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Meta-Analysis

What is the benefit of endoscopic ultrasound-guided gastrojejunal anastomosis for patients with benign gastric outlet obstruction? A systematic review with meta-analysis

Giacomo Emanuele Maria Rizzo[a,*], Antonio Facciorusso[b], Cecilia Binda[c], Stefano Mazza[d], Marcello Maida[e,f], Gabriele Rancatore[a], Lucio Carrozza[a,g], Dario Ligresti[a], Aurelio Mauro[d], Andrea Anderloni[d], Carlo Fabbri[c], Ilaria Tarantino[a], and the I-EUS Working Group

[a] Endoscopy Service, Department of Diagnostic and Therapeutic Services, IRCCS - ISMETT, Palermo, Italy, University of Pittsburgh Medical Center Italy (UPMCI), Palermo, Italy
[b] Gastroenterology Unit, Department of Medical Sciences, University of Foggia, Foggia, Italy
[c] Gastroenterology and Digestive Endoscopy Unit, Forlì-Cesena Hospitals, AUSL Romagna, Forlì-Cesena, Italy
[d] Digestive Gastroenterology and Endoscopy unit, IRCCS Foundation, Policlinico San Matteo, Pavia, Italy
[e] Department of Medicine and Surgery, University of Enna 'Kore', Enna, Italy
[f] Gastroenterology Unit, Umberto I Hospital, Enna, Italy
[g] Gastroenterology Unit, Papardo Hospital, Messina, Italy

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ABSTRACT

Background: Gastric outlet obstruction for benign indications (bGOO) is an uncommon condition, typically treated with surgery when medical therapy or endoscopic treatments fail. At present, endoscopic ultrasound (EUS)-guided gastrojejunostomy (GJ) may prove to be an effective alternative.
Aims: We performed a systematic review with meta-analysis evaluating outcomes of EUS-GJ for bGOO.
Methods: A comprehensive search was conducted up to February 2025. Pooled estimates were obtained using a random-effects model. Study quality was evaluated using the Newcastle–Ottawa quality scale. Heterogeneity was evaluated with I^2 statistic. Technical success, clinical success, recurrence rate, and adverse events (AE) rate were the main outcomes.
Results: Fifteen (15) studies, including a total of 376 patients, were identified. Pooled technical success was 95.8 % (CI 95 %, 93.8 %-97.8 %, I^2 =0 %), while clinical success was 93.4 % (CI 95 %, 90.4 %-96.5 %, I^2= 31.83 %). Pooled recurrence rate was 11.6 % (CI 95 %, 5.5 %-17.7 %, I2=32.36 %). The pooled rate of AE was 11.6 % (CI 95 %, 6.8–16.5 %, I^2 = 57.18 %). Subgroup analyses found differences in safety when AE classification was used (17 % use vs. 6 % no use, $p = 0.02$) and based on quality of studies (low 22 % vs. moderate 10 % vs. high 3 %, $p = 0.04$).
Conclusion: In conclusion, our findings show that EUS-GJ is effective and safe in those patients with bGOO in whom other endoscopic treatments fail, and surgery is not an option or could be performed as bridge-to-surgery. Our results suggest that safety is influenced by the use of AE classification and the quality of studies.

1. Introduction

Gastric outlet obstruction (GOO) commonly occurs in advanced malignancies (mGOO) involving and infiltrating the duodenum and pylorus (pancreatic, duodenal, biliary, gastric or ampullary cancers), sometimes concurrently arising with both duodenal and biliary obstruction [1,2]. GOO may also occur in patients with benign diseases (bGOO), and requires interventions to overcome the symptoms [3]. GOO causes debilitating symptoms such as nausea, vomiting, inability to tolerate oral intake, and prevents adequate nutritional intake, influencing severely on the patient's quality of life (QoL) [4]. At present, endoscopic ultrasound (EUS)-guided gastroejejunostomy (GJ) is a well-known technique used for the treatment of mGOO, showing encouraging results [5–8]. The rationale for us-

* Corresponding author at: Endoscopy Service, Department of Diagnostic and Therapeutic Services, IRCCS - ISMETT Palermo, Italy.
E-mail address: grizzo@ismett.edu (G.E.M. Rizzo).

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ing endoscopic treatment lies in its lower risk of complications and morbidity compared to surgery [9]. Moreover, EUS-GJ may also have an additional role as a bridging procedure (e.g., for nutritional optimization) in the management of bGOO for those patients who eventually require subsequent surgery. At the moment, only small specific studies have been published on bGOO [10], and the proper use of EUS-GJ is still under evaluation for these patients, so larger sample sizes are essential to reach conclusions on technical and clinical outcomes in this setting. Therefore, we performed a systematic review with meta-analysis evaluating technical success, clinical success, recurrence rate, and safety of EUS-GJ in cases of benign GOO.

2. Materials and methods

This systematic review with meta-analysis was undertaken to evaluate outcomes of EUS-GJ for those patients suffering from benign GOO. The study followed the recommendations of the Cochrane Collaboration Group [11], according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [12]. We searched for studies among the main international databases, such as PubMed/Medline, Embase, Web of Science Core Collection (Clarivate), and Cochrane Library up to February 2025, with no lower date limit. These databases were systematically searched by two independent reviewers (G.E.M.R. and I.T.) for studies assessing technical success of EUS-GJ in cases of bGOO. There were no restrictions on publication status. The database searches were supplemented with hand-cross literature searches of reference lists from potentially eligible articles and, furthermore, in international conference platforms to find additional eligible abstracts. The strings used for the search included terms such as GOO, benign gastric outlet obstruction, EUS-GJ, gastrojejunostomy, gastroenterostomy, EUS-guided anastomosis, etc. (details in **Supplementary Materials**).

2.1. Inclusion and exclusion criteria

Two authors (G.E.M.R. and S.M.) assessed the eligibility of the studies, and discordances in eligibility assessment of individual studies were solved by discussion with a third author (I.T.). Studies were eligible for the meta-analysis if 1) they included patients with bGOO, 2) patients with bGOO who underwent EUS-guided gastroenteroanastomosis (EUS-GJ), 3) outcomes of interest (technical and clinical success) were reported 4) data regarding patients with bGOO were extractable in cases of cohorts with mixed etiologies (malignant and benign). Exclusion criteria included non-human studies, case-control studies, case reports, case series (defined as fewer than 5 patients), review articles, non-English publications, and studies in which essential information was missing or could not be obtained from the authors.

2.2. Data extraction

Two authors (G.E.M.R. and S.M.) independently extracted study level and patient-level variables from all the eligible studies. Study-level data included the name of the first author, publication year, design, number of centers and duration of follow-up. Patient-level and technical data included etiology of the benign disease, type of lumen apposing metal stent (LAMS) placed, technique of EUS-GJ, and time to oral feeding, when available.

2.3. Outcomes

The primary outcome was technical success of EUS-GJ with LAMS placement. Secondary outcomes were clinical success, safety, and recurrence of GOO symptoms. Definitions of technical success, clinical success, and the use of classifications for reporting AE were extracted. Clinical success had two definitions: 1) a definition specifying the type of oral diet tolerated after procedure ("*definition 1*"); 2), and the resolution of symptoms including tolerating oral feeding after procedure without specifying what kind of diet ("*definition 2*").

2.4. Quality assessment

The Newcastle Ottawa Scale (NOS) was used to assess the quality of the studies [13], with discrepancies resolved by consensus among researchers. Each parameter in the NOS scale was scored 0 or 1 or 2. Studies with total scores of 8 or greater were classified as high quality, those with scores between 6 and 7 were classified as moderate quality, and scores lower than 5 were classified as low quality.

2.5. Statistical analysis

Pooled estimates were obtained using a random-effects model with the generic inverse variance method. The method of moments estimator, proposed by DerSimonian and Laird, was used to assess between-study variance [14,15]. Meanwhile, heterogeneity among study-specific estimates was assessed using the inconsistency index (I^2) [16], and cut-off points of $<$30 %, 30–59 %, 60–75 %, and $>$75 % were considered to suggest low, moderate, substantial, and considerable heterogeneities, respectively. Study characteristics were summarized using descriptive statistics. The Hozo method was used to convert median to mean age, and weighted mean according to sample size of each study was used to report descriptive statistics. We considered a priori subgroups based on study-level variables (number of centers, type of publication, definition of clinical success, presence of classification of AE, and study quality). Cochran's Q test was used for evaluating significant differences among the subgroups. We calculated pooled rates with 95 % confidence intervals (CI) for all outcomes of interest. Cochran's Q test (interaction test) was used for subgroup differences, and a p value $<$0.05 was considered statistically significant. Because of the low number of studies (and patients) included in the meta-analysis, meta-regression analysis was not done, as recommended by the Cochrane Handbook for Systematic Reviews of Interventions [16]. Funnel plotting was not used to evaluate potential publication bias due to its inaccuracy for proportions, as reported by Hunter et al. [17]; as a result, the Doi plot was used for evaluation of publication bias [18]. We used a combination plot (Doi-Galbraith plot) for a graphical overview of both study symmetry and heterogeneity at a glance. The LFK index was used to quantify the asymmetry of the Doi plot. All statistics were processed using the statistical software STATA (Statistics and data science, version 18, College Station, Texas, 77,845, USA).

3. Results

Our primary search identified 70 articles. We excluded 39 studies because they were not consistent with our aim, including reviews, editorials, and letters to the editor. In addition, duplicate articles were removed. After the identification and screening process, 22 of the initial studies were reviewed for inclusion and exclusion criteria **(Supplementary Figure S1).** Finally, 15 studies, including a total of 376 patients, were selected for meta-analysis. Eleven studies [10,19–28] were full publications, all of which were retrospective, four single center [22,24,26,29], three bicenter [19,21,25], and four multicenter [10,20,23,28]. Four studies were abstracts [29–32], three of which recently presented at two of the main international consensus conferences worldwide (European Society of Gastroin-

testinal Endoscopy [ESGE] and Days and Digestive Diseases Week [DDW] 2024).

3.1. Clinical and technical findings

Weighted mean age was 59.0 years. Etiology varied across the studies, moving from more common chronic pancreatitis (CP) to strictures either due to peptic ulcers or at post-surgical anastomotic site (Table 1). Two studies did not report the type of LAMS placed [29,31], while all the others used Axios type (Boston Scientific). Six studies [19,20,22,24,26,28] specified whether patients had previous endoscopic treatments (endoscopic dilation or enteral stenting; **Supplementary Table 1**). The definition of technical success was conceptually homogeneous among the studies reporting it (defined mostly as "the adequate positioning and deployment of the stent as determined endoscopically and confirmed radiologically"), while the definition of clinical success differed among studies. Specifically, 7 studies [21,22,24,25,27,28,30] reported definition 1, and eight studies [10,19,20,26,29–32] definition 2 (**Supplementary Table 2**). Five studies did not report any AE classification system, while 7 [20–22,24–26,28] used the ASGE (American Society of Gastrointestinal Endoscopy) lexicon grading system [33], and two [10,27] applied the AGREE classification for severity of AE [34]. Kahaleh et al. [23] used a "Classification of Adverse Events as per Surgical Complications Grade Definition". More details regarding AE are reported in **Supplementary Table 3**. Six studies [19,20,24,26,28,30] reported the rate of LAMS dilation, ranging from 100 % in two studies [19,24] to 9.1 % in one of the latest studies [28]. The stent removal time was reported in 5 studies [10,22,26,28,32] either as mean or median. The weighted mean of stent removal time among studies was 136.16 days after converting the median applying the Hozo method.

3.2. Outcomes

3.2.1. Technical success

The pooled technical success was 95.8 % (CI 95 %, 93.8 %–97.8 %, Fig. 1A), in the absence of heterogeneity (I^2=0 %). Thirteen studies [10,19,20,22,24–30,32] reported the technique used for EUS-GJ, including balloon-assisted, oro-jejunal tube-assisted, EUS-guided double-balloon-occluded gastrojejunostomy bypass (EPASS), direct gastroenterostomy, and free-hand technique. Subgroups analysis of technical success showed no significant differences among subgroups (**Supplementary Figure S2**).

3.2.2. Clinical success and recurrence

The pooled clinical success was 93.4 % (CI 95 %, 90.4 %–96.5 %, Fig. 1B), with a low heterogeneity (I^2= 31.83 %). According to the type of publication, the pooled clinical success for studies in abstract form was 88.3 % (CI 95 %, 80.8 %–95.9 %, I^2=54.67 %), while it was 96.3 % (CI 95 %, 93.7 %–99 %, I^2=0 %) for full publications (p = 0.05) (Fig. 2A). Subgroups according to study design showed that studies involving one or two centers had a pooled clinical success of 97.1 % (CI 95 %, 94.3 %–100 %, I^2=0 %), while multicenter studies showed a clinical success of 89.3 % (CI 95 %, 83.7 %–94.8 %, I^2=48.32 %, p = 0.014, Fig. 2**B**). Recurrence of symptoms was reported in 8 studies [10,19–22,24,28,32], showing a pooled rate of 11.6 % (CI 95 %, 5.5 %–17.7 %, I^2=32.36 %, Fig. 3) in a weighted mean of follow-up of 409.64 days. Mean follow-up varied across the studies, moving from a mean of 150 days to 832 days. No significant differences were identified in the subgroup analysis regarding the pooled recurrence rate (**Supplementary Figure S4**).

3.2.3. Safety

Safety, in terms of pooled AE rate , was 11 .6 % (CI 95 % , 6.8–16.5 %, Fig. 4A), with a substantial heterogeneity (I^2= 57.18 %). Details of reported AE are shown in Supplementary **Table 3**. According to subgroup analysis, the pooled AE rate was 8.6 % (CI 95 %, 3.2 %–14 %, I^2=21.91 %) in studies involving one or two centers, while it was 7.4 % (CI 95 %, 4.5 %–10.4 %, I^2=74.63 %) among multicenter studies (**Supplementary Figure S5A**). The pooled AE rate was 7 % (CI 95 %, 3 %–10. %) in the subgroup of abstracts, while it was 16 % (CI 95 %, 8 %–25 %) among full publication studies, resulting significantly different (p = 0.04, **Supplementary Figure S5B**). Studies using an AE classification system (e.g., ASGE or AGREE) had a pooled AE rate of 17 % (CI 95 %, 9 %–26 %, I^2=68.93 %), which was significantly different (p = 0.002) from those studies which did not report it (6 %, CI 95 %, 3 %–10 %, I^2=0 %, Fig. 4B).

3.3. Quality assessment

According to the NOS, 1 [10] study was of high quality, 12 studies [19–22,24–28,30–32] were of moderate quality, and 2 of low quality [23,29] (**Supplementary Table 4**). When evaluating clinical success among the subgroups according to quality, those studies with moderate quality showed a clinical success of 92 % (CI 95 %, 87 %–96 %, I^2=44.5 %), which was not significantly different (p = 0.39) compared to those with low quality (97 %, CI 95 %, 91 %–100 %, I^2=0 %, **Supplementary Figure S6**). When evaluating safety according to quality, significant differences were seen (p = 0.043) among studies with moderate quality (AE rate: 9.9 %, CI 95 %, 6.5 %–13.3 %, I^2=0 %), high quality (1 study, 2.6 %, CI 95 %, 0 %–7.5 %) and low quality studies (21.5 %, CI 95 %, 0 %–59.9 %, I^2=93.9 %, **Supplementary Figure S7**).

3.4. Publication bias

Graphical evaluation of the combined Doi-Galbraith plots showed asymmetric distribution of the studies in all the outcomes, suggesting the presence of publication bias. The Doi-Galbraith plot of technical success is shown in Fig. 5, while those regarding clinical success, recurrence, and safety are reported in the Supplementary Materials (**Supplementary Figure S8**). Moreover, the LFK index was −0.03 for technical success, and −0.28 for clinical success, suggesting the absence of publication bias [35].

4. Discussion

EUS-GJ for the treatment of GOO is spreading globally, particularly in cases of malignancy, helping to effectively achieve relief of symptoms, and quickly focus on oncologic outcomes [8]. Data regarding the application of EUS-GJ for bGOO have also been slowly increasing worldwide since 2015, when Khashab et al. treated 7 patients with EUS-GJ [19]. Thus far, benign conditions causing GOO have rarely been treated with EUS-GJ, likely due to the low incidence and lack of robust data regarding this specific clinical setting, especially regarding long-term outcomes, and the off-label use of LAMS. Our systematic review highlighted that benign conditions causing GOOs are post-ulcer stenosis, acute pancreatitis, pancreatic fluid collections (PFCs), radiation-induced stricture, caustic ingestion, benign tumor, Crohn's disease, and eosinophilic gastroenteritis [36,37]. Obstruction is the least common complication of peptic ulcer disease, occurring in approximately 2 % of cases. Even in patients with Zollinger-Ellison syndrome, 10 % of whom develop duodenal or pyloric strictures, GOO rarely occurs [38]. Chronic pancreatitis and, to a lesser extent, severe acute pancreatitis, can cause gastrointestinal (GI) or duodenal obstruction [10], so we more commonly found CP as cause of bGOO among the included studies. Notably, GI obstruction is rare as a clinical presentation in cases of CP compared to other CP-related complications

Table 1
Characteristics of the studies included in the meta-analysis.

First author, Year	Design	Overall patients, n	Patients with bGOO, n	Age, years Mean (SD or IQR)	Male sex, n (%)	Etiology of bGOO	Type of LAMS	Follow-up length	Quality assessment
Khashab, 2015	Retrospective, bicenter	10	7	49.85 ± 3.72	5 (71.4 %)	Chronic pancreatitis: 3; NSAID stricture: 1; Peptic stricture: 1 Duodenal Hematoma: 1; SMAS: 1	Axios, 15 mm	Mean 150 days (range 96–227 days)	6
Chen, 2018	Retrospective, multicenter	26	26	57.7 ± 13.9	14 (53.8 %)	Chronic pancreatitis: 11; Surgical anastomosis: 6; Peptic ulcer disease: 5; Acute pancreatitis: 1; SMAS: 1.	Axios 15 mm (2, 7.7 %); Hot Axios 15 mm (24, 92.3 %)	Median 176.5 (IQR: 47 – 445.75)	7
Kerdsirichairat, 2019	Retrospective, bicenter	57	9	NR	NR	Peptic stricture (n = 2, 3.5 %); Surgical anastomotic stricture (n = 2, 3.5 %); SMAS (n = 1, 1.7 %); Small bowel Crohn's disease (n = 1, 1.7 %); Severe adhesion (n = 1, 1.7 %); Severe intramural duodenal hematoma from acute pancreatitis (n = 1, 1.7 %); Caustic injury (n = 1, 1.7 %)	Axios	Median 319.5 days (IQR 168.8 – 598 days)	7
James, 2020	Retrospective, single center	22	22	54.2 ± 13.4	13 (59.1 %)	Peptic stricture (n = 5; 22. 7 %); Anastomotic stricture (n = 4; 18. 2 %); Duodenal hematoma (n = 3; 13. 6 %); Recurrent acute pancreatitis (n = 1; 4. 5 %); Chronic pancreatitis (n = 4; 18. 2 %); Pancreatic pseudocyst (n = 1; 4. 5 %) and walled off pancreatic necrosis (n = 4; 18. 2 %)	Axios, 15 mm (16, 76.2 %) and 20 mm (5, 23.8 %).	Mean 564 days (± 381)	7
Sameera, 2020^	Retrospective, single center	72	17	57.9 ± 21.5	10 (58.8)	Groove pancreatitis (n 14); SMA syndrome (n 1) = postsurgical inflammation (n 1) fl= Other (n 1)	NR	NR	4
Sobani, 2021	Retrospective, single center	33	8	44.75±19.51	4 (50 %)	Peptic stricture (n 4) = chronic pancreatitis (n 2) = SMA syndrome (n 2)	Axios, 20 mm (n = 8, 100 %)	Mean 291.75 ± 211.40 days	7
Havre, 2021	Retrospective, bicenter	56	5	68.4 ± 8.20	5 (100 %)	Aorto-duodenal syndrome (n = 2); Chronic pancreatitis (n = 3)	Axios	Median 26 (20–135) weeks	7
Kahaleh, 2023	Retrospective, multicenter	103	31	58 ± 16.2	19 (61 %)	Stricture from various causes[#]	Axios, 15 mm (n = 10, 32 %), 20 mm (n = 21, 67.7 %) [Cautery tip in 67 .7 %]	Mean 6.4 months	5

(*continued on next page*)

Table 1 (*continued*)

First author, Year	Design	Overall patients, n	Patients with bGOO, n	Age, years Mean (SD or IQR)	Male sex, n (%)	Etiology of bGOO	Type of LAMS	Follow-up length	Quality assessment
Rizvi, 2023§	Retrospective, multicenter	72	72	54.8 ± 17.8	42 (58 %)	Surgical anastomotic stricture (n = 14; 1 9 %); Peptic stricture (n = 12; 1 7 %); Chronic pancreatitis (n = 11; 1 5 %); Acute pancreatitis (n = 9; 1 3 %); SMAS (n = 7; 1 0 %); Caustic stricture (n = 4; 6 %); Crohn's disease stricture (n = 2; 3 %); Duodenal hematoma (n = 2; 3 %)	Axios, 20 mm (n = 40, 59 %)	Mean 426.3 (±443.9) days	7
Abel, 2024	Retrospective, single center	48	18	63.6 ± 13.25	11 (61.1 %)	Pancreatitis (n = 6); NSAID induced stricture (n = 4); Peptic stricture (n = 2); SMA syndrome (n = 3) radiation-induced stricture (n = 1); Anastomotic stricture (n = 1) duodenal hematoma (n = 1)	Axios, 20 mm (n = 14, 77.8 %), 15 mm (n = 4, 22.2 %)	NR	6
Fimiano. 2024*	Retrospective, single center	8	8	62.75 ± 11.69	6 (75 %)	Acute pancreatitis (n = 2); Groove pancreatitis (n = 1); Chronic pancreatitis (n = 3); Post-surgical stricture (n = 1); Peptic disease (n = 1)	NR	Mean 12 (± 6) months	6
Martinez-Ortega, 2024*	Retrospective, multicenter	69	69	62.96 ± 19.4	50 (73 %)	Intraluminal GI stricture (11 peptic, 3 anastomotic, 1 other)	Axios 20 mm (n = 50, 72 %)	Median 1.2 years (IQR 0.33–1.3)	6
Wannhoff, 2024	Retrospective, multicenter	39	39	(median 55 27–76) 53.25 ± 8.17&	24 (63.1 %)	Biliary pancreatitis (n 14) = Alcoholic pancreatitis (n 13) = Post-ERCP pancreatitis (n 3) = Pancreatitis - other (n 8)	Axios, 10 mm (n = 1), 15 mm (n = 17), 20 mm (n = 17)	Median 23 months (range 3–45)°	8
Gonzalez, 2024	Retrospective, single center	87	34	53.22 ± 17.39	18 (52.9 %)	Chronic pancreatitis (n = 9); Gastroparesis (n = 16); Aorto-mesenteric pince (n = 1); Crohn's disease (n = 2); Caustic (n = 1); Surgical dysfunction GJ (n = 2)	Hot Axios, 20 mm (n = 34, 100 %)	Mean 27.76 (± 94.46) months	6
Rizzo, 2025	Retrospective, multicenter	216	11	68.2 ± 17.4	4 (36.4 %)	Chronic pancreatitis stricture 6 (54. 5 %); Pyloric stricture after chemotherapy 2 (18. 2 %); Anastomotic stricture 1 (9. 1 %); Peptic stricture 1 (9. 1 %); Fluid collection after surgery causing compression 1 (9. 1 %)	Axios, 15 mm (n = 5, 45.5 %) 20 mm (n = 6, 54.5 %)	Median 200 (IQR 482) days	6

* Abstract at ESGE Days 2024;.
§ Abstract at DDW 2024;^Abstract;.
# Authors did not specify the benign etiologies,.
° data from 25 patients with follow-up of >3 months,.
& mean and standard deviation were calculated using the Hozo methodbGOO: benign gastric outlet obstruction; AE: adverse events; SD: standard deviation; IQR: interquartile range; EUS: endoscopic ultrasound; LAMS: lumen-apposing metal stent; NSAID: non-steroidal anti-inflammatory drugs; SMAS: superior mesenteric artery syndrome; GI: gastrointestinal; NS: not specified; NR: not reported.

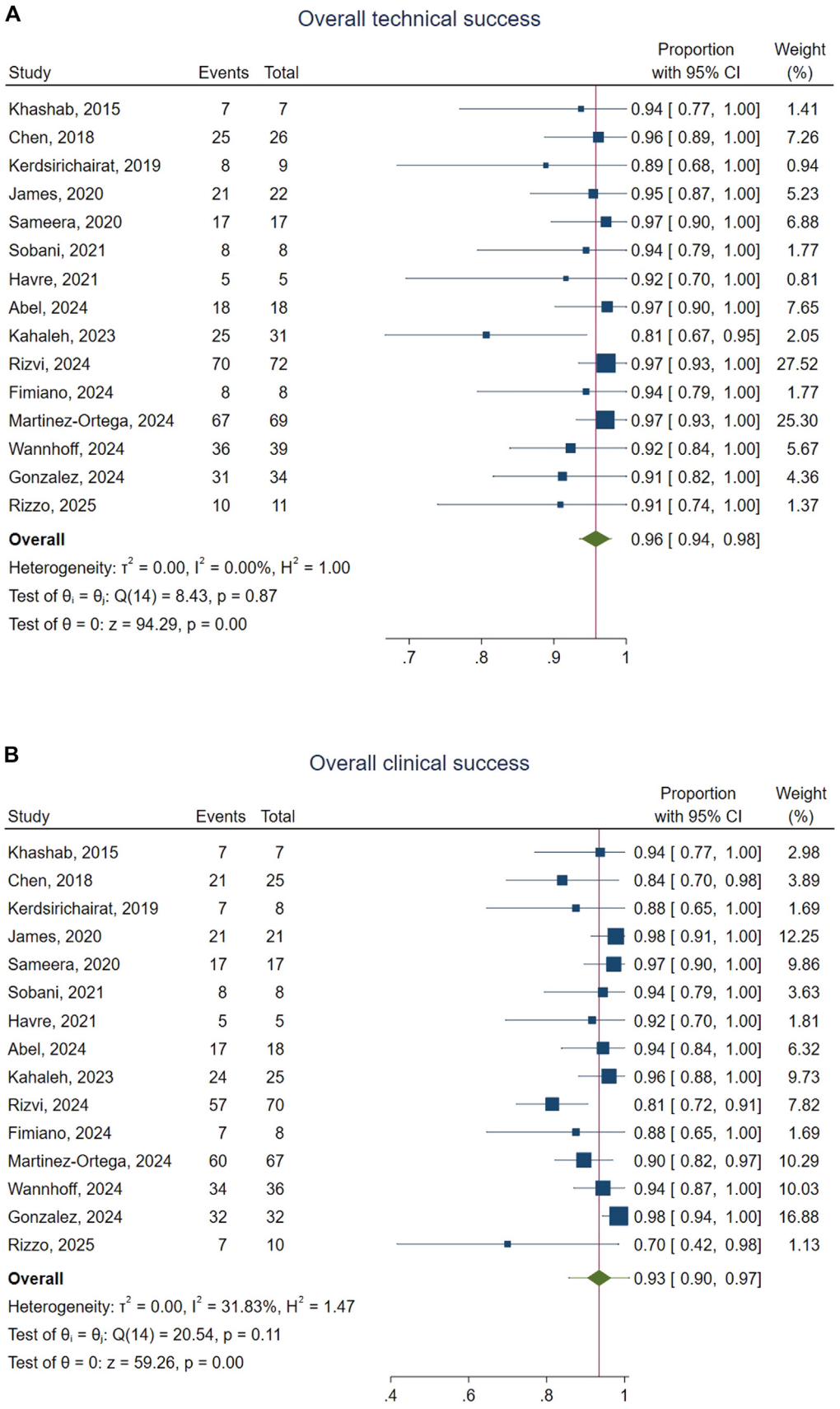

Fig. 1. Forest plots showing: A) overall technical success; B) overall clinical success.

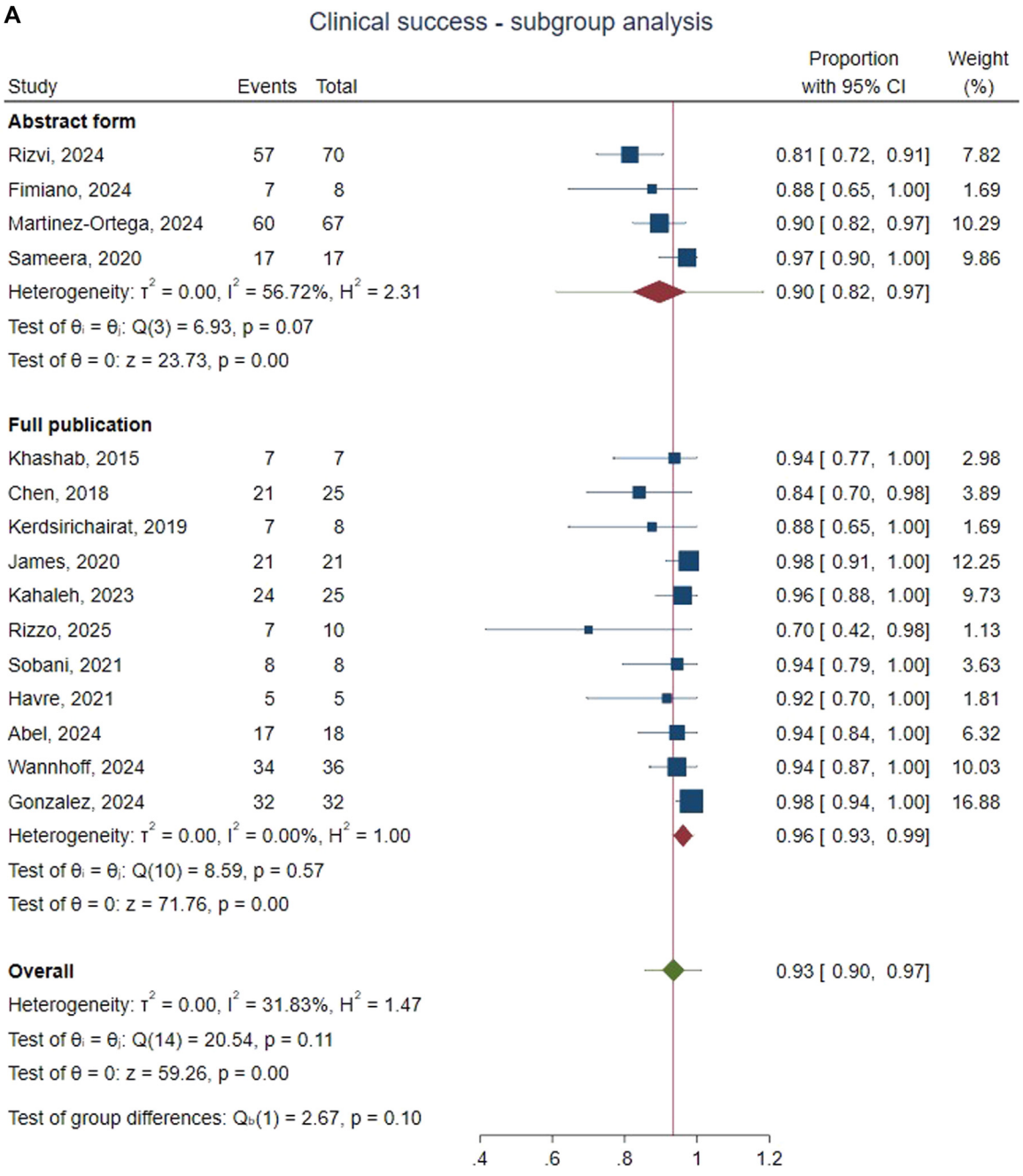

Fig. 2. Subgroup analyses regarding clinical success according to: A) type of publication B) study design.

like pain, jaundice or pseudocysts. In fact, the CP-related GI obstruction can be caused by an underlying pancreatic cancer, even if it is not known at the time of obstructive clinical presentation. Additionally, other systemic complications of CP, such as pancreatic exocrine and endocrine insufficiency, chronic inflammation, and dysbiosis can contribute as concurrent and additional factors related to the development of GI obstruction symptoms. Therefore, a multidisciplinary approach in tertiary centers is fundamental in determining the best treatment.

Patients with bGOO requiring EUS-GJ have mostly been those who have experienced failure of other endoscopic treatments (e.g., dilation or enteral stenting) as identified in 6 studies in our analysis [19,20,22,24,26,28], or those who are unfit for surgery or refuse it. EUS-GJ can sometimes become a bridging therapy, as specified in one of the included studies [32], showing the use of EUS-GJ as transitory treatment for 23.2 % of patients. Consequently, data are scarce, and come from retrospective series, some of which were recently presented as abstracts in international conferences [29–32]. Therefore, providing robust data regarding interventional endoscopy for bGOO is mandatory for the evolutional era of interventional endoscopy. Our systematic search identified 15 studies, including 376 patients, which showed a high technical and clinical success, 95.8 % and 93.4 %, respectively. Unfortunately, all of the studies were retrospective, thus potentially containing missing data. Nonetheless, there was low heterogeneity for the primary outcomes, reflecting similar results among the included studies, while it was significantly moderate for the AE rate (I^2= 57.18 %).

A recent and similar meta-analysis has been published [39], though it has many limitations: debatable data extraction, interpretation, and analyses, probably resulting in weaker results than

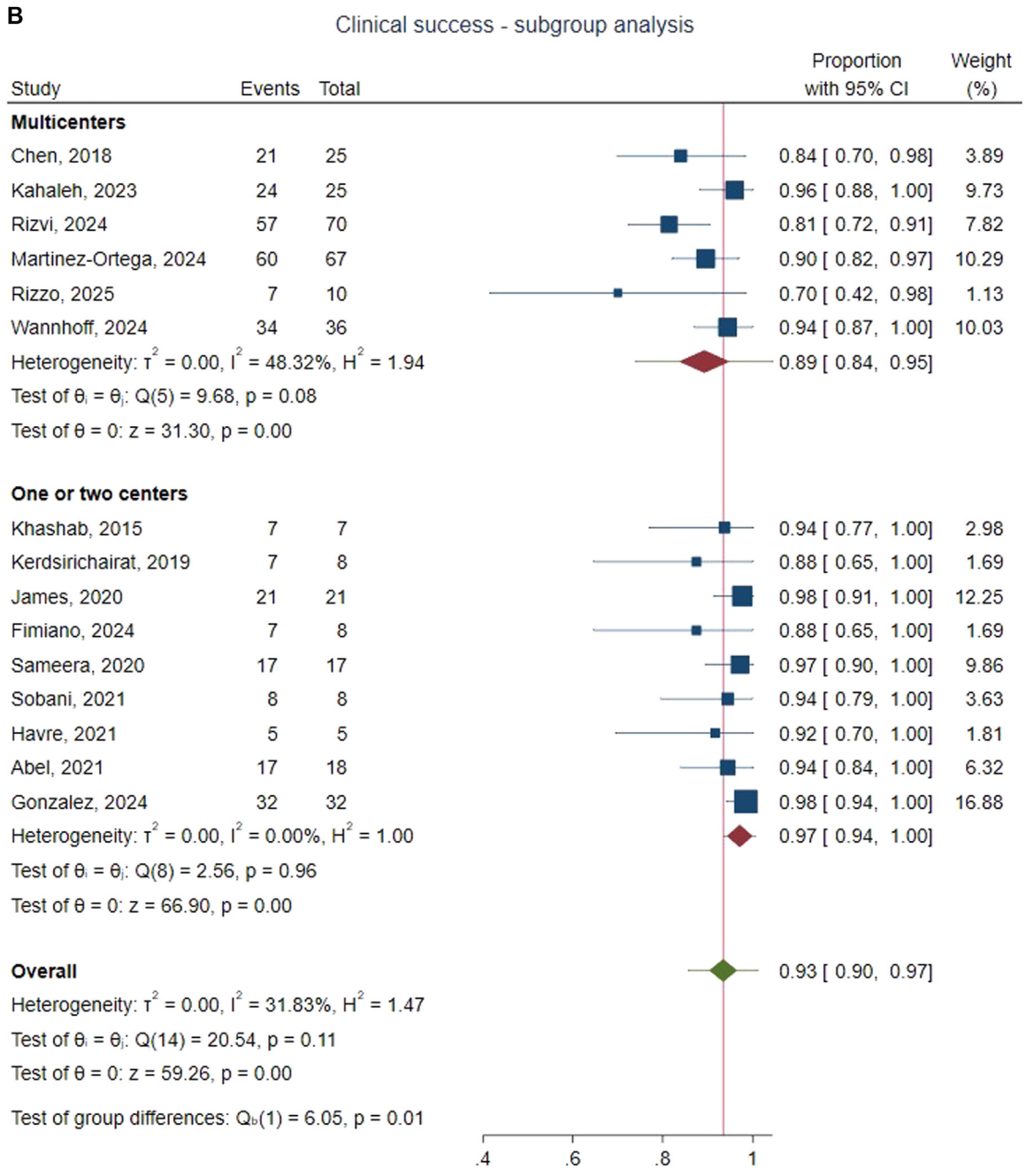

Fig. 2. Continued

ours. Specifically, our study included a higher number of studies (15 vs. 10) and consequently higher number of patients (376 vs. 181), highlighting differences in the research process and criteria. Indeed, authors report definitions of clinical and technical success among the inclusion criteria, even if the definitions differ among studies; for this reason we reported the subgroup analysis. Furthermore, they did not specify that one study was not a full paper [29], while we included a total of four abstracts thanks to a deeper research, also performing a subgroup analysis for exploring differences with full publication papers. It is worth noting that clinical success is slightly lower and heterogeneous among studies in abstract form (90 %; I^2=56.72 %) compared to full papers (96 %; I^2=0 %), though the differences are not significant ($p = 0.10$). However, it could suggest less care in extracting and evaluating data when presenting an abstract. We should pay attention when interpreting these results until full papers are available. In addition, the authors of the similar meta-analysis [39] did not report evaluation of publication bias, which we analyzed deeply using adequate plots for meta-analysis of proportions (Doi-Galbraith plot) associated with quantitative evaluation of the asymmetry (LFK index), which did not show publication bias. Our results differ slightly from their analyses, depending also on differences in the methodology: they evaluated clinical success using the total number of patients as denominator, even if the denominator should be the total number of technically successful procedures. Moreover, they considered total patients as denominator for the analysis of recurrence and reintervention. Since recurrence can be evaluated only in those patients achieving clinical success, our analysis considered the number of patients with clinical success after the procedure as denominator for the pooled rate of recurrence. Incidentally, the de-

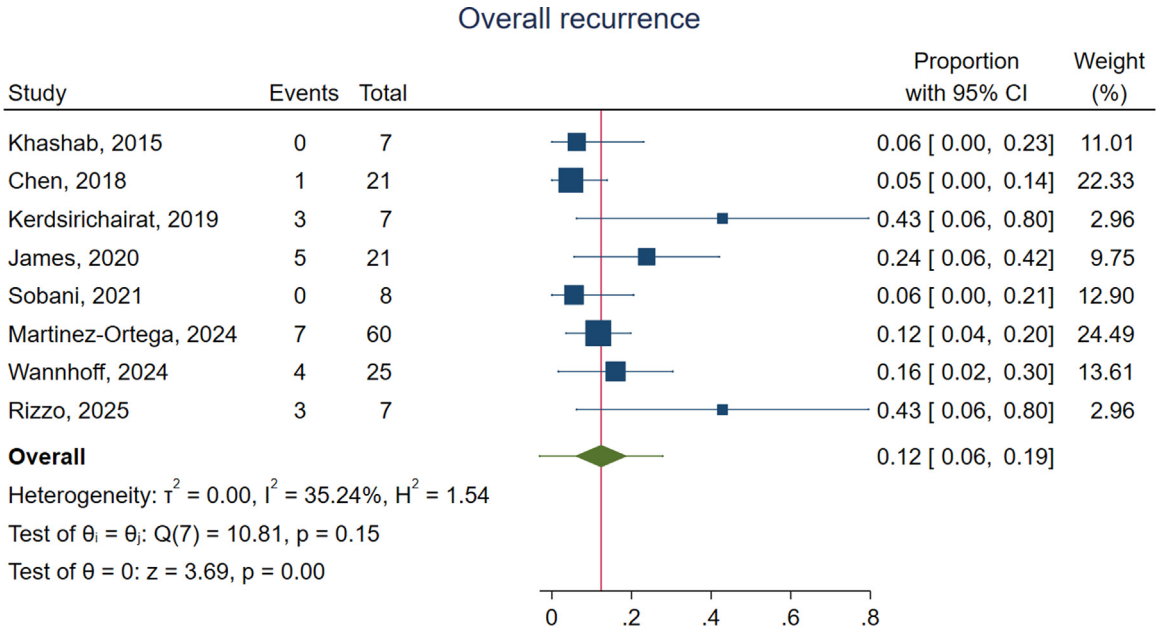

Fig. 3. Forest plots for overall recurrence of symptoms.

nominator of one study [10] differed from the number of clinical successes, as specified by the authors, who reported 4 recurrences among those patients ($n = 25$) with >3 months of follow up. The latter points, added to our higher number of studies ($n = 8$ vs. $n = 6$ for recurrence), explains our different pooled rate (12 % vs. 7 %).

However, at present no clear predictors of EUS-GJ success have been identified in benign disease causing GOO. Therefore, we performed subgroup analyses to identify variables, which may significantly impact the estimated rates, to ensure the robustness of the results, stimulating new hypotheses regarding factors influencing the results, and providing potential foundations for future research.

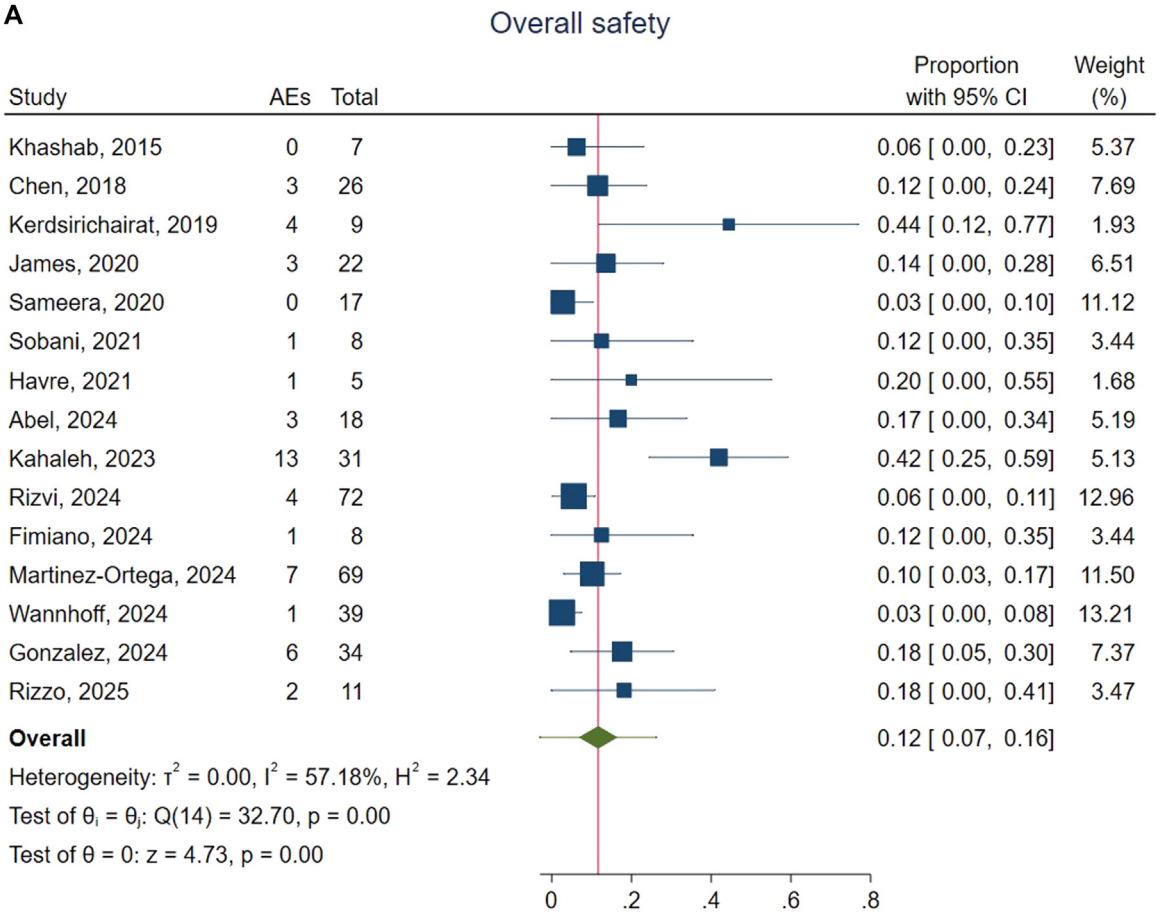

Fig. 4. Forest plots for safety: A) overall safety; B) subgroup analysis based on the use of AE classification system.

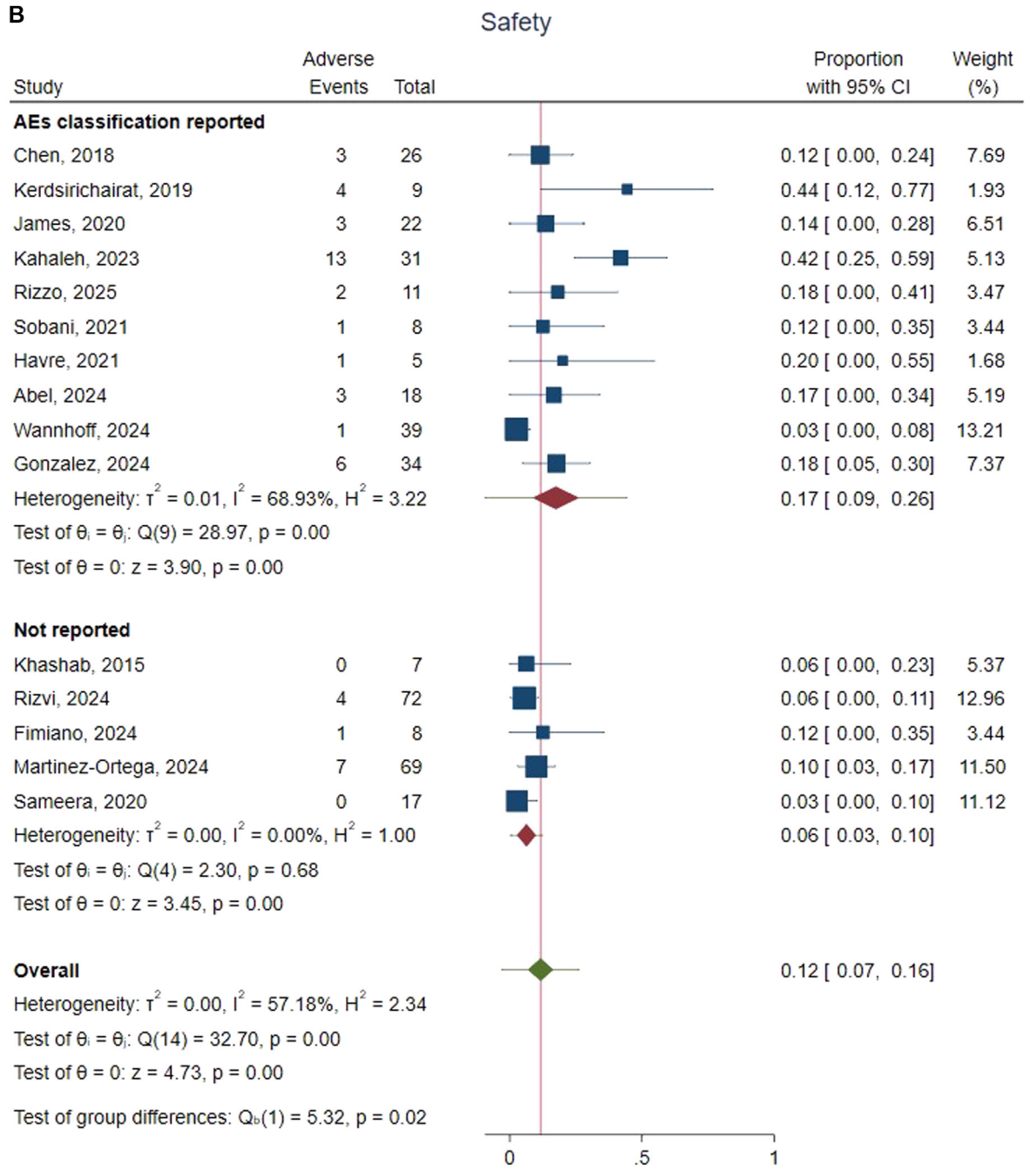

Fig. 4. Continued

Unfortunately, we did not find significant differences among the *a priori* subgroups when exploring factors influencing technical success. In addition, we could not evaluate more deeply further technical factors, though some were partially reported, such as the type of LAMS used: (the Axios type [Boston Scientific] was the LAMS used among all studies reporting it), the stent diameter (20 or 15 mm) or the tip (with or without cautery), so we can limit our analysis only to a descriptive evaluation (Table 1). Overall, the LAMS diameter used among the older studies was mainly the 15-mm, while the larger one slightly increased to be more frequently used among the most recent studies, both because initially the 20-mm was not available, and because the operators likely developed higher confidence in the technique and the safety profile over time from its use in mGOO [40,41]. In the future, we will likely use mostly the 20-mm LAMS for EUS-GJ. However, the moderate heterogeneity seen in clinical success (I^2=31.83 %) was partially based on the variety of its definition, such as "definition 1," specifying the type of post-procedural diet, which had a lower clinical success (92 %), while those that did not generally report the post-procedural resumption of feeding had a higher rate (94 % for "definition 2"). It is also fundamental to standardize how to report clinical success, including timeframe in the definition, which was specified only in 4 studies [23,24,26,27]. In addition, clinical success significantly differed ($p = 0.01$) depending on the number of centers, so it was higher (97 %) among single/bicenter studies, compared to multicentric studies (89 %). Gathering data on this novel approach in a single center or between two centers could lead to a reduction in the differences in the management and operators' learning curve, which seems to impact outcomes. This hypothesis might also explain the heterogeneity among multicentric

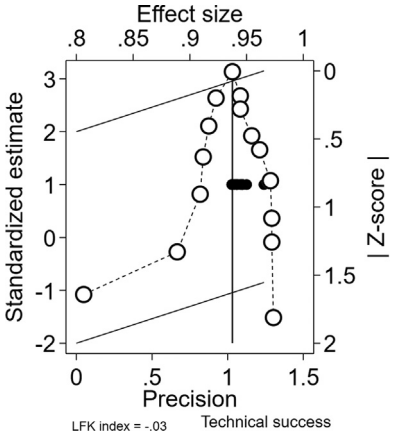

Fig. 5. Graphical evaluation of publication bias through Doi plot (including LFK index) for technical success.

studies (I^2=48.32 %), which was not present among the single-center/bicentric studies (I^2=0 %).

The recurrence rate (12 %) could well indicate that those patients who achieve clinical success (denominator of recurrence) do not experience recurrence in most cases, given that some recurrence was due to reinterventions for stent cleaning of food impaction, as reported in 3 studies [20–22]. Therefore, adequate diet indications and patient support during follow-up might also reduce this rate. Prospective studies with adequate long-term follow-up may confirm this hypothesis, and should also focus on finding predictors of long-term clinical success. In fact, some authors [21,22] reported that clinical recurrences in patients undergoing a reintervention did not show stent dysfunction, food impaction, or any other stent-related issue, so it is likely that the patients' symptoms were related to other functional conditions, such as gastroparesis, and were finally treated either by prokinetic medications or by percutaneous gastrostomy.

Our findings showed an acceptable safety profile (AE rate 1 2 %), even if heterogeneity was moderate, as mentioned above. On the other hand, surgery for bGOO showed a 33 % rate of post-surgical AE (43). Our subgroup analysis found significant differences among studies reporting AE according to standardized classifications and those which did not use classification systems (AE rate 17 % vs. 12 %, respectively, $p = 0.02$). This could plausibly be explained by the fact that when using standard definitions it easier to identify and report an AE, which leads to a reduction in missing data, thus increasing the rate, and an AE could likely be missed without the application of standardized classifications in the internal protocols of the centers.

To our knowledge, our meta-analysis is the largest and the most analytical in the evaluation the efficacy and safety of this EUS-GJ for bGOO. Our study has the strength of having low heterogeneity among the included studies; furthermore, the sensitivity analyses allowed investigation of those variables that could influence the outcomes. Moreover, no publication bias was identified for the main outcomes (technical and clinical success), increasing the reliability of our study. Conversely, the limitations include the retrospective nature of all the studies available in the literature, and that some included studies had few patients, even if small-study bias was identified only when evaluating safety and recurrence. Larger studies may resolve this bias for the latter outcomes in future analyses. Another limitation regards the lack of individual data that would allow a sensitivity analysis based on the etiology of bGOO, which could lead to a better selection of patients who are candidates for EUS-GJ.

In conclusion, EUS-GJ is effective and safe in those patients with bGOO. Our results highlight that using classification systems for AE and improving the quality of studies influence the pooled rate of safety. Further attempts at identifying the best management of this condition are imperative to standardize the definition of clinical success and to identify proper outcomes in this setting. Other outcomes, such as the patient QoL or nutritional status are still unexplored, so future prospective studies with long-term follow-up should also focus on these and on further technical features, such as the removal time of the stent, and whether it is beneficial to exchange the stent in select patients.

Authors' contributions

Giacomo Emanuele Maria Rizzo: conceptualization, methodology, resources, writing - original draft, software, supervision, Project administration. Antonio Facciorusso: data curation and supervision. Cecilia Binda: review & editing; Stefano Mazza: data curation, resources, writing- review & editing; Marcello Maida: resources; Gabriele Rancatore: resources; Lucio Carrozza: resources; Dario Ligresti: resources; Aurelio Mauro: Writing - review & editing, resources; Andrea Anderloni: supervision, resources, validation; Carlo Fabbri: supervision, resources, validation; Ilaria Tarantino: Writing - review & editing, supervision, validation.

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Conflict of interest

Dr. Ilaria Tarantino is consultant for Olympus and Boston Scientific. All the other authors have no conflict of interest to declare.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.dld.2025.03.012.

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