Laparoscopic versus EUS-guided Gastroenterostomy for Gastric Outlet Obstruction: An International Multicentre Propensity Score-Matched Comparison.

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Abstract

Background and aims:

In the management of gastric outlet obstruction (GOO), EUS-guided gastroenterostomy (EUS-GE) seems safe and more effective than enteral stenting. However, comparisons to laparoscopic gastroenterostomy (L-GE) are scarce. Our aim was to perform a propensity score-matched comparison between EUS-GE and L-GE.

Methods:

An international, multicentre retrospective analysis was performed of consecutive EUS-GE and L-GE procedures in 3 academic centers (Jan-2015 to May-2020), using propensity score-matching in order to minimize selection bias. A standard maximum propensity score difference of 0.1 was applied, also considering underlying disease and oncological staging.

Results:

Overall, 77 patients were treated with EUS-GE and 48 patients with L-GE. By means of propensity score-matching, 37 patients were allocated to both groups, resulting in 74 (1:1) matched patients.

Technical success was achieved in 35/37 EUS-GE-treated patients (94.6%) vs. 100% in the L-GE group (p=0.493). Clinical success, defined as eating without vomiting or GOO Scoring System ≥ 2, was achieved in 97.1% and 89.2% respectively (p=0.358). Median time to oral intake (1 (IQR 0.3-1.0) vs. 3 (IQR 1.0-5.0) days, p<0.001) and median hospital stay (4 (IQR 2-8) vs 8 (IQR 5.5-20) days, p<0.001) were significantly shorter in the EUS-GE group. Overall adverse events (AEs) (2.7% vs. 27.0%, p=0.007) and severe AEs (0.0% vs. 16.2%, p=0.025) were identified more frequently in the L-GE group.

Conclusion:

For patients with GOO, EUS-GE and L-GE showed almost identical technical and clinical success. However, reduced time to oral intake, shorter median hospital stay and lower rate of adverse events suggest that the EUS-guided approach might be preferable.

Keywords

Gastric outlet syndrome, laparoscopic gastrojejunostomy, endoscopic ultrasound, LAMS.

Introduction

Gastric outlet obstruction (GOO), defined by a mechanical obstruction of the duodenum, pylorus or antrum, may result from various diseases. The underlying aetiology has shifted from mainly peptic ulcer disease in the past, to predominantly malignant causes at present[1,2]. In the most recent cohorts, GOO was caused by underlying malignancy in up to 85% of patients, the majority of which could be attributed to pancreatic cancer[3,4,5,6,7]. On the other hand, peptic ulcer disease and chronic pancreatitis are still the most prevalent causes of benign GOO[8,9]. Consequences of GOO, such as nausea, vomiting, anorexia, need for nasogastric tube decompression and subsequent loss of body mass, may further aggravate this complex clinical entity, increasing morbidity, reducing quality of life and significantly influencing tolerability and efficacy of oncological treatments[10]. Before the advent of endoscopic ultrasound-guided gastroenterostomy (EUS-GE), management of GOO mainly relied on surgical gastroenterostomy, the standard of care for many years[11,12]. Since the late nineties, placement of metal enteral stents was found to provide higher efficacy regarding early re-initiation of oral intake, as well as reduce hospital stay and major adverse events (AE)[11], albeit at the expense of more recurrent obstructive symptoms due to stent dysfunction[13,14]. Since 2012, EUS-GE has found its way from initial animal studies, into daily practice of tertiary centres[15,16]. This EUS-guided approach has become a minimally invasive alternative for patients with both benign or malignant GOO[3,4] and demonstrated higher clinical success and lower need for re-interventions compared to enteral stenting[5,17]. There is still uncertainty regarding the place of EUS-GE in daily clinical practice, due to a lack of data comparing this technique to the current reference standard, laparoscopic gastroenterostomy (L-GE), in patients stratified according to potential confounders, such as oncological staging and pre-procedural fragility[18-20].

Our aim was to perform a propensity score-matched comparison of EUS-GE to L-GE, using a large retrospective international multicentre cohort.

Methods

Patients and study design

A retrospective analysis was performed of all consecutive L-GE and EUS-GE procedures performed for GOO at the Amsterdam University Medical Centers, location AMC and VUmc (the Netherlands), IRCCS San Raffaele Scientific Institute Milan (Italy) and University Hospitals Leuven (Belgium) between January 2015 and May 2020. For both procedures, identical variables were extracted from patients' electronical medical charts. Inclusion criteria consisted of: (1) symptomatic GOO, (2) endoscopic or radiological confirmation of benign or malignant gastro-duodenal stenosis and (3) treatment with EUS-GE or L-GE. Considering the surgical procedures, only strictly "pure" laparoscopic gastroenterostomies were eligible for inclusion, as to minimize confounding effects of adjunctive procedures, such as metastasectomy, hepatico-enterostomy or cholecystectomy, often performed simultaneously. Each patient gave his or her consent with regards to the procedure. This study was furthermore approved by the central Institutional Review Board (study identifier: s64254) at the University Hospitals Leuven and at each participating center.

Endpoints

Technical success was defined as the successful creation of a gastro-enteric anastomosis by use of the initially chosen technique (see below for technical considerations). If additional approaches or techniques had to be involved or additional self-expandable metal stents (SEMS) were needed, this was regarded as a technical failure.

Food intake grading was defined using the GOO Scoring System (GOOSS) (0= no intake, 1= liquid only, 2= soft solids, 3= almost full diet, 4= full diet)[21,22]; symptomatic GOO was defined as a GOOSS of 0. In concordance with previous work[7], clinical success was defined as eating without vomiting or a GOOSS of ≥2 and was ascertained by evaluation of the electronic patient file, where this parameter is recorded as part of standard practice. Regarding safety, the ASGE lexicon for adverse events was used to stratify AE in mild, moderate, severe or fatal events[23].

Secondary endpoints were: hospital stay, weight change after 2 months, gastroenterostomy dysfunction, distal obstruction rates, 'time to oral intake' and 'time to full diet' (GOOSS of 4). For EUS-GE procedural time was extracted from the endoscopic electronic reporting system. For L-GE, procedural time was retrieved by revision of the anaesthesiology report, exactly stating the beginning and the end of the procedure. Gastroenterostomy dysfunction was defined as recurrence of obstructive symptoms (GOOSS < 1) after former clinical success, with confirmation of recurrent GOO by endoscopy or imaging studies. Mechanical obstructions located downstream the GE site, without signs of EUS-GE or L-GE dysfunction, were annotated as 'distal obstructions', but not registered as GE dysfunction.

Procedure: the Wireless EUS-gastroenterostomy Simplified Technique (WEST)

All EUS-GE are performed under deep sedation with propofol or general anaesthesia, using a electrocautery-enhanced lumen apposing metal stent (LAMS) and the Wireless EUS-gastroenterostomy Simplified Technique (WEST) as previously described, under prophylactic antibiotic therapy (Video)[24,25].

After a 7Fr nasobiliary catheter or enteral feeding tube is placed, through the gastric or duodenal stenosis into the jejunum, water is infused in the targeted loop of small bowel (Figure 1, upper left panel). Using a combination of fluoroscopy and EUS-guided identification of the catheter (Figure 1, upper middle panel) the dilated jejunal or enteric loop is accessed using the biflanged electrocautery-enhanced LAMS (Hot-Axios; Boston Scientific, Marlborough, MA, USA). Following successful intraluminal access to the small bowel, the distal flange is deployed under endosonographic guidance; the device is then

retracted (Figure 1, upper right panel), favouring apposition of the gastric and enteric wall and allowing the opening of the proximal flange inside the endoscope channel (Figure 1, lower left panel); the device is finally pushed outside the working channel together with a careful scope retraction, resulting in deployment of the proximal flange into the gastric lumen. Afterwards, successful deployment is confirmed by either EUS (Figure 1, lower left panel), direct endoscopic visualisation (Figure 2) or, if needed, combined with fluoroscopy and contrast injection (Figure 1, lower middle panel).

Procedure: Laparoscopic gastroenterostomy:

Following CO2-insufflation (12-15 mmHg intra-abdominal pressure) by a Veress needle or by open introduction, 4-5 trocars are introduced: one camera port around the umbilicus and 3 to 4 trocars at different positions in the upper abdomen. Next, Treitz' ligament is identified and two electrocautery incisions are made, one in the dorsal or anterior gastric wall and one in the jejunum. An anterior, dorsal latero-lateral or side-to-side isoperistaltic gastroenteric anastomosis is constructed. The exact location of the gastroenteric anastomosis, with regards to Treitz' ligament, varies from 30cm to 60cm. During the surgical approach a 60mm blue Echelon stapler (Johnson & Johnson, New Brunswick, New Jersey, USA) or 60mm Endo GIA universal stapler (Medtronic Ltd., Dublin, Ireland) is used depending on the preference of the surgeon, with additional staplers and sutures covering the staple line as needed. During construction of the gastroenteric anastomosis, a 36 French nasogastric tube is temporarily placed through the defect in the majority of cases, in an effort to maintain and confirm patency while stapling or suturing. Anti-traction sutures are used when appropriate. If not in place before the surgical procedure, a nasogastric tube is inserted afterwards and the patient remained on nil per mouth. In this study we only included "pure" L-GE for comparison to EUS-GJ and excluded procedures were adjunctive treatments, such as cholecystectomy, hepaticojejunostomy or metastasectomy were performed. All surgical procedures were performed by gastrointestinal surgeons with extensive experience in laparoscopic gastrointestinal surgery, operating in high-volume academic centres.

Statistical analysis

Categorical variables were reported as frequencies (%) and Fisher's test was used to compare these variables. Continuous variables were reported as medians and interquartile range (IQR) or means ± standard deviation (SD). Student's *t* test and Mann-Whitney *U* test were used for comparing continuous variables as appropriate. Differences in outcomes are shown as odds ratio (OR) and 95% confidence interval (CI). Kaplan-Meier curves were used for overall post-procedural survival analysis, whereas the log-rank test was used for corresponding comparisons. Furthermore, learning curve effect was evaluated by comparing the initial 50% of procedures with the second half of EUS-GE procedures in each centre. A multiple logistic regression was performed to identify predictors of clinical failure: age, gender, pancreatic cancer, presence of ascites or peritoneal carcinomatosis, use of 15mm LAMS and balloon dilation, as well as learning curve were used as variables. P-values <0.05 were considered statistically significant.

A propensity score-matched analysis was performed in an effort to minimize selection bias. Age, sex, underlying disease, corresponding disease stage, presence of ascites and presence of peritoneal carcinomatosis were used as variables. The aforementioned variables were selected based on: (1) analysis of previous literature and (2) significant differences between the two groups after univariate analysis. In four previously published studies, which performed a multivariate analysis, peritoneal carcinomatosis and ascites were identified as factors associated with clinical and technical failure respectively[3,4,7,26]
A standard maximum propensity score difference of 0.1 was admitted for matching.
SPSS version 26.0 (IBM, Chicago, IL, USA) was used for matching and statistical analysis, whereas Graphpad Prism version 9.0.0 for Windows (Graphpad Software, San Diego, CA, USA) was used for the Kaplan-Meier curves and survival analysis.

Results

Overall, we identified 126 patients, one of whom was excluded due to missing data, resulting in a total of 77 patients (62%) who underwent EUS-GE and 48 patients (38%) undergoing L-GE.

Baseline characteristics are shown in Table 1. Ascites (22.1% vs. 4.2%, p=0.009) and pancreatic cancer-induced GOO (48.1% vs. 29.2%, p=0.037) were significantly more frequent in the EUS-GE group, whereas underlying benign disease was identified significantly less (3.9% vs. 14.6%, p=0.044) when compared to L-GE-treated patients (Table 1). Technical success (94.8% (95% CI: 87.0-98.4) vs. 100% (95% CI: 91.2-100.0), p=0.297) was similar when comparing both groups, while a trend towards higher per-protocol clinical success amongst EUS-GE-treated patients was observed (97.3% (95% CI: 90.0-99.8) vs. 87.5% (95% CI: 74.9-94.5), OR 5.07 (95% CI: 0.98-26.28), p=0.057) (Table 2).

Overall, 15mm and 20mm LAMS were utilized in 11 and 64 patients respectively, with higher clinical success rates (81.8% (95% CI: 51.2-96.0) vs. 100% (95% CI: 93.0-100.0) respectively, p=0.021) and a trend towards shorter median hospital stay (5 days (2.8-11) vs. 4 days (2.0-11), p=0.054) when 20mm LAMS were utilized. Intraprocedural balloon dilation of the central part of the LAMS immediately after its placement was performed in 26% of patients and did not affect efficacy outcomes (Supplementary Table 1). Although two primary clinical failures occurred in patients in whom 15mm LAMS were used without dilation, multivariate analysis did not identify any significant independent risk factors for clinical failure (Supplementary Table 2). Overall AEs (6.5% (95%CI: 2.5-14.7) vs 31.3% (95% CI: 19.9-45.4), OR 0.15 (95% CI: 0.05-0.46), p<0.001), and severe AEs (2.6% (95% CI: 0.2-9.5) vs 18.8% (95%CI: 10.0-32.2), OR 0.12 (95% CI: 0.03-0.59), p=0.007) occurred significantly less frequently in EUS-GE versus L-GE treated patients (Table 2).

Propensity score-matched analysis

By means of propensity score matching, 37 patients were allocated to each group, resulting in a total of 74 (1:1) matched patients (Figure 3). The propensity score-matched cohort revealed an overall mean age of 66.5 ± 11.8 years, 44.6% were female, 36.5% had underlying pancreatic cancer, with 31.1% and 6.8% of patients exhibiting peritoneal carcinomatosis and ascites. Underlying benign disease was present in four (5.4%) patients. Baseline comparisons between EUS-GE and L-GE-treated patients are shown in Table 3. No significant differences between both study groups were identified.

Efficacy

In the propensity score-matched EUS-GE group, two technical failures occurred, due to inability to advance the nasobiliary catheter through the stenosis. This resulted in a technical success rate of 94.6% (35 out of 37 patients, 95% CI: 81.4-99.4), compared to 100% (95% CI: 88.8-100.0), p=0.493) amongst L-GE-treated patients (Table 4). Clinical success rates by means of intention to treat analysis (91.9% (95% CI: 78.0-97.9) vs. 89.2% (95% CI: 74.7-96.3), p=1.000), as well as per-protocol analysis were comparable (97.1% (95% CI: 84.2-100.0) vs. 89.2% (95% CI: 74.7-96.3), p=0.358), with primary non-functional surgical gastroenterostomy in three L-GE-patients. Procedure time (46 minutes (IQR 37.5-80.0) vs. 85 minutes (73.0-110), p<0.001), median time to oral intake (1 day (IQR 0.3-1.0) vs. 3 days (IQR 1.0-5.0), p<0.001) and median time to full diet (2 days (IQR 1.0-3.8) vs. 9 days (IQR 4.0-23), p<0.001) were significantly shorter in the EUS-GE group.

After a median follow-up of 77 days (IQR 27-160) in the EUS group and 123 days in the surgical group (IQR 32-262), gastroenterostomy dysfunction rates (none in both groups) did not differ. With two-months' weight change available in 51.4% and 56.8% of patients treated with EUS-GE and L-GE respectively, no significant differences were detected (-0.3kg (IQR -2.4-1.1) vs. 0kg (IQR -3.0-0.7), p=0.159).

Safety and postoperative outcomes

The overall number of AEs in the propensity score-matched cohort was lower amongst EUS-GE treated patients (2.7% (95% CI: 0.01-15.1) vs. 27% (95% CI: 15.2-43.1), OR 0.07 (95% CI: 0.01-0.62), p=0.007) (Table 4). Most AEs in the L-GE group (6 out of 10) were severe, mainly consisting of anastomotic leaks (n=4, 10.8%) or bleeding (n=2, 5.4%), necessitating surgical reintervention in three patients (8.1%), while no severe AEs were registered among EUS-GE treated patients (0.0% (95% CI: 0.0-11.2) vs. 16.2% (95% CI: 7.3-31.5), OR 0.07 (95% CI: 0.00-1.19), p=0.025). Mild (2.7% in each group) and moderate AE rates (0.0% (95% CI: 0.0-11.2) vs. 8.1% (95% CI: 2.1-22.0), p=0.240) were similar in both groups. In two L-GE patients, endoscopic reinterventions was deemed necessary in the context of postoperative bleeding and placement of a trans-anastomotic stent to treat a dysfunctional surgical anastomosis.

A significantly shorter median hospital stay (4 days (IQR 2.0-8.0) vs. 8 days (IQR 5.5-20), p<0.001) was observed amongst EUS-GE-treated patients. Survival analysis did not reveal a significant difference in post-procedural survival in the matched cohort, nor in the overall cohort (Figure 4).

Learning Curve Assessment

When comparing the first to the second half of both the overall and propensity score-matched EUS-GE cohorts (Supplementary Table 3), no significant differences were found in terms of safety and efficacy.

Discussion

In the current analysis, we performed the first propensity score-matched comparison between EUS-GE and L-GE. We found that EUS-GE achieved similar technical and clinical success, with significantly lower overall and severe AEs, faster resumption of oral intake and earlier discharge compared to L-GE. Whilst the EUS-GE technical and clinical success rate was in line with previously published studies[3-9,27], we observed that technical success depended mainly on the ability to pass a nasobiliary catheter through the stenosis. Furthermore, amongst all technical variables, only LAMS calibre might have some influence on clinical outcome, although this was not confirmed by multivariate analysis.

The paucity of published comparative data makes it difficult to identify a well-defined place for EUS-GE in the management of patients with GOO, especially compared to the more established techniques such as surgery and enteral stenting. Only a single large multicentre retrospective study comparing open gastroenterostomy to EUS-GE has been published so far[7]. The authors reported lower AEs compared to the open surgical approach, at the cost of a lower, but not statistically significant, technical success rate. Surprisingly, length of hospital stay amongst both groups was similar. One can speculate whether this was related to the limited experience available at the time, which may have influenced clinical decisions regarding timing of discharge and general post-EUS-GE management. In our cohort, most patients were discharged after a median of 4 days (IQR 2.0-8.0) compared to 8 days (IQR 5.5-20) in the L-GE group, which may an impact on health care costs and quality of life. We chose to compare our EUS-GE cohort with laparoscopic surgery, as it has proven superior to open surgery, in and outside the context of gastroenterostomy, showing lower morbidity and earlier recovery compared to open surgery, making the L-GE approach the most desired comparator[18]. One previous multicentre retrospective analysis evaluated the efficacy and safety of EUS-GE compared to L-GE, this study only included 25 patients undergoing EUS-GE and did not correct for potential confounding factors or bias[19]. The authors demonstrated increased safety and lower costs using EUS-GE, while retaining similar efficacy to L-GE, even if they detected a non-significant difference in technical success in favour of L-GE[19].

The surgical adverse event rate observed in our study (31.3%), was similar to those reported by Perez-Miranda, et al (41%)[19] and Kashab, et al (25%)[7], suggesting that the superior safety outcomes of EUS-GE observed in our analysis were not due to inferior performance of the surgical comparator group. Furthermore, when comparing surgical adverse events rates in historical cohorts of surgical palliative gastroenterostomy, similar[28-30] or higher[31-33] adverse event rates were seen when compared to the current analysis.

When considering previous comparisons of EUS-GE with enteral stenting, limited evidence suggests that the latter is associated with a lower rate of clinical success and higher rates of stent failure requiring re-intervention[5,17]. These findings have been confirmed in studies comparing enteral stenting with surgical gastroenterostomy, suggesting that enteral stenting should be considered in the context of very limited life expectancy only[13,34].

There are some issues when comparing previous EUS-GE data with our current analysis. First, several techniques have been described for performing EUS-GE, which include the endoscopic ultrasonography-guided double-balloon-occluded gastrojejunostomy bypass (EPASS)-technique, natural orifice transluminal endoscopic surgery (NOTES), rendez-vous methods including balloon-assisted gastroenterostomy, and the direct or 'free-hand'-techniques[7,35-37]. These techniques have been interchangeably used throughout several studies[3,4,7,8,19], complicating reliable direct comparisons of results. Secondly, several previous papers have published overlapping study cohorts, rendering data interpretation somewhat complicated[4,19,20,35,38]. Third, the use of different LAMS with a limited number of studies also including cases where Niti-S Spaxus LAMS (Taewoong Medical Co. Ltd., Ilsan, Korea) were used instead of the Hot-Axios[3,7,26]. Regarding different EUS-GE approaches, a comparative study has shown that the direct method achieves similar technical and clinical success, with a similar safety profile when

compared to balloon-assisted EUS-GE[3]. However, in the context of the direct method, procedure time was more than twice shorter (35.7 vs. 89.9min, p<0.001), thus suggesting the direct technique as the preferred method. In all of our patients, only the Wireless EUS-gastroenterostomy Simplified Technique (WEST) was used, indicating that there is no need for a 19G 'finder'-needle, as has been described in the direct technique, or a guidewire and balloon in order to perform EUS-GE safely and effectively[3,24,25]. We recommend against inflating the targeted loop of small bowel by water or contrast injection using a 19-gauge needle, such as in the setting of EUS-directed transenteric ERCP (EDEE)[39], an approach which may carry a higher theoretical risk of puncturing a more distal enteric loop or even the colon. We do recommend using the most straightforward technique available, in an effort to reduce the number of additional accessories requiring exchange, which in our opinion carries an increased risk of adverse events by complicating positioning, visualisation and, as time passes, reduction in small bowel distention.

While the usefulness of EUS-GE in malignant disease has been reported in various studies, the evidence of this procedure in benign disease has been increasing since only recently[5,7,17]. Doubts concerning LAMS patency and long-term results have led to restricted use in benign diseases. In 2020, James et al. published their series on EUS-GE in benign disease, revealing that surgery was averted in 83.3% of patients and regression of the benign stricture allowed for LAMS removal in the majority of patients over time[9]. Together with long-term follow-up data published in 2019[6], which showed a 15% recurrence rate after a median follow-up time of 169 (malignant disease) and 319.5 days (benign disease), we can conclude that especially in patients with malignant disease GOO, recurrence is an issue. In our current propensity score-matched analysis gastroenterostomy dysfunction did not occur at all, although two cases of distal enteric obstruction, due to metastatic peritoneal disease, were identified in the EUS-GE group, compared to one in the L-GE-group.

In comparison to various other studies, where there was no mention of the incidence of ascites[3,4,6-9,17,19], 21% of our patients underwent EUS-GE despite the presence of ascites, without any significant related AEs. Although ascites has been regarded as a strict contraindication for EUS-GE, these results, together with a retrospective analysis in 2019[5], suggest that patients with mild or localized ascites can be considered for EUS-GE without risking leakage or subsequent peritonitis, provided that there is no tense ascites and that the LAMS trajectory is not compromised due to fluid interference.

Limitations and strengths:

Several limitations of the current study should be addressed. First, the retrospective nature of this analysis might have inadvertently introduced some bias. Secondly, due to the study design, a certain degree of missing data was identified, most especially in the context of body weight evolution. Third, generalizability of our data might be an issue, as all endoscopists were highly trained and operating in high-volume settings.

We have tried to address some of these limitations in our study design. We included a propensity score-matched design, correcting for the selected variables to limit selection bias. These specific variables were chosen as they were differently distributed amongst the two treatment groups, whilst potentially influencing technical and clinical success, as well as 'time to oral intake', 'time to full diet', overall survival and gastroenterostomy dysfunction rates. One of the disadvantages of propensity score-matching, is the dependence on the matching criteria. We therefore included various variables as to provide a stringent matching process. To reduce larger treatment effects and higher degrees of bias of single centre studies, we involved three different tertiary referral centres recruiting similar patients and all performing EUS-GE using the WEST approach[24,25]. Finally, with 77 patients in whom EUS-GE was performed, our study is one of the largest published original cohorts of EUS-GE, and the largest study to date to compare EUS-GE with L-GE.

In conclusion, this study suggests that in patients with gastric outlet syndrome, EUS-GE and L-GE provide almost identical technical and clinical success rates. Lower time to oral intake, shorter hospital stay and a lower rate of adverse events prudentially suggest that EUS-GE should be the preferred approach in patients with GOO. While awaiting high-quality prospective confirmation, these findings should guide gastroenterologists, oncologists and surgeons in considering EUS-GE for treating GOO, especially in the setting of malignancy, where patients will benefit from the least invasive technique with the highest expected efficacy.

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Figure legend

Figure 1. Stepwise approach to the Wireless EUS-gastroenterostomy Simplified Technique (WEST).
Upper left: Fluoroscopic image, placement of a 7Fr nasobiliary catheter or enteral feeding tube through the gastric or duodenal stenosis into the jejunum. Confirmation of the distal position by contrast opacification.
Upper middle: Endoscopic ultrasound image, showing distention of the targeted loop of small bowel after infusion of water.
Upper right: Using a combination of fluoroscopy and EUS-guided identification of the catheter, the dilated jejunal or enteric loop is accessed using the biflanged electrocautery-enhanced LAMS, after which the distal flange is deployed under endosonographic guidance. The device is then retracted onto the gastric wall.
Lower left: Endoscopic ultrasound image, after compressing the gastric and enteric wall, as well as deployment of the proximal flange inside the endoscope channel, the device is finally pushed outside the working channel together with a careful scope retraction, resulting in deployment of the proximal flange into the gastric lumen.
Lower middle: Fluoroscopic evaluation after LAMS release, showing the successful deployment of the LAMS between the stomach and small bowel.
Lower right: Endoscopic view, after recannulation with a diagnostic catheter.

Figure 2. Direct endoscopic visualisation of successful gastroenterostomy.

Figure 3. Study flowchart.

Figure 4. Post-procedural survival analysis.

Tables

Table 1. Overall baseline characteristics.

	EUS-GE (n=77)		L-GE (n=48)		*P* value
Variable					
Age (years), mean ± SD	65	±12.3	66	±11.6	0.478
Female, n (%)	36	(46.8%)	19	(39.6%)	0.432
Median follow up duration, days (IQR)	76	(36-136)	122	(35-274)	0.057
Primary disease					
Pancreatic cancer	37	(48.1%)	14	(29.2%)	0.037
Biliary/gallbladder cancer	9	(11.7%)	2	(4.2%)	0.149
Gastric cancer	7	(9.1%)	5	(10.4%)	0.807
Duodenal cancer	11	(14.3%)	10	(20.8%)	0.341
Breast cancer	2	(2.6%)	2	(4.2%)	0.463
Colorectal cancer	2	(2.6%)	1	(2.1%)	1.000
NET	1	(1.3%)	0	(0.0%)	0.384
Ampullary cancer	0	(0.0%)	1	(2.1%)	0.384
NSCLC	3	(3.9%)	1	(2.1%)	1.000
Benign disease	3	(3.9%)	7	(14.6%)	0.044
Disease stage					
Local invasion	25	(32.5%)	13	(27.1%)	0.555
Liver metastases	8	(10.4%)	9	(18.8%)	0.193
Peritoneal metastastases	8	(10.4%)	10	(20.8%)	0.122
Diffuse metastatic	19	(24.7%)	9	(18.8%)	0.512
Disease manifestations					
Ascites	17	(22.1%)	2	(4.2%)	0.009
Peritoneal carcinomatosis	20	(26.0%)	16	(33.3%)	0.420

Table 2. Overall outcomes.

	EUS-GE (n=77)		L-GE (n=48)		OR (95% CI), *P* value
Efficacy					
Technical success, n (%)	73	(94.8%)	48	(100%)	0.17 (0.01-3.20), 0.297
Clinical success, n (%)	71	(92.2%)	42	(87.5%)	1.69 (0.51-5.58), 0.534
Per protocol clinical success, n (%)	71	(97.3%)	42	(87.5%)	5.07 (0.98-26.28), 0.057
Median time to oral intake, days (IQR)	1	(0-1)	3	(1-5)	<0.001
Full diet tolerability, n (%)	32	(41.6%)	19	(39.6%)	1.16 (0.56-2.44), 0.854
Median time to full diet, days (IQR)	2	(1-4)	8	(4-21)	<0.001
Gastroenterostomy dysfunction, n (%)	1	(1.3%)	0	(0.0%)	1.90 (0.08-47.64), 1.000
Median time to dysfunction, days (IQR)	243	N/A	N/A	N/A	N/A
Distal obstruction, n (%)	8	(10.4%)	1	(1.3%)	5.45 (0.66-45.02), 0.151
Median time to distal obstruction, days (IQR)	34	(18-138)	13	N/A	N/A
Safety					
Overall adverse events, n (%)	5	(6.5%)	15	(31.3%)	0.15 (0.05-0.46), <0.001
Mild, n(%)	2	(2.6%)	1	(2.1%)	1.25 (0.11-14.21), 1.000
Post-procedural fever, n (%)	2	(2.6%)	0	(0.0%)	3.21 (0.15-68.35), 0.523
Moderate, n(%)	1	(1.3%)	5	(10.4%)	0.11 (0.01-1.00), 0.106
Sepsis, n (%)	1	(1.3%)	0	(0.0%)	1.90 (0.08-47.64), 1.000
Need for re-endoscopy, n (%)	0	(0.0%)	4	(8.3%)	0.06 (0.00-1.21), 0.020
Severe, n(%)	2	(2.6%)	9	(18.8%)	0.12 (0.03-0.59), 0.007
Intra-peritoneal LAMS deployment, n (%)	2	(2.6%)	N/A	N/A	N/A
Anastomotic leak, n (%)	N/A	N/A	3	(6.3%)	N/A
Anastomotic bleeding, n (%)	N/A	N/A	2	(4.2%)	N/A
Surgical re-intervention, n (%)	N/A	N/A	3	(6.3%)	N/A
Fatal, n(%)	0	(0.0%)	0	(0.0%)	1.000
Other					
Median procedure duration, min (IQR)	51	(36 - 79.8)	95	(75 - 118)	<0.001
Median hospital stay, days (IQR)	4	(2 - 10.5)	8	(5 - 20)	<0.001
Median weight change after 2 months, kg (IQR)	-1	(-4.0 - 1.1)	-0,4	(-4.2 - 0.8)	0.390
Median post-procedural survival, days (IQR)	103	(44 - 252)	147	(68 - 335)	0.246

Abbreviations: CI: confidence interval, EUS-GE: Endoscopic ultrasound-guided gastroenterostomy, IQR: interquartile range, LGE: laparoscopic gastroenterostomy, N/A: not applicable, OR: odds ratio.

Table 3. Matched cohort: baseline characteristics.

Variable		EUS-GE (n=37)		L-GE (n=37)		*P* value
Age (years), mean ± SD		66.5	±12.5	66.4	±11.1	0.954
Female, n(%)		18	(48.7%)	15	(40.5%)	0.640
Median follow up duration, days (IQR)		77	27-160	123	32-262	0.105
Primary disease						
	Pancreatic cancer	15	(40.5%)	13	(35.1%)	0.811
	Biliary/gallbladder cancer	5	(13.5%)	2	(5.4%)	0.430
	Gastric cancer	5	(13.5%)	5	(13.5%)	1.000
	Duodenal cancer	6	(16.2%)	8	(21.6%)	0.768
	Benign disease	2	(5.4%)	2	(5.4%)	1.000
	Breast cancer	1	(2.7%)	1	(2.7%)	1.000
	Colorectal cancer	2	(5.4%)	0	(0.0%)	0.493
	NET	1	(2.7%)	0	(0.0%)	1.000
	Ampullary cancer	0	(0.0%)	1	(2.7%)	1.000
	NSCLC	1	(2.7%)	1	(2.7%)	1.000
Disease stage						
	Local invasion	15	(40.5%)	12	(32.4%)	0.630
	Liver metastases	6	(16.2%)	8	(21.6%)	0.768
	Peritoneal metastastases	6	(16.2%)	7	(18.9%)	1.000
	Diffuse metastatic	8	(21.6%)	6	(16.2%)	0.768
Disease manifestations						
	Ascites	3	(8.1%)	2	(5.4%)	1.000
	Peritoneal carcinomatosis	10	(27.0%)	13	(35.1%)	0.616

Table 4. Matched cohort: outcome comparisons.

	EUS-GE (n=37)		L-GE (n=37)		OR (95% CI), *P* value
Efficacy					
Technical success, n (%)	35	(94.6%)	37	(100%	0.19 (0.01-4.08), 0.493
Clinical success, n (%)	34	(91.9%)	33	(89.2%)	1.37 (0.29-6.62), 1.000
Per protocol clinical success, n (%)	34/35	(97.1%)	33	(89.2%)	4.12 (0.44-38.83), 0.358
Median time to oral intake, days (IQR)	1	(0.3-1.0)	3	(1.0-5.0)	<0.001
Full diet at discharge, n (%)	21	(56.8%)	14	(37.8%)	2.16 (0.85-5.46), 0.162
Median time to full diet, days (IQR)	2	(1.0-3.8)	9	(4.0-23)	<0.001
Gastroenterostomy dysfunction, n (%)	0	(0.0%)	0	(0.0%)	1.000
Distal obstruction, n (%)	2	(5.4%)	1	(2.7%)	2.06 (0.18-23.72), 1.000
Safety					
Overall adverse events, n (%)	1	(2.7%)	10	(27.0%)	0.07 (0.01-0.62), 0.007
Mild, n(%)	1	(2.7%)	1	(2.7%)	1.000
Moderate, n(%)	0	(0.0%)	3	(8.1%)	0.13 (0.01-2.64), 0.240
Endoscopic reintervention	0	(0.0%)	2	(5.4%)	0.19 (0.01-4.08), 0.493
Severe, n(%)	0	(0.0%)	6	(16.2%)	0.07 (0.00-1.19), 0.025
Surgical reintervention	0	(0.0%)	3	(8.1%)	0.13 (0.01-2.64), 0.240
Anastomotic leak	0	(0.0%)	4	(10.8%)	0.10 (0.01-1.91), 0.115
Anastomotic bleed	0	(0.0%)	2	(5.4%)	0.19 (0.01-4.08), 0.493
Fatal, n(%)	0	(0.0%)	0	(0.0%)	1.000
Other					
Median procedure duration, min (IQR)	46	(37.5-80)	85	(73.0-110)	<0.001
Median hospital stay, days (IQR)	4	(2.0-8.0)	8	(5.5-19.5)	<0.001
Median 2-months' weight change, kg (IQR)	-0,3	(-2.4-1.1)	0	(-3.0-0.7)	0.159
Median post-procedural survival, days (IQR)	96	(41.5-248)	152	(43.5-282)	0.317

Abbreviations: CI: confidence interval, EUS-GE: Endoscopic ultrasound-guided gastroenterostomy, IQR: interquartile range, LGE: laparoscopic gastroenterostomy, N/A: not applicable, OR: odds ratio.

Supplementary tables

Supplementary table 1. Sub-analysis comparing 15mm and 20mm LAMS efficacy and outcomes with or without balloon dilation.

Variable:	15mm LAMS (n=11)		20mm LAMS (n=64)		*P*-value
Technical success, n (%)	11/11	100%	62/64	96.9%	1.000
Clinical success*, n (%)	9/11	81.8%	62/62	100%	0.021
Median time to oral intake, days (IQR)	1	(0-1)	1	(0-1)	0.826
Full diet tolerability, n (%)	6	54.5%	45	70.3%	0.314
Median time to full diet, days (IQR)	2	(1-3)	2	(1-4)	0.099
Overall adverse events, n (%)	1	9.1%	4	6.5%	0.558
Gastroenterostomy dysfunction, n (%)	0	0.0%	1	1.6%	1.000
Median time to dysfunction, days (IQR)	N/A	N/A	243	N/A	N/A
Median hospital stay, days (IQR)	5	(2.8-11)	4	(2.0-11)	0.054
Median weight change after 2 months, kg (IQR)	-1,4	(-5.2-0.6)	-1	(-4.0-1.1)	0.430
Variable:	**With LAMS dilation (n=20)**		**Without LAMS dilation (n=55)**		***P*-value**
Technical success, n (%)	20/20	100%	53/55	96.4%	1.000
Clinical success*, n (%)	20/20	100%	51/53	96.2%	1.000
Median time to oral intake, days (IQR)	1	(0-1)	1	(0-1)	0.153
Full diet tolerability, n (%)	10	50.0%	39	70.9%	0.107
Median time to full diet, days (IQR)	2.5	(1-4)	2	(2-8)	0.254
Overall adverse events, n (%)	1	5.0%	4	7.3%	0.579
Gastroenterostomy dysfunction, n (%)	1	5.0%	0	0.0%	1.000
Median time to dysfunction, days (IQR)	243	N/A	N/A	N/A	N/A
Median hospital stay, days (IQR)	5	(2.0-11)	4	(2.0-11)	0.022
Median weight change after 2 months, kg (IQR)	-1.4	(-5.1-0.7)	-1	(-4.0-1.1)	0.849

Abbreviations: IQR: interquartile range, LAMS: lumen-apposing metal stent, kg: kilogram, N/A: not applicable.

*: per-protocol analysis.

Supplementary table 2. Multivariate analysis of variables in EUS-GE clinical failure.

Variable	OR	95% CI	*P*-value
Age	0.98	0.90-1.03	0.532
Gender, female	2.95	0.46-11.18	0.132
Pancreatic cancer	3.14	0.69-20.22	0.115
Ascites	8.39	1.29-375.4	0.104
Peritoneal carcinomatosis	2.65	0.44-28.94	0.305
15mm LAMS	2.45	0.14-14.09	0.332
Balloon dilation	0.11	0.01-0.72	0.059
Learning curve, first 50%	1.30	0.37-15.49	0.726

Supplementary table 3. Learning curve assessment: comparison between first and second half of the EUS-GE cohorts.

Propensity score-matched EUS-GE cohort:	First 50% (n=18)		Second 50% (n=19)		*P*-value
Technical success, n (%)	17/18	94.4%	18/19	94.7%	1.000
Clinical success, n (%)	17/18	94.4%	17/19	89.5%	1.000
Per protocol clinical success, n (%)	17/17	100%	17/18	94.4%	1.000
Overall adverse events, n (%)	1	5.6%	1	5.3%	1.000
Median procedure duration, min (IQR)	51	(34-84)	46	(40-83)	0.719
Overall EUS-GE cohort:	First 50% (n=38)		Second 50% (n=39)		*P*-value
Technical success, n (%)	37/38	97.4%	36/39	92.3%	0.615
Clinical success, n (%)	37/38	97.4%	34/39	87.2%	0.200
Per protocol clinical success, n (%)	37/37	100%	34/36	94.4%	0.240
Overall adverse events, n (%)	3	7.9%	3	7.7%	1.000
Median procedure duration, min (IQR)	49	(36-78)	52	(33-83)	0.719

Abbreviations: EUS-GE: Endoscopic ultrasound-guided gastroenterostomy, IQR: interquartile range.

Laparoscopic versus EUS-guided Gastroenterostomy for Gastric Outlet Obstruction: An International Multicentre Propensity Score-Matched Comparison.

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Abstract

Background and aims:

In the management of gastric outlet obstruction (GOO), EUS-guided gastroenterostomy (EUS-GE) seems safe and more effective than enteral stenting. However, comparisons to laparoscopic gastroenterostomy (L-GE) are scarce. Our aim was to perform a propensity score-matched comparison between EUS-GE and L-GE.

Methods:

An international, multicentre retrospective analysis was performed of consecutive EUS-GE and L-GE procedures in 3 academic centers (Jan-2015 to May-2020), using propensity score-matching in order to minimize selection bias. A standard maximum propensity score difference of 0.1 was applied, also considering underlying disease and oncological staging.

Results:

Overall, 77 patients were treated with EUS-GE and 48 patients with L-GE. By means of propensity score-matching, 37 patients were allocated to both groups, resulting in 74 (1:1) matched patients.

Technical success was achieved in 35/37 EUS-GE-treated patients (94.6%) vs. 100% in the L-GE group (p=0.493). Clinical success, defined as eating without vomiting or GOO Scoring System ≥ 2, was achieved in 97.1% and 89.2% respectively (p=0.358). Median time to oral intake (1 (IQR 0.3-1.0) vs. 3 (IQR 1.0-5.0) days, p<0.001) and median hospital stay (4 (IQR 2-8) vs 8 (IQR 5.5-20) days, p<0.001) were significantly shorter in the EUS-GE group. Overall adverse events (AEs) (2.7% vs. 27.0%, p=0.007) and severe AEs (0.0% vs. 16.2%, p=0.025) were identified more frequently in the L-GE group.

Conclusion:

For patients with GOO, EUS-GE and L-GE showed almost identical technical and clinical success. However, reduced time to oral intake, shorter median hospital stay and lower rate of adverse events suggest that the EUS-guided approach might be preferable.

Keywords

Gastric outlet syndrome, laparoscopic gastrojejunostomy, endoscopic ultrasound, LAMS.

Introduction

Gastric outlet obstruction (GOO), defined by a mechanical obstruction of the duodenum, pylorus or antrum, may result from various diseases. The underlying aetiology has shifted from mainly peptic ulcer disease in the past, to predominantly malignant causes at present[1,2]. In the most recent cohorts, GOO was caused by underlying malignancy in up to 85% of patients, the majority of which could be attributed to pancreatic cancer[3,4,5,6,7]. On the other hand, peptic ulcer disease and chronic pancreatitis are still the most prevalent causes of benign GOO[8,9]. Consequences of GOO, such as nausea, vomiting, anorexia, need for nasogastric tube decompression and subsequent loss of body mass, may further aggravate this complex clinical entity, increasing morbidity, reducing quality of life and significantly influencing tolerability and efficacy of oncological treatments[10]. Before the advent of endoscopic ultrasound-guided gastroenterostomy (EUS-GE), management of GOO mainly relied on surgical gastroenterostomy, the standard of care for many years[11,12]. Since the late nineties, placement of metal enteral stents was found to provide higher efficacy regarding early re-initiation of oral intake, as well as reduce hospital stay and major adverse events (AE)[11], albeit at the expense of more recurrent obstructive symptoms due to stent dysfunction[13,14]. Since 2012, EUS-GE has found its way from initial animal studies, into daily practice of tertiary centres[15,16]. This EUS-guided approach has become a minimally invasive alternative for patients with both benign or malignant GOO[3,4] and demonstrated higher clinical success and lower need for re-interventions compared to enteral stenting[5,17]. There is still uncertainty regarding the place of EUS-GE in daily clinical practice, due to a lack of data comparing this technique to the current reference standard, laparoscopic gastroenterostomy (L-GE), in patients stratified according to potential confounders, such as oncological staging and pre-procedural fragility[18-20].

Our aim was to perform a propensity score-matched comparison of EUS-GE to L-GE, using a large retrospective international multicentre cohort.

Methods

Patients and study design

A retrospective analysis was performed of all consecutive L-GE and EUS-GE procedures performed for GOO at the Amsterdam University Medical Centers, location AMC and VUmc (the Netherlands), IRCCS San Raffaele Scientific Institute Milan (Italy) and University Hospitals Leuven (Belgium) between January 2015 and May 2020. For both procedures, identical variables were extracted from patients' electronical medical charts. Inclusion criteria consisted of: (1) symptomatic GOO, (2) endoscopic or radiological confirmation of benign or malignant gastro-duodenal stenosis and (3) treatment with EUS-GE or L-GE. Considering the surgical procedures, only strictly "pure" laparoscopic gastroenterostomies were eligible for inclusion, as to minimize confounding effects of adjunctive procedures, such as metastasectomy, hepatico-enterostomy or cholecystectomy, often performed simultaneously. Each patient gave his or her consent with regards to the procedure. This study was furthermore approved by the central Institutional Review Board (study identifier: s64254) at the University Hospitals Leuven and at each participating center.

Endpoints

Technical success was defined as the successful creation of a gastro-enteric anastomosis by use of the initially chosen technique (see below for technical considerations). If additional approaches or techniques had to be involved or additional self-expandable metal stents (SEMS) were needed, this was regarded as a technical failure.

Food intake grading was defined using the GOO Scoring System (GOOSS) (0= no intake, 1= liquid only, 2= soft solids, 3= almost full diet, 4= full diet)[21,22]; symptomatic GOO was defined as a GOOSS of 0. In concordance with previous work[7], clinical success was defined as eating without vomiting or a GOOSS of ≥2 and was ascertained by evaluation of the electronic patient file, where this parameter is recorded as part of standard practice. Regarding safety, the ASGE lexicon for adverse events was used to stratify AE in mild, moderate, severe or fatal events[23].

Secondary endpoints were: hospital stay, weight change after 2 months, gastroenterostomy dysfunction, distal obstruction rates, 'time to oral intake' and 'time to full diet' (GOOSS of 4). For EUS-GE procedural time was extracted from the endoscopic electronic reporting system. For L-GE, procedural time was retrieved by revision of the anaesthesiology report, exactly stating the beginning and the end of the procedure. Gastroenterostomy dysfunction was defined as recurrence of obstructive symptoms (GOOSS < 1) after former clinical success, with confirmation of recurrent GOO by endoscopy or imaging studies. Mechanical obstructions located downstream the GE site, without signs of EUS-GE or L-GE dysfunction, were annotated as 'distal obstructions', but not registered as GE dysfunction.

Procedure: the Wireless EUS-gastroenterostomy Simplified Technique (WEST)

All EUS-GE are performed under deep sedation with propofol or general anaesthesia, using a electrocautery-enhanced lumen apposing metal stent (LAMS) and the Wireless EUS-gastroenterostomy Simplified Technique (WEST) as previously described, under prophylactic antibiotic therapy (Video)[24,25].

After a 7Fr nasobiliary catheter or enteral feeding tube is placed, through the gastric or duodenal stenosis into the jejunum, water is infused in the targeted loop of small bowel (Figure 1, upper left panel). Using a combination of fluoroscopy and EUS-guided identification of the catheter (Figure 1, upper middle panel) the dilated jejunal or enteric loop is accessed using the biflanged electrocautery-enhanced LAMS (Hot-Axios; Boston Scientific, Marlborough, MA, USA). Following successful intraluminal access to the small bowel, the distal flange is deployed under endosonographic guidance; the device is then

retracted (Figure 1, upper right panel), favouring apposition of the gastric and enteric wall and allowing the opening of the proximal flange inside the endoscope channel (Figure 1, lower left panel); the device is finally pushed outside the working channel together with a careful scope retraction, resulting in deployment of the proximal flange into the gastric lumen. Afterwards, successful deployment is confirmed by either EUS (Figure 1, lower left panel), direct endoscopic visualisation (Figure 2) or, if needed, combined with fluoroscopy and contrast injection (Figure 1, lower middle panel).

Procedure: Laparoscopic gastroenterostomy:

Following CO2-insufflation (12-15 mmHg intra-abdominal pressure) by a Veress needle or by open introduction, 4-5 trocars are introduced: one camera port around the umbilicus and 3 to 4 trocars at different positions in the upper abdomen. Next, Treitz' ligament is identified and two electrocautery incisions are made, one in the dorsal or anterior gastric wall and one in the jejunum. An anterior, dorsal latero-lateral or side-to-side isoperistaltic gastroenteric anastomosis is constructed. The exact location of the gastroenteric anastomosis, with regards to Treitz' ligament, varies from 30cm to 60cm. During the surgical approach a 60mm blue Echelon stapler (Johnson & Johnson, New Brunswick, New Jersey, USA) or 60mm Endo GIA universal stapler (Medtronic Ltd., Dublin, Ireland) is used depending on the preference of the surgeon, with additional staplers and sutures covering the staple line as needed. During construction of the gastroenteric anastomosis, a 36 French nasogastric tube is temporarily placed through the defect in the majority of cases, in an effort to maintain and confirm patency while stapling or suturing. Anti-traction sutures are used when appropriate. If not in place before the surgical procedure, a nasogastric tube is inserted afterwards and the patient remained on nil per mouth. In this study we only included "pure" L-GE for comparison to EUS-GJ and excluded procedures were adjunctive treatments, such as cholecystectomy, hepaticojejunostomy or metastasectomy were performed. All surgical procedures were performed by gastrointestinal surgeons with extensive experience in laparoscopic gastrointestinal surgery, operating in high-volume academic centres.

Statistical analysis

Categorical variables were reported as frequencies (%) and Fisher's test was used to compare these variables. Continuous variables were reported as medians and interquartile range (IQR) or means ± standard deviation (SD). Student's *t* test and Mann-Whitney *U* test were used for comparing continuous variables as appropriate. Differences in outcomes are shown as odds ratio (OR) and 95% confidence interval (CI). Kaplan-Meier curves were used for overall post-procedural survival analysis, whereas the log-rank test was used for corresponding comparisons. Furthermore, learning curve effect was evaluated by comparing the initial 50% of procedures with the second half of EUS-GE procedures in each centre. A multiple logistic regression was performed to identify predictors of clinical failure: age, gender, pancreatic cancer, presence of ascites or peritoneal carcinomatosis, use of 15mm LAMS and balloon dilation, as well as learning curve were used as variables. P-values <0.05 were considered statistically significant.

A propensity score-matched analysis was performed in an effort to minimize selection bias. Age, sex, underlying disease, corresponding disease stage, presence of ascites and presence of peritoneal carcinomatosis were used as variables. The aforementioned variables were selected based on: (1) analysis of previous literature and (2) significant differences between the two groups after univariate analysis. In four previously published studies, which performed a multivariate analysis, peritoneal carcinomatosis and ascites were identified as factors associated with clinical and technical failure respectively[3,4,7,26]
A standard maximum propensity score difference of 0.1 was admitted for matching.
SPSS version 26.0 (IBM, Chicago, IL, USA) was used for matching and statistical analysis, whereas Graphpad Prism version 9.0.0 for Windows (Graphpad Software, San Diego, CA, USA) was used for the Kaplan-Meier curves and survival analysis.

Results

Overall, we identified 126 patients, one of whom was excluded due to missing data, resulting in a total of 77 patients (62%) who underwent EUS-GE and 48 patients (38%) undergoing L-GE.

Baseline characteristics are shown in Table 1. Ascites (22.1% vs. 4.2%, p=0.009) and pancreatic cancer-induced GOO (48.1% vs. 29.2%, p=0.037) were significantly more frequent in the EUS-GE group, whereas underlying benign disease was identified significantly less (3.9% vs. 14.6%, p=0.044) when compared to L-GE-treated patients (Table 1). Technical success (94.8% (95% CI: 87.0-98.4) vs. 100% (95% CI: 91.2-100.0), p=0.297) was similar when comparing both groups, while a trend towards higher per-protocol clinical success amongst EUS-GE-treated patients was observed (97.3% (95% CI: 90.0-99.8) vs. 87.5% (95% CI: 74.9-94.5), OR 5.07 (95% CI: 0.98-26.28), p=0.057) (Table 2).

Overall, 15mm and 20mm LAMS were utilized in 11 and 64 patients respectively, with higher clinical success rates (81.8% (95% CI: 51.2-96.0) vs. 100% (95% CI: 93.0-100.0) respectively, p=0.021) and a trend towards shorter median hospital stay (5 days (2.8-11) vs. 4 days (2.0-11), p=0.054) when 20mm LAMS were utilized. Intraprocedural balloon dilation of the central part of the LAMS immediately after its placement was performed in 26% of patients and did not affect efficacy outcomes (Supplementary Table 1). Although two primary clinical failures occurred in patients in whom 15mm LAMS were used without dilation, multivariate analysis did not identify any significant independent risk factors for clinical failure (Supplementary Table 2). Overall AEs (6.5% (95%CI: 2.5-14.7) vs 31.3% (95% CI: 19.9-45.4), OR 0.15 (95% CI: 0.05-0.46), p<0.001), and severe AEs (2.6% (95% CI: 0.2-9.5) vs 18.8% (95%CI: 10.0-32.2), OR 0.12 (95% CI: 0.03-0.59), p=0.007) occurred significantly less frequently in EUS-GE versus L-GE treated patients (Table 2).

Propensity score-matched analysis

By means of propensity score matching, 37 patients were allocated to each group, resulting in a total of 74 (1:1) matched patients (Figure 3). The propensity score-matched cohort revealed an overall mean age of 66.5 ± 11.8 years, 44.6% were female, 36.5% had underlying pancreatic cancer, with 31.1% and 6.8% of patients exhibiting peritoneal carcinomatosis and ascites. Underlying benign disease was present in four (5.4%) patients. Baseline comparisons between EUS-GE and L-GE-treated patients are shown in Table 3. No significant differences between both study groups were identified.

Efficacy

In the propensity score-matched EUS-GE group, two technical failures occurred, due to inability to advance the nasobiliary catheter through the stenosis. This resulted in a technical success rate of 94.6% (35 out of 37 patients, 95% CI: 81.4-99.4), compared to 100% (95% CI: 88.8-100.0), p=0.493) amongst L-GE-treated patients (Table 4). Clinical success rates by means of intention to treat analysis (91.9% (95% CI: 78.0-97.9) vs. 89.2% (95% CI: 74.7-96.3), p=1.000), as well as per-protocol analysis were comparable (97.1% (95% CI: 84.2-100.0) vs. 89.2% (95% CI: 74.7-96.3), p=0.358), with primary non-functional surgical gastroenterostomy in three L-GE-patients. Procedure time (46 minutes (IQR 37.5-80.0) vs. 85 minutes (73.0-110), p<0.001), median time to oral intake (1 day (IQR 0.3-1.0) vs. 3 days (IQR 1.0-5.0), p<0.001) and median time to full diet (2 days (IQR 1.0-3.8) vs. 9 days (IQR 4.0-23), p<0.001) were significantly shorter in the EUS-GE group.

After a median follow-up of 77 days (IQR 27-160) in the EUS group and 123 days in the surgical group (IQR 32-262), gastroenterostomy dysfunction rates (none in both groups) did not differ. With two-months' weight change available in 51.4% and 56.8% of patients treated with EUS-GE and L-GE respectively, no significant differences were detected (-0.3kg (IQR -2.4-1.1) vs. 0kg (IQR -3.0-0.7), p=0.159).

Safety and postoperative outcomes

The overall number of AEs in the propensity score-matched cohort was lower amongst EUS-GE treated patients (2.7% (95% CI: 0.01-15.1) vs. 27% (95% CI: 15.2-43.1), OR 0.07 (95% CI: 0.01-0.62), p=0.007) (Table 4). Most AEs in the L-GE group (6 out of 10) were severe, mainly consisting of anastomotic leaks (n=4, 10.8%) or bleeding (n=2, 5.4%), necessitating surgical reintervention in three patients (8.1%), while no severe AEs were registered among EUS-GE treated patients (0.0% (95% CI: 0.0-11.2) vs. 16.2% (95% CI: 7.3-31.5), OR 0.07 (95% CI: 0.00-1.19), p=0.025). Mild (2.7% in each group) and moderate AE rates (0.0% (95% CI: 0.0-11.2) vs. 8.1% (95% CI: 2.1-22.0), p=0.240) were similar in both groups. In two L-GE patients, endoscopic reinterventions was deemed necessary in the context of postoperative bleeding and placement of a trans-anastomotic stent to treat a dysfunctional surgical anastomosis.

A significantly shorter median hospital stay (4 days (IQR 2.0-8.0) vs. 8 days (IQR 5.5-20), p<0.001) was observed amongst EUS-GE-treated patients. Survival analysis did not reveal a significant difference in post-procedural survival in the matched cohort, nor in the overall cohort (Figure 4).

Learning Curve Assessment

When comparing the first to the second half of both the overall and propensity score-matched EUS-GE cohorts (Supplementary Table 3), no significant differences were found in terms of safety and efficacy.

Discussion

In the current analysis, we performed the first propensity score-matched comparison between EUS-GE and L-GE. We found that EUS-GE achieved similar technical and clinical success, with significantly lower overall and severe AEs, faster resumption of oral intake and earlier discharge compared to L-GE. Whilst the EUS-GE technical and clinical success rate was in line with previously published studies[3-9,27], we observed that technical success depended mainly on the ability to pass a nasobiliary catheter through the stenosis. Furthermore, amongst all technical variables, only LAMS calibre might have some influence on clinical outcome, although this was not confirmed by multivariate analysis.

The paucity of published comparative data makes it difficult to identify a well-defined place for EUS-GE in the management of patients with GOO, especially compared to the more established techniques such as surgery and enteral stenting. Only a single large multicentre retrospective study comparing open gastroenterostomy to EUS-GE has been published so far[7]. The authors reported lower AEs compared to the open surgical approach, at the cost of a lower, but not statistically significant, technical success rate. Surprisingly, length of hospital stay amongst both groups was similar. One can speculate whether this was related to the limited experience available at the time, which may have influenced clinical decisions regarding timing of discharge and general post-EUS-GE management. In our cohort, most patients were discharged after a median of 4 days (IQR 2.0-8.0) compared to 8 days (IQR 5.5-20) in the L-GE group, which may an impact on health care costs and quality of life. We chose to compare our EUS-GE cohort with laparoscopic surgery, as it has proven superior to open surgery, in and outside the context of gastroenterostomy, showing lower morbidity and earlier recovery compared to open surgery, making the L-GE approach the most desired comparator[18]. One previous multicentre retrospective analysis evaluated the efficacy and safety of EUS-GE compared to L-GE, this study only included 25 patients undergoing EUS-GE and did not correct for potential confounding factors or bias[19]. The authors demonstrated increased safety and lower costs using EUS-GE, while retaining similar efficacy to L-GE, even if they detected a non-significant difference in technical success in favour of L-GE[19].
The surgical adverse event rate observed in our study (31.3%), was similar to those reported by Perez-Miranda, et al (41%)[19] and Kashab, et al (25%)[7], suggesting that the superior safety outcomes of EUS-GE observed in our analysis were not due to inferior performance of the surgical comparator group. Furthermore, when comparing surgical adverse events rates in historical cohorts of surgical palliative gastroenterostomy, similar[28-30] or higher[31-33] adverse event rates were seen when compared to the current analysis.

When considering previous comparisons of EUS-GE with enteral stenting, limited evidence suggests that the latter is associated with a lower rate of clinical success and higher rates of stent failure requiring re-intervention[5,17]. These findings have been confirmed in studies comparing enteral stenting with surgical gastroenterostomy, suggesting that enteral stenting should be considered in the context of very limited life expectancy only[13,34].

There are some issues when comparing previous EUS-GE data with our current analysis. First, several techniques have been described for performing EUS-GE, which include the endoscopic ultrasonography-guided double-balloon-occluded gastrojejunostomy bypass (EPASS)-technique, natural orifice transluminal endoscopic surgery (NOTES), rendez-vous methods including balloon-assisted gastroenterostomy, and the direct or 'free-hand'-techniques[7,35-37]. These techniques have been interchangeably used throughout several studies[3,4,7,8,19], complicating reliable direct comparisons of results. Secondly, several previous papers have published overlapping study cohorts, rendering data interpretation somewhat complicated[4,19,20,35,38]. Third, the use of different LAMS with a limited number of studies also including cases where Niti-S Spaxus LAMS (Taewoong Medical Co. Ltd., Ilsan, Korea) were used instead of the Hot-Axios[3,7,26]. Regarding different EUS-GE approaches, a comparative study has shown that the direct method achieves similar technical and clinical success, with a similar safety profile when

compared to balloon-assisted EUS-GE[3]. However, in the context of the direct method, procedure time was more than twice shorter (35.7 vs. 89.9min, p<0.001), thus suggesting the direct technique as the preferred method. In all of our patients, only the Wireless EUS-gastroenterostomy Simplified Technique (WEST) was used, indicating that there is no need for a 19G 'finder'-needle, as has been described in the direct technique, or a guidewire and balloon in order to perform EUS-GE safely and effectively[3,24,25]. We recommend against inflating the targeted loop of small bowel by water or contrast injection using a 19-gauge needle, such as in the setting of EUS-directed transenteric ERCP (EDEE)[39], an approach which may carry a higher theoretical risk of puncturing a more distal enteric loop or even the colon. We do recommend using the most straightforward technique available, in an effort to reduce the number of additional accessories requiring exchange, which in our opinion carries an increased risk of adverse events by complicating positioning, visualisation and, as time passes, reduction in small bowel distention.

While the usefulness of EUS-GE in malignant disease has been reported in various studies, the evidence of this procedure in benign disease has been increasing since only recently[5,7,17]. Doubts concerning LAMS patency and long-term results have led to restricted use in benign diseases. In 2020, James et al. published their series on EUS-GE in benign disease, revealing that surgery was averted in 83.3% of patients and regression of the benign stricture allowed for LAMS removal in the majority of patients over time[9]. Together with long-term follow-up data published in 2019[6], which showed a 15% recurrence rate after a median follow-up time of 169 (malignant disease) and 319.5 days (benign disease), we can conclude that especially in patients with malignant disease GOO, recurrence is an issue. In our current propensity score-matched analysis gastroenterostomy dysfunction did not occur at all, although two cases of distal enteric obstruction, due to metastatic peritoneal disease, were identified in the EUS-GE group, compared to one in the L-GE-group.

In comparison to various other studies, where there was no mention of the incidence of ascites[3,4,6-9,17,19], 21% of our patients underwent EUS-GE despite the presence of ascites, without any significant related AEs. Although ascites has been regarded as a strict contraindication for EUS-GE, these results, together with a retrospective analysis in 2019[5], suggest that patients with mild or localized ascites can be considered for EUS-GE without risking leakage or subsequent peritonitis, provided that there is no tense ascites and that the LAMS trajectory is not compromised due to fluid interference.

Limitations and strengths:

Several limitations of the current study should be addressed. First, the retrospective nature of this analysis might have inadvertently introduced some bias. Secondly, due to the study design, a certain degree of missing data was identified, most especially in the context of body weight evolution. Third, generalizability of our data might be an issue, as all endoscopists were highly trained and operating in high-volume settings.

We have tried to address some of these limitations in our study design. We included a propensity score-matched design, correcting for the selected variables to limit selection bias. These specific variables were chosen as they were differently distributed amongst the two treatment groups, whilst potentially influencing technical and clinical success, as well as 'time to oral intake', 'time to full diet', overall survival and gastroenterostomy dysfunction rates. One of the disadvantages of propensity score-matching, is the dependence on the matching criteria. We therefore included various variables as to provide a stringent matching process. To reduce larger treatment effects and higher degrees of bias of single centre studies, we involved three different tertiary referral centres recruiting similar patients and all performing EUS-GE using the WEST approach[24,25]. Finally, with 77 patients in whom EUS-GE was performed, our study is one of the largest published original cohorts of EUS-GE, and the largest study to date to compare EUS-GE with L-GE.

In conclusion, this study suggests that in patients with gastric outlet syndrome, EUS-GE and L-GE provide almost identical technical and clinical success rates. Lower time to oral intake, shorter hospital stay and a lower rate of adverse events prudentially suggest that EUS-GE should be the preferred approach in patients with GOO. While awaiting high-quality prospective confirmation, these findings should guide gastroenterologists, oncologists and surgeons in considering EUS-GE for treating GOO, especially in the setting of malignancy, where patients will benefit from the least invasive technique with the highest expected efficacy.

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Figure legend

Figure 1. Stepwise approach to the Wireless EUS-gastroenterostomy Simplified Technique (WEST).
Upper left: Fluoroscopic image, placement of a 7Fr nasobiliary catheter or enteral feeding tube through the gastric or duodenal stenosis into the jejunum. Confirmation of the distal position by contrast opacification.
Upper middle: Endoscopic ultrasound image, showing distention of the targeted loop of small bowel after infusion of water.
Upper right: Using a combination of fluoroscopy and EUS-guided identification of the catheter, the dilated jejunal or enteric loop is accessed using the biflanged electrocautery-enhanced LAMS, after which the distal flange is deployed under endosonographic guidance. The device is then retracted onto the gastric wall.
Lower left: Endoscopic ultrasound image, after compressing the gastric and enteric wall, as well as deployment of the proximal flange inside the endoscope channel, the device is finally pushed outside the working channel together with a careful scope retraction, resulting in deployment of the proximal flange into the gastric lumen.
Lower middle: Fluoroscopic evaluation after LAMS release, showing the successful deployment of the LAMS between the stomach and small bowel.
Lower right: Endoscopic view, after recannulation with a diagnostic catheter.

Figure 2. Direct endoscopic visualisation of successful gastroenterostomy.

Figure 3. Study flowchart.

Figure 4. Post-procedural survival analysis.

Tables

Table 1. Overall baseline characteristics.

	EUS-GE (n=77)		L-GE (n=48)		*P* value
Variable					
Age (years), mean ± SD	65	±12.3	66	±11.6	0.478
Female, n (%)	36	(46.8%)	19	(39.6%)	0.432
Median follow up duration, days (IQR)	76	(36-136)	122	(35-274)	0.057
Primary disease					
Pancreatic cancer	37	(48.1%)	14	(29.2%)	0.037
Biliary/gallbladder cancer	9	(11.7%)	2	(4.2%)	0.149
Gastric cancer	7	(9.1%)	5	(10.4%)	0.807
Duodenal cancer	11	(14.3%)	10	(20.8%)	0.341
Breast cancer	2	(2.6%)	2	(4.2%)	0.463
Colorectal cancer	2	(2.6%)	1	(2.1%)	1.000
NET	1	(1.3%)	0	(0.0%)	0.384
Ampullary cancer	0	(0.0%)	1	(2.1%)	0.384
NSCLC	3	(3.9%)	1	(2.1%)	1.000
Benign disease	3	(3.9%)	7	(14.6%)	0.044
Disease stage					
Local invasion	25	(32.5%)	13	(27.1%)	0.555
Liver metastases	8	(10.4%)	9	(18.8%)	0.193
Peritoneal metastastases	8	(10.4%)	10	(20.8%)	0.122
Diffuse metastatic	19	(24.7%)	9	(18.8%)	0.512
Disease manifestations					
Ascites	17	(22.1%)	2	(4.2%)	0.009
Peritoneal carcinomatosis	20	(26.0%)	16	(33.3%)	0.420

Table 2. Overall outcomes.

	EUS-GE (n=77)		L-GE (n=48)		OR (95% CI), *P* value
Efficacy					
Technical success, n (%)	73	(94.8%)	48	(100%)	0.17 (0.01-3.20), 0.297
Clinical success, n (%)	71	(92.2%)	42	(87.5%)	1.69 (0.51-5.58), 0.534
Per protocol clinical success, n (%)	71	(97.3%)	42	(87.5%)	5.07 (0.98-26.28), 0.057
Median time to oral intake, days (IQR)	1	(0-1)	3	(1-5)	<0.001
Full diet tolerability, n (%)	32	(41.6%)	19	(39.6%)	1.16 (0.56-2.44), 0.854
Median time to full diet, days (IQR)	2	(1-4)	8	(4-21)	<0.001
Gastroenterostomy dysfunction, n (%)	1	(1.3%)	0	(0.0%)	1.90 (0.08-47.64), 1.000
Median time to dysfunction, days (IQR)	243	N/A	N/A	N/A	N/A
Distal obstruction, n (%)	8	(10.4%)	1	(1.3%)	5.45 (0.66-45.02), 0.151
Median time to distal obstruction, days (IQR)	34	(18-138)	13	N/A	N/A
Safety					
Overall adverse events, n (%)	5	(6.5%)	15	(31.3%)	0.15 (0.05-0.46), <0.001
Mild, n(%)	2	(2.6%)	1	(2.1%)	1.25 (0.11-14.21), 1.000
Post-procedural fever, n (%)	2	(2.6%)	0	(0.0%)	3.21 (0.15-68.35), 0.523
Moderate, n(%)	1	(1.3%)	5	(10.4%)	0.11 (0.01-1.00), 0.106
Sepsis, n (%)	1	(1.3%)	0	(0.0%)	1.90 (0.08-47.64), 1.000
Need for re-endoscopy, n (%)	0	(0.0%)	4	(8.3%)	0.06 (0.00-1.21), 0.020
Severe, n(%)	2	(2.6%)	9	(18.8%)	0.12 (0.03-0.59), 0.007
Intra-peritoneal LAMS deployment, n (%)	2	(2.6%)	N/A	N/A	N/A
Anastomotic leak, n (%)	N/A	N/A	3	(6.3%)	N/A
Anastomotic bleeding, n (%)	N/A	N/A	2	(4.2%)	N/A
Surgical re-intervention, n (%)	N/A	N/A	3	(6.3%)	N/A
Fatal, n(%)	0	(0.0%)	0	(0.0%)	1.000
Other					
Median procedure duration, min (IQR)	51	(36 - 79.8)	95	(75 - 118)	<0.001
Median hospital stay, days (IQR)	4	(2 - 10.5)	8	(5 - 20)	<0.001
Median weight change after 2 months, kg (IQR)	-1	(-4.0 - 1.1)	-0,4	(-4.2 - 0.8)	0.390
Median post-procedural survival, days (IQR)	103	(44 - 252)	147	(68 - 335)	0.246

Abbreviations: CI: confidence interval, EUS-GE: Endoscopic ultrasound-guided gastroenterostomy, IQR: interquartile range, LGE: laparoscopic gastroenterostomy, N/A: not applicable, OR: odds ratio.

Table 3. Matched cohort: baseline characteristics.

	EUS-GE (n=37)		L-GE (n=37)		*P* value
Variable					
Age (years), mean ± SD	66.5	±12.5	66.4	±11.1	0.954
Female, n(%)	18	(48.7%)	15	(40.5%)	0.640
Median follow up duration, days (IQR)	77	27-160	123	32-262	0.105
Primary disease					
Pancreatic cancer	15	(40.5%)	13	(35.1%)	0.811
Biliary/gallbladder cancer	5	(13.5%)	2	(5.4%)	0.430
Gastric cancer	5	(13.5%)	5	(13.5%)	1.000
Duodenal cancer	6	(16.2%)	8	(21.6%)	0.768
Benign disease	2	(5.4%)	2	(5.4%)	1.000
Breast cancer	1	(2.7%)	1	(2.7%)	1.000
Colorectal cancer	2	(5.4%)	0	(0.0%)	0.493
NET	1	(2.7%)	0	(0.0%)	1.000
Ampullary cancer	0	(0.0%)	1	(2.7%)	1.000
NSCLC	1	(2.7%)	1	(2.7%)	1.000
Disease stage					
Local invasion	15	(40.5%)	12	(32.4%)	0.630
Liver metastases	6	(16.2%)	8	(21.6%)	0.768
Peritoneal metastastases	6	(16.2%)	7	(18.9%)	1.000
Diffuse metastatic	8	(21.6%)	6	(16.2%)	0.768
Disease manifestations					
Ascites	3	(8.1%)	2	(5.4%)	1.000
Peritoneal carcinomatosis	10	(27.0%)	13	(35.1%)	0.616

Table 4. Matched cohort: outcome comparisons.

	EUS-GE (n=37)		L-GE (n=37)		OR (95% CI), *P* value
Efficacy					
Technical success, n (%)	35	(94.6%)	37	(100%	0.19 (0.01-4.08), 0.493
Clinical success, n (%)	34	(91.9%)	33	(89.2%)	1.37 (0.29-6.62), 1.000
Per protocol clinical success, n (%)	34/35	(97.1%)	33	(89.2%)	4.12 (0.44-38.83), 0.358
Median time to oral intake, days (IQR)	1	(0.3-1.0)	3	(1.0-5.0)	<0.001
Full diet at discharge, n (%)	21	(56.8%)	14	(37.8%)	2.16 (0.85-5.46), 0.162
Median time to full diet, days (IQR)	2	(1.0-3.8)	9	(4.0-23)	<0.001
Gastroenterostomy dysfunction, n (%)	0	(0.0%)	0	(0.0%)	1.000
Distal obstruction, n (%)	2	(5.4%)	1	(2.7%)	2.06 (0.18-23.72), 1.000
Safety					
Overall adverse events, n (%)	1	(2.7%)	10	(27.0%)	0.07 (0.01-0.62), 0.007
Mild, n(%)	1	(2.7%)	1	(2.7%)	1.000
Moderate, n(%)	0	(0.0%)	3	(8.1%)	0.13 (0.01-2.64), 0.240
Endoscopic reintervention	0	(0.0%)	2	(5.4%)	0.19 (0.01-4.08), 0.493
Severe, n(%)	0	(0.0%)	6	(16.2%)	0.07 (0.00-1.19), 0.025
Surgical reintervention	0	(0.0%)	3	(8.1%)	0.13 (0.01-2.64), 0.240
Anastomotic leak	0	(0.0%)	4	(10.8%)	0.10 (0.01-1.91), 0.115
Anastomotic bleed	0	(0.0%)	2	(5.4%)	0.19 (0.01-4.08), 0.493
Fatal, n(%)	0	(0.0%)	0	(0.0%)	1.000
Other					
Median procedure duration, min (IQR)	46	(37.5-80)	85	(73.0-110)	<0.001
Median hospital stay, days (IQR)	4	(2.0-8.0)	8	(5.5-19.5)	<0.001
Median 2-months' weight change, kg (IQR)	-0,3	(-2.4-1.1)	0	(-3.0-0.7)	0.159
Median post-procedural survival, days (IQR)	96	(41.5-248)	152	(43.5-282)	0.317

Abbreviations: CI: confidence interval, EUS-GE: Endoscopic ultrasound-guided gastroenterostomy, IQR: interquartile range, LGE: laparoscopic gastroenterostomy, N/A: not applicable, OR: odds ratio.

Supplementary tables

Supplementary table 1. Sub-analysis comparing 15mm and 20mm LAMS efficacy and outcomes with or without balloon dilation.

Variable:	15mm LAMS (n=11)		20mm LAMS (n=64)		*P*-value
Technical success, n (%)	11/11	100%	62/64	96.9%	1.000
Clinical success*, n (%)	9/11	81.8%	62/62	100%	0.021
Median time to oral intake, days (IQR)	1	(0-1)	1	(0-1)	0.826
Full diet tolerability, n (%)	6	54.5%	45	70.3%	0.314
Median time to full diet, days (IQR)	2	(1-3)	2	(1-4)	0.099
Overall adverse events, n (%)	1	9.1%	4	6.5%	0.558
Gastroenterostomy dysfunction, n (%)	0	0.0%	1	1.6%	1.000
Median time to dysfunction, days (IQR)	N/A	N/A	243	N/A	N/A
Median hospital stay, days (IQR)	5	(2.8-11)	4	(2.0-11)	0.054
Median weight change after 2 months, kg (IQR)	-1,4	(-5.2-0.6)	-1	(-4.0-1.1)	0.430
Variable:	**With LAMS dilation (n=20)**		**Without LAMS dilation (n=55)**		***P*-value**
Technical success, n (%)	20/20	100%	53/55	96.4%	1.000
Clinical success*, n (%)	20/20	100%	51/53	96.2%	1.000
Median time to oral intake, days (IQR)	1	(0-1)	1	(0-1)	0.153
Full diet tolerability, n (%)	10	50.0%	39	70.9%	0.107
Median time to full diet, days (IQR)	2.5	(1-4)	2	(2-8)	0.254
Overall adverse events, n (%)	1	5.0%	4	7.3%	0.579
Gastroenterostomy dysfunction, n (%)	1	5.0%	0	0.0%	1.000
Median time to dysfunction, days (IQR)	243	N/A	N/A	N/A	N/A
Median hospital stay, days (IQR)	5	(2.0-11)	4	(2.0-11)	0.022
Median weight change after 2 months, kg (IQR)	-1.4	(-5.1-0.7)	-1	(-4.0-1.1)	0.849

Abbreviations: IQR: interquartile range, LAMS: lumen-apposing metal stent, kg: kilogram, N/A: not applicable.

*: per-protocol analysis.

Supplementary table 2. Multivariate analysis of variables in EUS-GE clinical failure.

Variable	OR	95% CI	*P*-value
Age	0.98	0.90-1.03	0.532
Gender, female	2.95	0.46-11.18	0.132
Pancreatic cancer	3.14	0.69-20.22	0.115
Ascites	8.39	1.29-375.4	0.104
Peritoneal carcinomatosis	2.65	0.44-28.94	0.305
15mm LAMS	2.45	0.14-14.09	0.332
Balloon dilation	0.11	0.01-0.72	0.059
Learning curve, first 50%	1.30	0.37-15.49	0.726

Supplementary table 3. Learning curve assessment: comparison between first and second half of the EUS-GE cohorts.

Propensity score-matched EUS-GE cohort:	First 50% (n=18)		Second 50% (n=19)		*P*-value
Technical success, n (%)	17/18	94.4%	18/19	94.7%	1.000
Clinical success, n (%)	17/18	94.4%	17/19	89.5%	1.000
Per protocol clinical success, n (%)	17/17	100%	17/18	94.4%	1.000
Overall adverse events, n (%)	1	5.6%	1	5.3%	1.000
Median procedure duration, min (IQR)	51	(34-84)	46	(40-83)	0.719
Overall EUS-GE cohort:	First 50% (n=38)		Second 50% (n=39)		*P*-value
Technical success, n (%)	37/38	97.4%	36/39	92.3%	0.615
Clinical success, n (%)	37/38	97.4%	34/39	87.2%	0.200
Per protocol clinical success, n (%)	37/37	100%	34/36	94.4%	0.240
Overall adverse events, n (%)	3	7.9%	3	7.7%	1.000
Median procedure duration, min (IQR)	49	(36-78)	52	(33-83)	0.719

Abbreviations: EUS-GE: Endoscopic ultrasound-guided gastroenterostomy, IQR: interquartile range.

Figure 1

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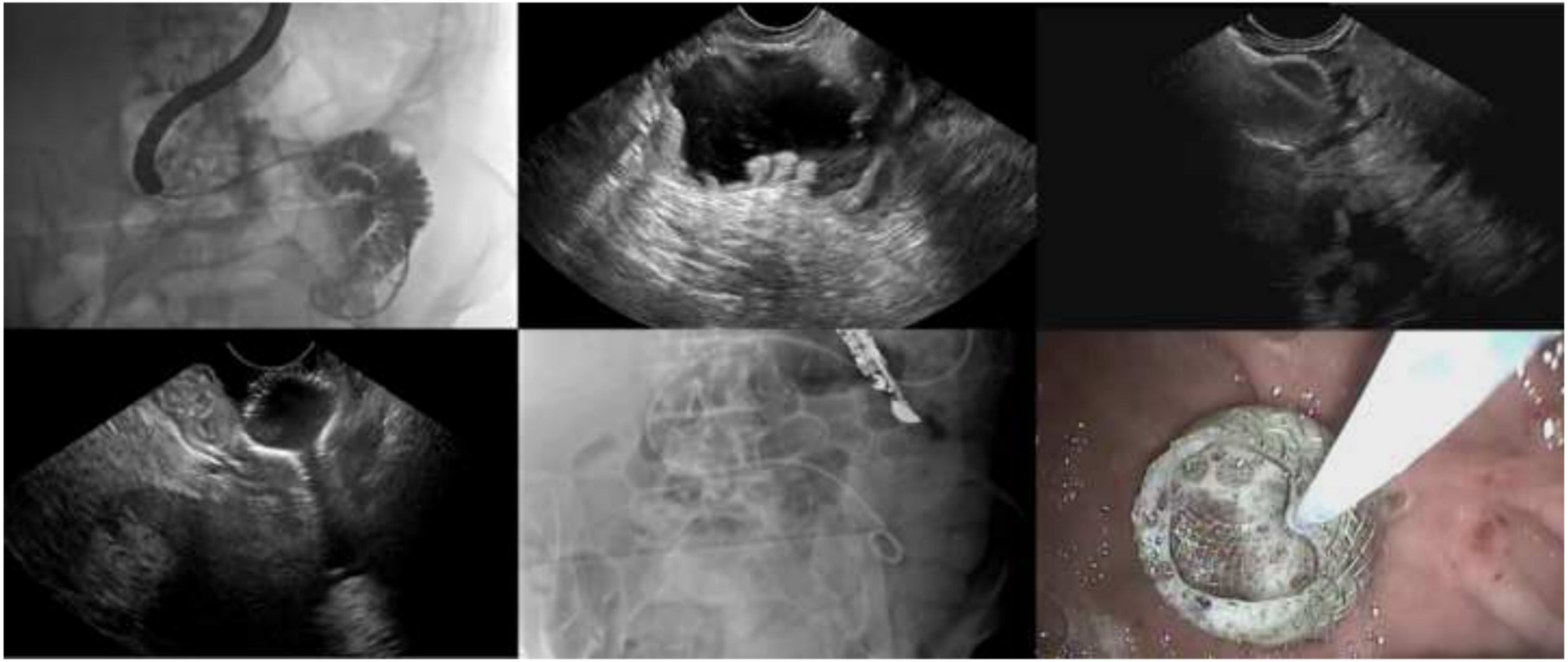

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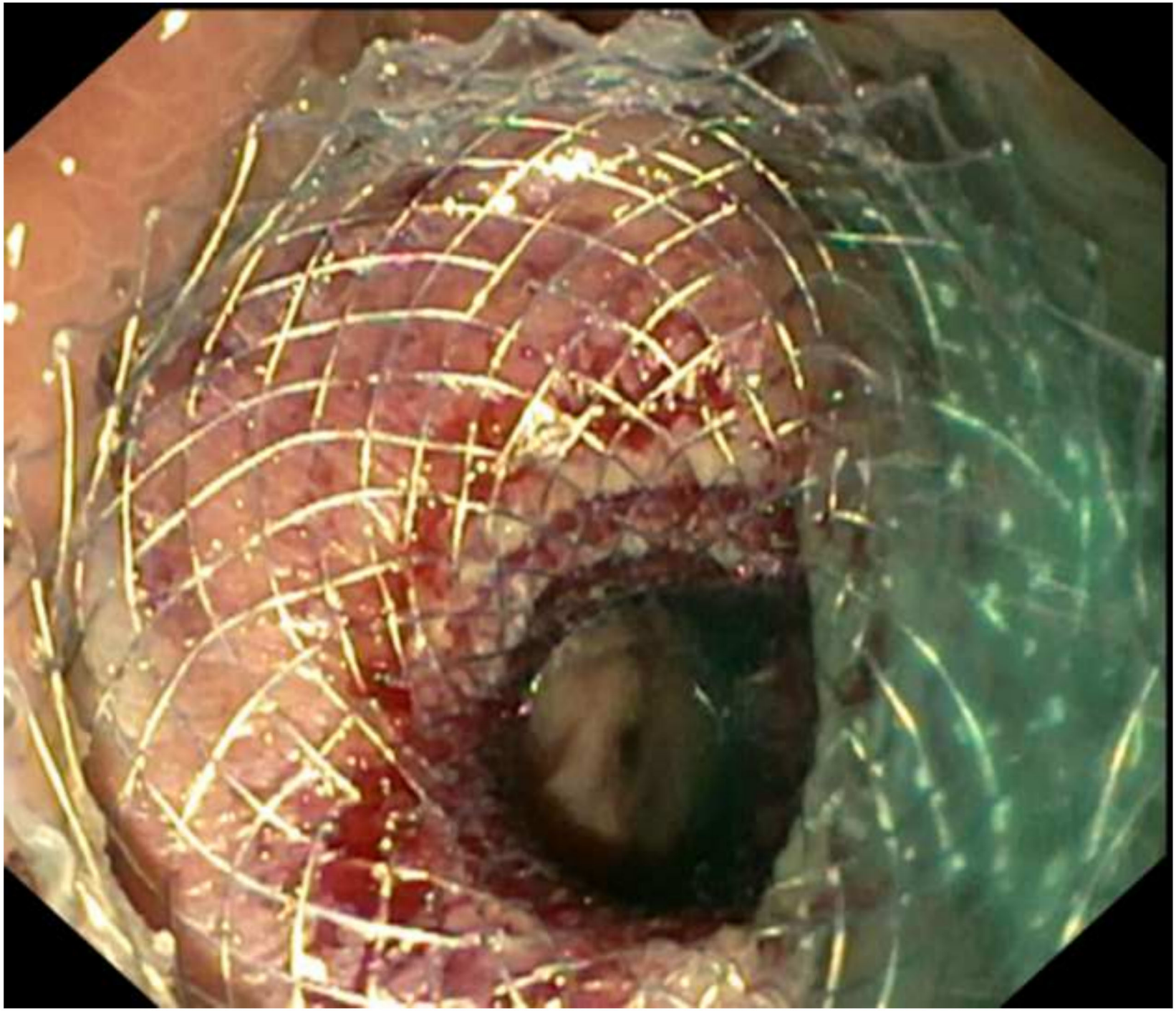

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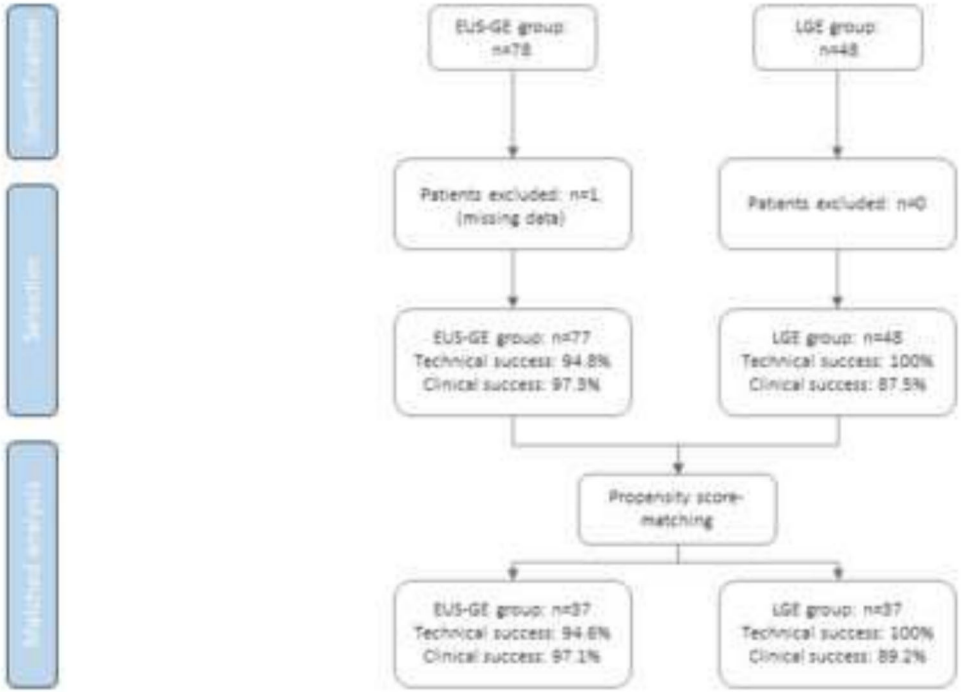

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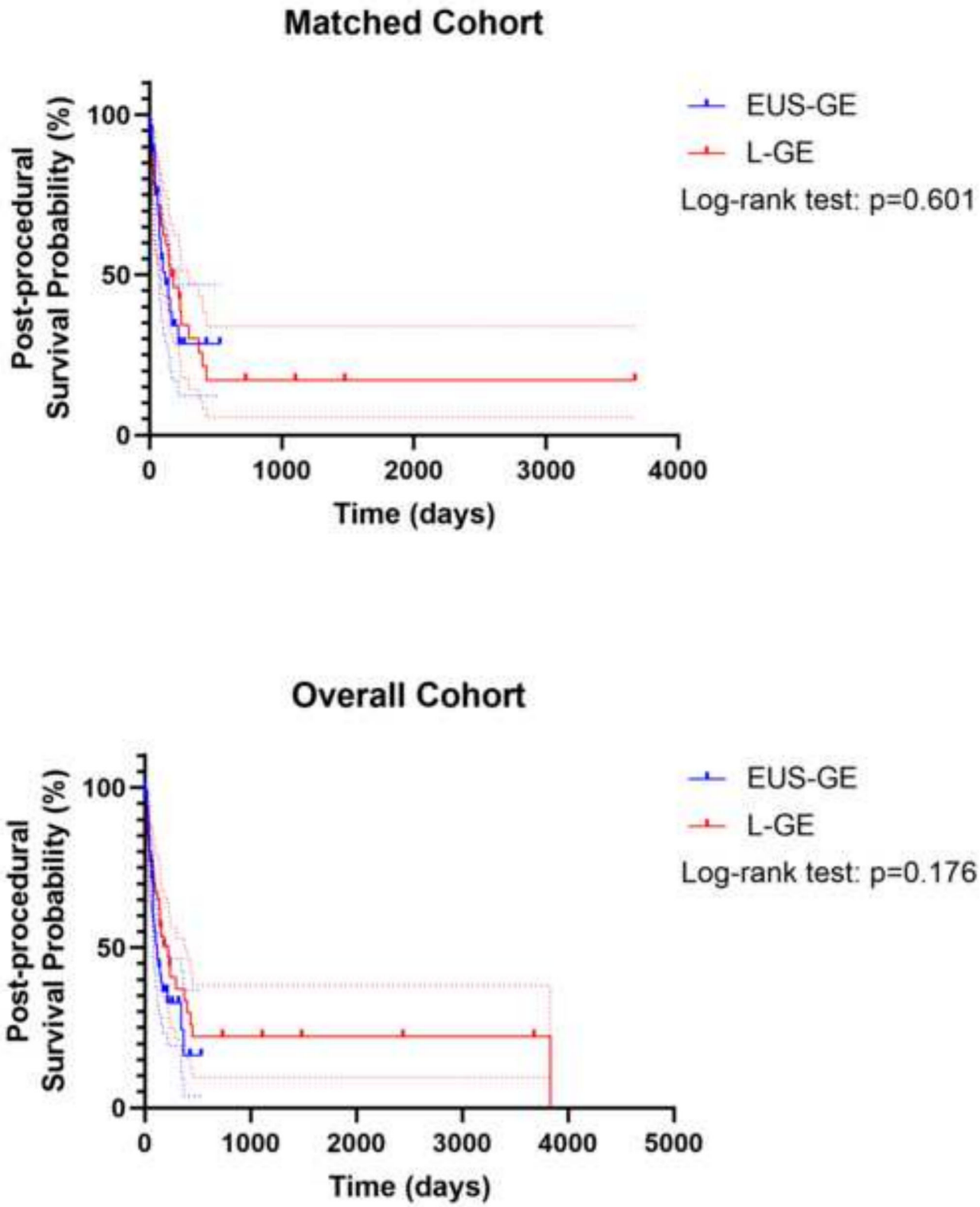

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Laparoscopic versus EUS-guided Gastroenterostomy for Gastric Outlet Obstruction: An International Multicentre Propensity Score-Matched Comparison.

Abbreviations:

AE: adverse event

ASGE: American society gastrointestinal endoscopy

CI: confidence interval

EUS: endoscopic ultrasound

EUS-GE: EUS-guided gastroenterostomy

GOO: gastric outlet obstruction

IQR: interquartile range

LAMS: lumen-apposing metal stent

L-GE: laparoscopic gastroenterostomy

OR: odds ratio

SD: standard deviation

SEMS: self-expandable metal stents

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