 7.2)	9.1 %
Takahara (2017)	4	41	9.8	(2.7, 23.1)	3.5 %
Tsauo (2017)	3	40	7.5	(1.6, 20.4)	3.5 %
Bekheet (2018)	3	46	6.5	(1.4, 17.9)	3.9 %
Choi (2018)	2	63	3.2	(0.4, 11.0)	4.8 %
Miwa (2020)	1	31	3.2	(0.1, 16.7)	2.9 %
Mo (2020)	4	31	12.9	(3.6, 29.8)	2.9 %
Yamao (2021)	16	366	4.4	(2.5, 7.0)	10.1 %
Pooled Duodenal SEMS	**105**	**1962**	**5.5**	**(4.1, 7.1)**	**100.0 %**
Heterogeneity: $P = 0.015$					
Pooled all treatments	**105**	**1962**	**5.5**	**(4.1, 7.1)**	**100.0 %**
Heterogeneity: $P = 0.015$					



h

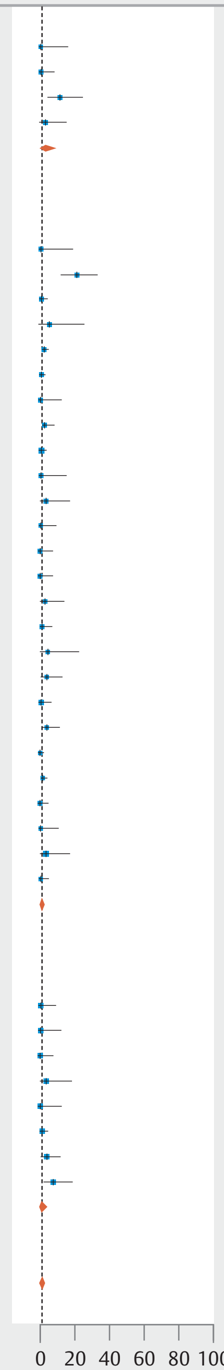
▶ **Fig. 3h** Analysis of safety outcomes. Outcomes for tissue overgrowth.

considered by some to be an absolute contraindication to EUS-GE [25]. Both covered and uncovered enteral SEMS have been utilized in the management of malignant GOO, although, covered SEMS are not universally available worldwide (unavailable in the US, while available in Asia and Europe). Compared to covered SEMS, uncovered duodenal SEMS are generally thought to have lower risk of migration and lower risk of impacting biliary and pancreatic drainage when it covers the papilla, but have higher risk of reobstruction from tumor ingrowth [26, 27]. Hence, the following factors could be considered in the choice of covered vs uncovered SEMS: 1) anticipated life expectancy and aggressiveness of the tumor; 2) extraluminal vs intraluminal tumors (tumor ingrowth is less of a problem in extrinsic tumors); 3) location of the tumor relative to the papilla; and 4) availability by region/country.

Life expectancy greater than 2 to 3 months should encourage the selection of an EUS-GE, due to its lower rates of reintervention, and although not borne out in this meta-analysis, a likely higher rate of initial clinical success as reported in some previous studies and based on our experience [22, 28]. For patients with combined obstruction of the bile duct and duodenum (common occurrence in periampullary malignancies) at centers with adequate endoscopic expertise, EUS-GE may have an advantage over endoscopic stenting because the site of intervention is away from the tumor site [29]. Therefore, the problem of reocclusion of the stent as a result of tumor overgrowth or ingrowth is unlikely compared to endoscopic enteral stenting [30]. In summary, when expertise is available, EUS-GE can be used in most cases for the treatment of malignant GOO as a less invasive alternative to surgery. However, patients with anticipated short survival, widespread metastasis, diffuse malignant infiltration of the gastric wall, or uncontrolled ascites are better approached with SEMS. Surgery can be reserved for patients with expected prolonged survival in whom less invasive procedures are not feasible or have failed.

Our study has strengths and limitations. In the absence of a 3-arm RCT, this meta-analysis compares the two most common palliative treatments for malignant GOO (duodenal stenting using SEMS and surgical GJ), as well as the newer EUS-GE procedure. Our eligibility criteria were relatively generous to include sufficient data to compare all three treatments. While this allowed an informative review, the quality of some studies included may be lower than reviews with stricter inclusion criteria [1]. Baseline characteristics among the three treatment arms were not equal for age and proportion of males; however, similarity of preprocedural GOOSS scores suggested that patients in all three treatment arms had similarly low levels of oral intake at baseline. Our analysis focused on palliative treatment of symptoms associated with malignant GOO, not on the treatment of associated conditions such as biliary obstruction, which is estimated to occur in 40 % to 92 % of patients with malignant GOO [31]. EUS-GE can be performed using at least three different techniques including direct EUS-GE, device-assisted EUS-GE, and EPASS double balloon-occluded gastrojejunostomy bypass [25]. Outcomes for specific techniques might vary compared to findings for our combined "EUS-GE" category. Time to post-

Study	# Deaths	Total	% Deaths	95% CI	Weight
EUS-GE					
Ge (2019)	0	22	0.0	(0.0, 15.4)	1.7 %
Kerdsirichairat (2019)	0	48	0.0	(0.0, 7.4)	2.6 %
Kastelijin (2020)	5	45	11.1	(3.7, 24.1)	2.5 %
Xu (2020)	1	36	2.8	(0.1, 14.5)	2.3 %
Pooled EUS-GE	**6**	**151**	**1.7**	**(0.0, 8.7)**	**9.0 %**
Heterogeneity: *P* = 0.005					
Duodenal SEMS					
Chiu (2015)	0	18	0.0	(0.0, 18.5)	1.5 %
JW Kim (2015)	14	67	20.9	(11.9, 32.6)	2.9 %
H Lee (2015)	0	102	0.0	(0.0, 3.6)	3.3 %
D Oh (2015)	1	20	5.0	(0.1, 24.9)	1.6 %
SY Oh (2015)	6	292	2.1	(0.8, 4.4)	3.9 %
Park (2015)	1	217	0.5	(0.0, 2.5)	3.8 %
Trotter (2015)	0	29	0.0	(0.0, 11.9)	2.0 %
Grunwald (2016)	2	100	2.0	(0.2, 7.0)	3.3 %
Kato (2016)	0	125	0.0	(0.0, 2.9)	3.4 %
Lye (2016)	0	24	0.0	(0.0, 14.2)	1.8 %
Okuwaki (2016)	1	31	3.2	(0.1, 16.7)	2.1 %
Sasaki (2016)	0	39	0.0	(0.0, 9.0)	2.3 %
Bulut (2017)	0	53	0.0	(0.0, 6.7)	2.7 %
Takahara (2017)	0	41	0.0	(0.0, 8.6)	2.4 %
Tsauo (2017)	1	40	2.5	(0.1, 13.2)	2.4 %
Ye (2017)	1	87	1.1	(0.0, 6.2)	3.1 %
Yoshida (2017)	1	23	4.3	(0.1, 21.9)	1.8 %
Bekheet (2018)	2	55	3.6	(0.4, 12.5)	2.7 %
Choi (2018)	0	63	0.0	(0.0, 5.7)	2.8 %
Ge (2019)	3	78	3.8	(0.8, 10.8)	3.0 %
Jang (2019)	0	183	0.0	(0.0, 2.0)	3.7 %
Ratone (2019)	3	220	1.4	(0.3, 3.9)	3.8 %
Sterpetti (2019)	0	87	0.0	(0.0, 4.2)	3.1 %
Alcala-Gonzalez (2020)	0	36	0.0	(0.0, 9.7)	2.3 %
Miwa (2020)	1	31	3.2	(0.1, 16.7)	2.1 %
Mo (2020)	0	90	0.0	(0.0, 4.0)	3.2 %
Pooled Duodenal SEMS	**37**	**2151**	**0.8**	**(0.2, 1.7)**	**70.9 %**
Heterogeneity: *P* < 0.001					
Surgical GJ					
Park (2015)	0	39	0.0	(0.0, 9.0)	2.3 %
Lye (2016)	0	30	0.0	(0.0, 11.6)	2.1 %
Ojima (2017)	0	53	0.0	(0.0, 6.7)	2.7 %
Perez-Miranda (2017)	1	29	3.4	(0.1, 17.8)	2.0 %
Yoshida (2017)	0	30	0.0	(0.0, 11.6)	2.1 %
Jang (2019)	1	127	0.8	(0.0, 4.3)	3.4 %
Ramos (2019)	2	60	3.3	(0.4, 11.5)	2.8 %
Yildirim (2020)	4	53	7.5	(2.1, 18.2)	2.7 %
Pooled Surgical GJ	**8**	**421**	**0.9**	**(0.1, 2.9)**	**20.0 %**
Heterogeneity: *P* = 0.031					
Pooled all treatments	**51**	**2723**	**0.9**	**(0.4, 1.7)**	**100.0 %**
Heterogeneity: *P* < 0.001					



i

▶ **Fig. 3i** Analysis of safety outcomes. Outcomes for deaths reported in AE section.

procedure return to oral intake and resumption of chemotherapy, and SEMS migration rates by postprocedure chemotherapy status could not be analyzed because they were incompletely reported or not reported among studies. Because it is a newer technique, limited data on EUS-GE were available for some estimates, e. g. only one EUS-GE study was represented in the analysis of GOO recurrence. Although available in some studies, data on mortality and survival rates was usually missing or of very low quality as has been reported previously [1]. Therefore, our estimated mortality rates may have low generalizability. Incomplete reporting (e. g. outcomes reported only in technically successful cases or other patient subgroup) was also a barrier to comprehensive data on all outcomes.

▶ **Table 2** Summary of efficacy and safety meta-analytic outcomes for three treatments for malignant gastric outlet obstruction.

	Duodenal SEMS			EUS-GJ			Surgical GJ			*P* value[1]
	N studies	N patients	% (95 % CI)	N studies	N patients	% (95 % CI)	N studies	N patients	% (95 % CI)	
Efficacy outcomes										
▪ Technical success	45	4413	99.4 % (98.9 % to 99.8 %)	8	245	95.3 % (89.3 % to 98.9 %)	13	564	99.9 % (99.5 % to 100.0 %)	0.0048
▪ Clinical success	45	4590	88.9 % (86.7 % to 90.9 %)	8	245	89.0 % (82.3 % to 94.3 %)	13	588	92.3 % (86.9 % to 96.3 %)	0.49
▪ Preprocedural GOOSS score	27	2655	0.62 (0.50 to 0.73)	2	65	0.60 (0.44 to 0.76)	6	215	0.68 (0.52 to 0.83)	0.78
▪ Postprocedural GOOSS score	19	2184	2.27 (2.12 to 2.41)	2	59	2.57 (1.83 to 3.32)	5	180	2.20 (1.48 to 2.92)	0.71
▪ Recurrence of GOO	11	573	28.7 % (19.7 % to 38.6 %)	1	25	4.0 % (0.0 % to 15.0 %)	8	342	16.9 % (11.6 % to 23.0 %)	0.0036
▪ Reintervention	33	2963	20.3 % (16.9 % to 23.9 %)	4	129	11.2 % (4.9 % to 19.6 %)	9	418	12.6 % (6.6 % to 20.1 %)	0.041
Safety outcomes										
▪ Any procedure-related adverse event	43	4285	18.7 % (14.7 % to 23.1 %)	6	189	21.9 % (16.3 % to 28.1 %)	16	746	23.8 % (18.6 % to 29.5 %)	0.32
▪ Bleeding	25	2854	1.7 % (0.9 % to 2.7 %)	4	141	2.9 % (0.2 % to 8.6 %)	9	412	5.2 % (3.2 % to 7.5 %)	0.0048
▪ Perforation	24	2823	1.6 % (1.1 % to 2.3 %)	3	105	2.8 % (0.0 % to 10.7 %)	3	170	2.0 % (0.0 % to 7.3 %)	0.88
▪ Stent migration	33	3451	4.8 % (3.6 % to 6.1 %)	4	116	2.4 % (0.0 % to 10.1 %)	0	–	–	0.45
▪ Stent occlusion	22	1993	12.9 % (7.9 % to 18.8 %)	3	69	0.5 % (0.0 % to 4.2 %)	0	–	–	0.0002
▪ Tissue ingrowth	22	2172	10.9 % (7.5 % to 14.8 %)	1	24	4.2 % (0.0 % to 15.6 %)	0	–	–	0.22
▪ Stent patency	3	140	85.9 % (79.7 % to 91.2 %)	0	–	–	0	–	–	–
▪ Tissue overgrowth	20	1962	5.5 % (4.1 % to 7.1 %)	0	–	–	0	–	–	–
▪ Laparoscopic complication	0	–	–	0	–	–	5	196	16.1 % (6.8 % to 28.2 %)	–
▪ Deaths reported in AE section	26	2151	0.8 % (0.2 % to 1.7 %)	4	151	1.7 % (0.0 % to 8.7 %)	8	421	0.9 % (0.1 % to 2.9 %)	0.89

▶ **Table 2** (Continuation)

	Duodenal SEMS			EUS-GJ			Surgical GJ			*P* value[1]
	N studies	N patients	% (95 % CI)	N studies	N patients	% (95 % CI)	N studies	N patients	% (95 % CI)	
▪ Total unique studies or patients	47	4711	–	8	243	–	18	818	–	

SEMS, self-expanding metal stent; EUS-GJ, endoscopic ultrasound-guided gastrojejunostomy; GOO, gastric outlet obstruction; GOOSS, Gastric Outlet Obstruction Scoring System; AE, adverse event.
[1] *P* value for comparison of duodenal SEMS vs. EUS-GJ vs. surgical GJ.

Conclusions

Duodenal SEMS, EUS-GE and surgical GJ achieve similar rates of clinical success and improved dietary intake. Safety profiles were similar except that bleeding was less common and reintervention was more common for duodenal SEMS. Based on less data than the other two treatments, EUS-GE appears to be a promising treatment for patients with malignant GOO for whom surgery is contraindicated or less desirable.

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Competing interests

Dr. Benias is a consultant for Boston Scientific and Fujifilm. Dr. Kozarek receives research support from Boston Scientific and the National Institutes of Health. Dr. Peetermans, Mr. McMullen and Ms. Gjata are full-time employees of Boston Scientific Corporation. Dr. Irani is a consultant for Boston Scientific and Gore.

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