Relationship of early acute complications and insertion site in push method percutaneous endoscopic gastrostomy

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Percutaneous endoscopic gastrostomy (PEG), which is frequently used for nutrition management in patients having difficulty with oral intake, is considered a safe procedure. However, serious complications may occur depending on site of the puncture. This study aimed to clarify whether push method PEG construction at the posterior wall (PW) of the greater curvature (GC) had a higher risk of complications. We retrospectively investigated the relationship between puncture site at the PW of the GC and early acute complications in 540 patients receiving PEG. Early acute complications were defined as bleeding or perforation within 30 days after the PEG procedure. PEG-related complications were observed in 80 patients in total, with early acute complications detected in 42 patients. PEG construction at the PW of the GC in 12 cases exhibited a significantly higher occurrence of early acute complications versus PEG at other sites (41.7% vs. 7.0%, \( p = 0.001 \)). Further, multivariate analysis revealed PW at the GC to be independently associated with early acute complications (OR 9.59, 95% CI 2.82–32.61; \( p = 0.0003 \)). It may be desirable to avoid PEG at the PW of the GC. If performed, clinicians should pay careful attention to early acute complications.

First performed by Gauderer et al. in 19801, percutaneous endoscopic gastrostomy (PEG) is a medical procedure to provide enteral nutrition for patients having difficulty with oral nutrient intake2. PEG has no inferiority to surgical gastrostomy in terms of morbidity or mortality3, with success rates of 95–100%4. Anderloni et al. assessed early and late (30-day) complications and mortality for PEG. The 30-day mortality rate was 1.8% and complications were detected in 1.7% of patients, which supported the safety of the PEG procedure5. However, the most frequent, albeit non-serious, complication was infection (50%), followed next by bleeding (32.1%), tube dislodgement (14.3%), and buried bumper syndrome (3.6%)5. Thus, serious complications may occur depending on the type and location of the puncture6,7. To the best of our knowledge, few reports have addressed the relationship between PEG site and complications. Lee et al. found that PEG tube insertion in the upper body of the stomach was a significant risk factor for early and late complications by multivariate analysis8. Those complications were suspectedly caused by relatively long distances between the gastric and abdominal walls for the upper body as compared with those for the lower body, which might have produced stronger tension between the abdominal and gastric walls during stomach contraction to induce slow or incomplete fistula formation8.

Gastrostomy should generally be made at the gastric anterior wall (AW) (Fig. 1a,b). However, when the AW of the stomach is far from the abdominal wall due to stomach rotation, the greater curvature (GC) can be selected for introducer modification of PEG tube insertion (Fig. 1a,b). After encountering two recent cases of serious complications following PEG by introducer modification at the posterior wall (PW) of the GC, we hypothesized a higher complication rate for PEG placement at the PW of the GC. To examine this notion, we retrospectively investigated the relationship between puncture site and complications in patients receiving PEG and described the clinical outcomes of the two cases.

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Results

Patient background. The clinical characteristics of all patients are summarized in Table 1. A total of 374 patients (69.3%) were male and median age was 72 years. Anti-platelet or anti-coagulant agents were given to 118 patients. PEG with push method insertion was indicated for such background diseases as head and neck cancer, neurological disease, cerebrovascular disease, and dementia in all cases. Forty-two early acute complications, including four severe acute complications, were noted.

Complications occurring within and later than 30 days after PEG. PEG-related complications were observed in 80 patients. Complications within 30 days after PEG were recorded in 62 patients, among which wound bleeding was the most frequent (32 cases), followed next by wound infection (five cases). Based on the evaluation criteria5, there were 42 cases with early acute complications. Complications at 30 days or more after PEG were observed in 18 patients (Table 2). Most wound bleeding cases were successfully treated by compression hemostasis or subcutaneous suturing. Of the four cases of severe acute complications, two were related to...
the PEG site at the PW of the GC: one with gastroepiploic artery bleeding (case 1) and the other with gastric perforation (case 2), as described below. The severe acute complications in the remaining two cases were related to the PEG procedure not with the PW of the GC. One patient who was complicated with an abscess as a severe complication case at 30 days or more after PEG received surgical abscess drainage (Table 2).

Table 1. Patient background and univariate analysis of PEG site (n = 540). Early acute complications were defined as bleeding and perforation. Severe acute complications were defined as those requiring surgical intervention. The significance of an association was evaluated using the chi-square test. Fisher’s exact probability test was used for groups with fewer than five samples. The Mann–Whitney U-test was employed to analyze continuous variables.

Table 2. Classification of complications (n = 80). PEG percutaneous endoscopic gastrostomy. *Defined as an early acute complication based on a reported definition5.

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### Table 3. Patient background and univariate analysis of early and non-early acute complication groups. Early acute complications were defined as bleeding and perforation. The significance of an association was evaluated using the chi-square test. The Mann–Whitney U-test was employed to analyze continuous variables. APTT, activated partial thromboplastin time; AW, anterior wall; BMI, body mass index; CRP, C-reactive protein; GC, greater curvature; OR, odds ratio; Plt, platelet count; PT%, prothrombin%; PW, posterior wall; WBC, white blood cell count. *Two-point fixation, three-point fixation, four-point fixation, and unknown. **In model 1, the three significant univariate analysis factors of anti-platelet or anti-coagulant agents, hemoglobin, and PW of the GC were included for multivariate analysis.

| Laboratory data | Early acute complication group (n = 42) | Non-early acute complication group (n = 498) | Univariate p-value | OR (95% CI) | Multivariate** p-value | OR (95% CI) |
|-----------------|--------------------------------------|---------------------------------------------|--------------------|-------------|------------------------|-------------|
| Age (years)     | 74 (32–89)                           | 71 (17–99)                                 | 0.211              | –           |                        | –           |
| Male, n (%)     | 30 (71.4)                            | 344 (69.1)                                 | 0.751              | 1.12 (0.56–2.25) |                        | –           |
| BMI             | 18.2 (12.8–25.0)                     | 18.4 (11.8–35.4)                           | 0.885              | –           |                        | –           |
| Anti-platelet or anti-coagulant agents, n (%) | 15 (35.7) | 103 (20.7) | 0.024 | 2.13 (1.09–4.15) | 0.053 | 1.97 (0.99–3.90) |
| Hemoglobin (g/dL) | 11.2 (6.6–15.3) | 12.2 (7–17.0) | 0.042 | – | 0.053 | 0.86 (0.73–1.00) |
| WBC (/µL)       | 6660 (3600–14,280)                   | 6160 (2410–19,840)                         | 0.318              | –           |                        | –           |
| Hemoglobin (g/dL) | 11.2 (6.6–15.3) | 12.2 (7–17.0) | 0.042 | – | 0.053 | 0.86 (0.73–1.00) |
| Plt (10⁴/µL)    | 23.6 (3.3–64.9)                     | 23.9 (3.8–64.9)                            | 0.568              | –           |                        | –           |
| Hemoglobin (g/dL) | 11.2 (6.6–15.3) | 12.2 (7–17.0) | 0.042 | – | 0.053 | 0.86 (0.73–1.00) |
| Albumin (g/dL)  | 3.2 (2–4.6)                         | 3.4 (1.7–4.9)                              | 0.164              | –           |                        | –           |
| CRP (mg/dL)     | 0.62 (0–11.7)                       | 0.51 (0–19.9)                              | 0.622              | –           |                        | –           |
| PT% (%)         | 89 (71.4–144.3)                     | 86.5 (7.1–144.3)                           | 0.643              | –           |                        | –           |
| APTT (s)        | 29.9 (20.4–87.4)                    | 28.9 (19.4–180)                            | 0.062              | –           |                        | –           |
| Operator experience (years) | 7.0 (3–36) | 7.0 (3–33) | 0.811 | – | – | – |
| Number of gastropexies* | 2 (4.8),11 (26.2), 27 (64.3), 2 (4.8) | 37 (7.4), 157 (31.5), 300 (60.2), 4 (0.9) | 0.473 | 0.77 (0.38–1.57) | 0.030 | 0.96 (0.42–2.22) |
| Three-point gastropexy | 11 (26.2) | 157 (31.5) | 0.473 | 0.77 (0.38–1.57) | 0.030 | 0.96 (0.42–2.22) |
| Four-point gastropexy | 27 (64.3) | 300 (60.2) | 0.607 | 1.19 (0.62–2.29) | 0.300 | 1.68 (0.82–3.44) |
| PW of GC, n (%) | 5 (11.9)                            | 7 (1.4)                                    | 0.001              | 9.48 (2.87–31.3) | 0.0003 | 9.59 (2.82–32.61) |
| GC side vs. AW side | 17 (40.5) | 134 (26.9) | 0.080 | 1.85 (0.97–3.53) | 0.043 | 1.67 (0.84–3.34) |

Comparisons of clinical indices in relation to PEG site. In order to clarify the clinical features of cases receiving PEG at the PW of the GC, patients were divided into two groups based on PEG site: the PW of the GC group (12 cases) and the other site group (528 cases). No remarkable differences were observed for complication risk factors between the PW of the GC group and the other site group, including the use of anti-platelet drugs and blood examination data (Table 1), apart from the frequency of esophageal hernia (41.7% vs. 17.3%, OR 3.41, 95% CI 1.06–11.0; p = 0.030). The presence of an esophageal hernia was an independent factor associated with PEG tube insertion at the PW of the GC in multivariate logistic regression analysis (OR 3.39, 95% CI 1.04–11.03; p = 0.042) including the two univariately significant factors above. Early acute complications (41.7% vs. 7.0%, OR 9.48, 95% CI 2.87–31.3; p = 0.001) and severe acute complications (16.7% vs. 0.4%, OR 52.6, 95% CI 6.72–411.6; p = 0.003) were significantly more frequent in the PW of the GC group than in the other site group (Table 1).

Comparisons of groups with and without early acute complications. In comparisons of clinical indices between early (less than 30 days after PEG) and non-early (30 days or more after PEG) acute complication groups to identify the risk factors for early acute complications of the PEG procedure, the frequency of patients who received anti-platelet drugs was significantly higher in the early acute complication group (35.7% vs. 20.7%, OR 2.13, 95% CI 1.09–4.15; p = 0.024), while hemoglobin was significantly lower (11.2 g/dL vs. 12.2 g/dL, p = 0.042). The frequency of the PEG site at the PW of the GC was significantly higher in the early acute complication group (11.9% vs. 1.4%, OR 9.48, 95% CI 2.87–31.3; p = 0.001) (Table 3). Among the three significant univariate factors above, PEG tube site at the PW of the GC was independently associated with early acute complications (OR 3.39, 95% CI 1.04–11.03; p = 0.042) including the two univariately significant factors above. Early acute complications (41.7% vs. 7.0%, OR 9.48, 95% CI 2.87–31.3; p = 0.001) and severe acute complications (16.7% vs. 0.4%, OR 52.6, 95% CI 6.72–411.6; p = 0.003) were significantly more frequent in the PW of the GC group than in the other site group (Table 1).

Relationship between gastropexy number and acute complications. Although it would appear that the risk of blood vessel damage increases with the number of punctures for PEG insertion, this notion has not been addressed to the best of our knowledge. We observed no remarkable differences for three-point
and four-point gastropexy in groups with or without early acute complications (three-point gastropexy: 26.2% vs. 31.5%; OR 0.77, 95% CI 0.38–1.57, \( p = 0.473 \), and four-point gastropexy: 64.9% vs. 60.2%; OR 1.19, 95% CI 0.62–2.29, \( p = 0.607 \)) (Table 3).

**Two cases of early acute severe complications.** Case 1 was a 60-year-old male patient who was indicated for PEG due to dysphagia from amyotrophic lateral sclerosis. Blood tests were unremarkable, and computed tomography (CT) detected no interfering organs between the stomach and abdominal wall (Fig. 2e). A finger sign was routinely confirmed. Four-point gastric wall fixation was performed (Fig. 2a), followed by dilator...
and PEG tube insertion at the PW of the GC (Figs. 1c, 2b). Hemorrhage was observed during insertion (Fig. 2c), for which compression homeostasis was performed by pulling on the tube for 10 min (Fig. 2d). Ensuing blood tests disclosed no anemia, with no bleeding until postoperative day 2. A small amount of intermittent hemorrhage was observed in the patient’s gauze dressing from postoperative day 3 (Fig. 1d). Hemostasis was achieved by pulling on the gastrostomy tube. Contrast-enhanced CT on postoperative day 8 did not indicate a pseudoaneurysm or hematoma. On postoperative day 11, two sutures were made in the skin at the margin of the PEG tube due to continuous bleeding (Fig. 1d). Three hours later, the patient went into shock and required urgent blood transfusion. Contrast-enhanced CT detected no intra-abdominal hemorrhage (Fig. 2f), although a hematoma in the stomach was evident (Figs. 1e, 2g). Emergency surgery revealed hemorrhage from the periphery of the gastroepiploic artery near the fistula, which was promptly ligated. In this case, the periphery of the gastroepiploic artery was presumably damaged during dilator insertion at the PW of the GC (Fig. 1c), likely since the left and right gastroepiploic arteries were anatomically located through the greater omentum on the GC side (Fig. 1a,b). The branch of the right gastroepiploic artery is longer at the PW than at the AW9.

Case 2 was a 60-year-old male patient. PEG was indicated for nutritional management because of food intake difficulty due to pharyngeal cancer growth. Blood tests were unremarkable except for an albumin level of 3.5 g/dL. Contrast-enhanced CT detected no interfering organs between the stomach and abdominal wall (Fig. 3e). The gastric AW was distant from the abdominal wall (Fig. 1f), which necessitated PEG insertion at the PW of the GC. The usual four-point gastric wall fixation was abandoned for three-point fixation (Figs. 1f, 3a). As the insertion dilator was difficult to place after the first skin incision, an additional incision was made prior to gastrostomy tube insertion into the stomach using a guide wire (Fig. 3a,b). Acute bleeding occurred soon after (Fig. 3c). Upon noticing a gastric perforation after washing away the blood (Fig. 3d), we immediately removed the gastrostomy tube and terminated the endoscopic procedure. After discontinuation, CT revealed free air in the abdominal cavity and subcutaneous emphysema in the abdominal wall (Fig. 3f) requiring urgent surgery. A hematoma was detected around the stomach wall, and the two-centimeter incision in the short-axis direction to the PW of the GC was visualized. We usually puncture the abdominal wall with a dilator or PEG tube in the AW of the stomach (Fig. 1b). If the stomach is rotated in the long axis, it is difficult to insert the dilator vertically into the AW of the middle body of the stomach (Fig. 1b). In this case, the dilator was likely inserted towards the PW site, and the stomach wall firstly became torn in the short-axis direction (Fig. 1f). Afterwards, the PEG tube was inserted nearby to the damaged stomach wall in the PW (Fig. 1g). Finally, the damaged stomach wall became torn due to the traction compression for bleeding (Fig. 1g).

Discussion

This study clarified that PEG tube insertion at the PW of the GC was an independent risk factor for early acute complications of the PEG procedure and described two cases of early acute complications recently encountered at our institution.

The overall complication rates at 2 weeks and 3 months after PEG construction have been reported as 39% and 27%, respectively10. Jafari et al. observed that 3.9% of 641 PEG cases displayed serious complications, including perforation, intra-abdominal abscess, and buried bumper syndrome11. Our cohort contained 80 complication cases in total (14.8%), 62 of which (11.5%) occurring within 30 days after the PEG procedure. Those included early acute complications in 42 cases (7.8%) that consisted mainly of wound bleeding (32 cases; 5.9%) and arterial bleeding (five cases; 0.9%). Sin et al. reported bleeding as the most frequent acute complication (12.8%) using pull-type (11.8%) or introducer-type (14.3%) gastrostomy12. We routinely used introducer-type gastrostomy to conduct PEG in this study. The above data suggest that clinicians should bear complications in mind, specifically bleeding, when performing the PEG procedure.

The mild bleeding sometimes encountered near the PEG wound site is typically managed by conservative treatment, such as simple pressure to the wound. Severe hemorrhage is rare, but can occur by vascular puncture or damage13–15 as seen in case 1. Indeed, we observed arterial bleeding in 0.9% (5/540) of cases after PEG tube insertion, two of which needed surgical treatment. Regarding bleeding complications, specifically with blood vessel injury as the suspected cause, a list of previous reports have been summarized in Table 4. The arteries surrounding the stomach involved in such injuries included the gastroepiploic artery16,17, gastric artery15,18–20, and splenic and superior mesenteric artery14,21,22. The artery injuries were caused by stomach rotation17, over-inflation of the stomach resulting in rotation15, multiple punctures18,19,22, loss of traction and torsional stress between ligaments and vessels23, and fibrosis and adhesions around the stomach due to postoperative cholecystectomy14,21. Our study revealed that the PEG procedures at the PW of the GC were significantly associated with acute complications, including arterial injury. This might have been on account that major arteries run near this area to elevate the risk of blood vessel injury. Clinicians should pay careful attention to arterial complications after PEG at the PW of the GC.

Previous cases of gastric perforation have been linked to insufficient gastric wall fixation18,21. In case 2, the operator had initially attempted to make four-point gastropexy as a square (Supplementary Fig. S1b). However, during the fourth point puncture, the operator noticed that the needle was tangentially inserted into the gastric wall, and not into the stomach. The operator then proceeded to puncture the dilator with under incomplete fixation in the form of an isosceles triangle instead of an equilateral one (Supplementary Fig. S1a,c). At that point, alternative methods should have been considered for a safer approach. The puncture power was tangentially directed along the spherical surface of the stomach wall of the PW of GC and was not transmitted perpendicularly to the stomach wall, creating a risk of stomach wall injury. After fixation, the thread of the sutures should be pulled in the opposite direction of the dilatation/puncture to give counter-traction for greater safety, which was done in the presented cases. To avoid the unnecessary puncture of gastroepiploic blood vessels, selecting three gastroepiploic points in the pattern of an equilateral triangle instead of four points may also reduce complications.
Figure 3. Endoscopic and CT images before and after PEG construction in case 2. (a) Three-point gastric wall fixation was performed near the PW of the GC. (b) As it was difficult to insert the dilator, a skin incision was added for placement of the gastrostomy tube into the stomach. (c) Bleeding occurred immediately after the procedure. (d) Gastric perforation was detected. (e) Before PEG construction, there was no intestinal interference between the stomach and abdominal wall. (f) After discontinuing PEG construction, there was free air in the abdominal cavity and subcutaneous emphysema in the abdominal wall.
Table 4. Reported cases of vessel injury associated with PEG insertion. AW anterior wall, B-SA branch of splenic artery, CS conservative treatment, EM embolization, GA gastric artery, GC greater curvature, GEP gastroepiploic artery, LC lesser curvature, LGA left gastric artery, OP operation, PB-SMA pancreatic branch of the superior mesenteric artery, PEG percutaneous endoscopic gastrostomy, Rt and Lt GEP right and left gastroepiploic artery, SGV short gastric vessel, SV and SMV splenic and superior mesenteric vein. – Not described.

| Injured blood vessel | PEG location site | Diagnosis time after PEG procedure | Number of insertions | Cause | Treatment | Outcome | References |
|----------------------|------------------|-----------------------------------|----------------------|-------|-----------|---------|------------|
| GEP                  | –                | –                                 | –                    | –     | OP –      | –       | 16         |
| Rt and Lt GEP        | GC               | 6.5 days                          | –                    | –     | Rotation of the stomach | EM Recovered | 19         |
| GA                   | GC               | 0 days                            | –                    | –     | Rotation of the stomach due to over-inflation | OP – | 19         |
| LGA                  | AW               | 50 min                            | 3                    | (1) Three-point gastric fixation (2) Multiple insertions | EM | Died | 19         |
| LGA                  | AW               | 3 days                            | 4                    | Multiple insertions | EM | Recovered | 21         |
| SGV                  | AW               | 12 h                              | –                    | –     | Traction and torsional stress on the spleen along the gastro-splenic ligament and splenic vessels derived from maximal gastric insufflation | OP | Recovered | 22         |
| SV and SMV           | AW               | 2.5 h                             | 2                    | (1) Long length of needle (7 cm) (2) Vertical or oblique displacement of needle (3) Fibrosis and adhesions between liver and stomach due to postoperative cholecystectomy | OP | Died | 24         |
| B-SA                 | 1 cm proximal to the pylorus | Several hours | 2 | Fibrosis and adhesions between liver and stomach due to postoperative cholecystectomy | CS | Died | 21         |
| PB-SMA               | LC of AW         | 1 day                             | 2                    | (1) Multiple insertions (2) Deep insertion | EM | Recovered | 22         |

During PEG tube insertion at the PW of the GC, especially for cases of esophageal hernia. In addition, direct percutaneous endoscopic jejunoanastomosis, percutaneous transesophageal gastro-tubing, safe gastric puncture point by a plain abdominal film with air insufflation technique, CT-guided PEG, and laparoscopy-assisted introducer PEG should be considered as alternative methods to achieve long-term enteral nutrition. It is important for clinicians to select from push and pull methods as flexibly as possible according to the patient’s condition in order to reduce the risk of severe complications.

Lastly, the use of aspirin or clopidogrel is not reportedly associated with an increased risk of bleeding. However, no studies have examined the risk of PEG construction in patients on prasugrel, ticagrelor, or direct oral anticoagulants. Since PEG candidates are also indicated for those medicines in the clinical setting, the frequency and dose of such drugs should be considered to reduce possible bleeding complications.

This study had several limitations. First, as the number of patients receiving PEG at the PW of the GC was small for multivariate analysis, additional cases are needed to statistically validate our results. Second, the final clinical outcome of some complications was not recorded in this retrospective study due to patient transfer to another hospital. However, we received no reports of severe PEG-associated complications from the subsequent institutions. Larger prospective investigations are required to clarify the outcomes of PEG procedures.

In conclusion, this 12-year analysis on PEG insertion site identified PEG at the PW of the GC as an independent risk factor for acute complications and described the details of two cases of severe complications involving this site that required urgent additional treatment. If unavoidable, PEG at the PW of the GC should be accompanied with careful observation for early acute bleeding complications.

Material and methods

Patients and study design. A retrospective review was performed using the medical records of patients who underwent PEG at Shinshu University Hospital (Nagano, Japan) and Matsumoto City Hospital (Nagano, Japan) during an approximately 12-year period between April 2008 and December 2019. A total of 570 patients were initially targeted for comparisons of PEG procedures based on medical charts, endoscopic reports, and radiographic images. Thirty cases were excluded for the following reasons: negative finger sign for safe puncture (13 cases), general condition exacerbation (11 cases), lack of endoscopic findings (two cases), superimposition with gastric cancer on the puncture route (one case), gastric ulcer scar on the puncture route (one case), non-passage of the esophagogastroduodenoscopy scope through the esophagus (one case), and no consent before procedure (one case). Ultimately, 540 patients were included in the analysis. Informed consent was obtained from all subjects or their legal guardians when appropriate. This study was conducted in accordance with the principles of the 1975 Declaration of Helsinki and approved by the institutional review board of Shinshu University School of Medicine (approval number: 4048) and Matsumoto City Hospital (approval number: 022).
Definitions of complications. Complications were divided into two groups based on onset time being within 30 days or 30 days or more after the PEG procedure (Table 2). Early acute complications were defined as bleeding or perforation related to PEG and included early severe complications according to a previous report. Severe acute complications were defined as those requiring surgical intervention within 30 days after PEG construction.

Determination of PEG tube insertion site. We defined the PEG tube insertion site from endoscopic images based on a previous study.

PEG procedure. All PEG procedures were performed by an endoscopist, an assistant doctor who directly participated in the surgery, and 1–2 nurses. An introducer-type gastrostomy set (PEG-24-introducer-type [Ideal button]; Olympus, Tokyo, Japan) and an upper gastrointestinal endoscope (GIF-Q260, GIF-XP260NS, or GIF-XP260; Olympus, Tokyo, Japan) were used following the administration of lidocaine spray as an oral local anesthesia and midazolam and/or pentazocine for sedation. Before PEG tube insertion, a finger sign by pressing with a finger on the body surface was conducted and endoscopically confirmed by compression in the gastric lumen. Transillumination was also performed, with the light identified through the abdominal wall to determine the best site for PEG tube insertion. The skin was disinfected with povidone-iodine and lidocaine was infiltrated into the skin with a 23-gauge needle. Four-point gastric wall fixation was performed before placement of the PEG tube, which was selected to be as long as possible. Then, a skin incision was made in the center of the four-point gastric fixation, a hole was made with a puncturing needle, and a guide wire was detained under endoscopic vision into the stomach. A dilator was inserted along the guide wire, the length of the gastrostomy was measured, and the gastrostomy tube was inserted after removing the dilator. The procedure was completed after confirming hemostasis. Prophylactic antibiotics (cefazolin sodium 1 g/dose twice a day on day 1 and once on the following day) were routinely administered at the time of each procedure. The PEG insertion site was disinfected with povidone-iodine for 1 week after the procedure.

Statistical analysis. Statistical analysis was performed by StatFlex software version 7.0.10 (Artec, Osaka, Japan). Continuous variables are presented as the median and lower to upper limit, and categorical variables are expressed as the frequency (%). The Mann–Whitney U-test was used to analyze continuous variables. The chi-square test was employed for categorical variable comparisons, with Fisher’s exact probability test adopted for groups with fewer than five samples. Statistically significant variables in the univariate model were subsequently used in multivariate analysis to identify independent predictors of complications. The odds ratio (OR) and 95% confidence interval (CI) were obtained by means of univariate and multivariate models. A p-value of < 0.05 was considered to indicate a statistically significant difference.

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References
1. Gauderer, M. W., Ponsky, J. L. & Izant, R. J. Gastrostomy without laparotomy: a percutaneous endoscopic technique. J. Pediatr. Surg. 15, 872–875 (1980).
2. Kurien, M., McAlindon, M., Westaby, D., Westaby, D. & Sanders, D. S. Percutaneous endoscopic gastrostomy (PEG) feeding. Br. Med. J. 340, 1074–1078 (2010).
3. Bravo, J. G. P. et al. Percutaneous endoscopic versus surgical gastrostomy in patients with benign and malignant diseases: a systematic review and meta-analysis. Clinics (Sao Paulo, Brazil), 71, 169–178 (2016).
4. Ikin, M. et al. Multidisciplinary practical guidelines for gastrointestinal access for enteral nutrition and decompression from the Society of Interventional Radiology and American Gastroenterological Association (AGA) Institute, with endorsement by Canadian Interventional Radiological Association (CIRA) and Cardiovascular and Interventional Radiological Society of Europe (CIRSE). Gastroenterology 141, 742–765 (2011).
5. Anderloni, A. et al. Complications and early mortality in percutaneous endoscopic gastrostomy placement in lombardy: a multicenter prospective cohort study. Dig. Liver Dis. 51, 1380–1387 (2019).
6. Burke, D. T. & Geller, A. J. Peritonitis secondary to the migration of a trans-hepatically-placed percutaneous endoscopic gastrostomy tube: a case report. Arch. Phys. Med. Rehabil. 90, 354–357 (2009).
7. Chiaparina, A., Hammami, M., Bassuner, J. & Hachem, C. Trans-hepatic percutaneous endoscopic gastrostomy tube placement: a case report of a rare complication and literature review. Gastroenterol. Res. 11, 145–149 (2018).
8. Lee, S. P. et al. Risk factors for complications of percutaneous endoscopic gastrostomy. Dig. Dis. Sci. 59, 117–125 (2014).
9. Prudius, V. et al. Vascular anatomy of the stomach related to resection procedures strategy. Surg. Radiol. Anat. 39, 433–440 (2017).
10. Blomberg, J. et al. Complications after percutaneous endoscopic gastrostomy in a prospective study. Scand. J. Gastroenterol. 47, 737–742 (2012).
11. Ifafari, A. et al. Complications after percutaneous endoscopic gastrostomy tube placement—a retrospective analysis. Zentralbl. Chir. 141, 442–445 (2016).
12. Lee, S. W. et al. Comparison of clinical outcomes associated with pull-type and introducer-type percutaneous endoscopic gastros- tomy. Cln. Endosc. 47, 530–537 (2014).
13. Veitch, A. M. et al. Endoscopy in patients on antiplatelet or anticoagulant therapy, including direct oral anticoagulants: British Society of Gastroenterology (BSG) and European Society of Gastrointestinal Endoscopy (ESGE) guidelines. Gut 65, 374–389 (2016).
14. Lau, G. & Lai, S. H. Fatal retroperitoneal haemorrhage: an unusual complication of percutaneous endoscopic gastrostomy. Forens. Sci. Int. 116, 69–75 (2001).
15. Schurink, C. A. et al. Percutaneous endoscopic gastrostomy: complications and suggestions to avoid them. Eur. J. Gastroenterol. Hepatol. 13, 819–823 (2001).
16. Amann, W. et al. Percutaneous endoscopic gastrostomy (PEG). 8 years of clinical experience in 232 patients. Surg. Endosc. 11, 741–744 (1997).

17. Lewis, M. B., Lewis, J., Marshall, H., Marshall, H. & Lossef, S. V. Massive hemorrhage complicating percutaneous endoscopic gastrostomy: treatment by means of transcatheter embolization of the right and left gastroepiploic arteries. J. Vasc. Interv. Radiol. 10, 319–323 (1999).

18. Bunai, Y. et al. Iatrogenic rupture of the left gastric artery during percutaneous endoscopic gastrostomy. Leg. Med. 11, S538–S540 (2009).

19. Hong, S. H. et al. A case of ruptured left gastric artery pseudoaneurysm complicating percutaneous endoscopic gastrostomy (PEG). Korean J. Gastrointest. Endosc. 39, 34–37 (2009).

20. Patel, B. B., Andrade, C., Doraiswamy, V. & Amodeo, D. Splanic avulsion following PEG tube placement: a rare but serious complication. ACG Case Rep. J. 2, 21–23 (2014).

21. Smale, E., Davison, A. M., Smith, M. & Pritchard, C. Fatal intra-abdominal haemorrhage following percutaneous endoscopic gastrostomy. BMJ Case Rep. https://doi.org/10.1136/bcr.06.2009.2044 (2009).

22. Lee, S. H. et al. Percutaneous endoscopic gastrostomy tube insertion-induced superior mesenteric artery injury treated with angiography. Korean J. Gastroenterol. 72, 308–312 (2018).

23. Angiol, L. G. et al. Hemorrhage and gastric perforation in patients with percutaneous endoscopic gastrostomy (PEG). Ann. Ital. Chir. 74, 195–201 (2003).

24. Shike, M. et al. Percutaneous endoscopic jejunostomy in cancer patients with previous gastric resection. Gastrointest. Endosc. 33, 372–374 (1987).

25. Toh Yoon, E. W. & Nishihara, K. Percutaneous transesophageal gastro-tubing (PTEG) as an alternative long-term tube feeding procedure when gastrostomy is not feasible. Ther. Adv. Gastroenterol. 10, 911–917 (2017).

26. Chang, W. K. et al. Positioning a safe gastric puncture point before percutaneous endoscopic gastrostomy. Int. J. Clin. Pract. 61, 1121–1125 (2006).

27. Albrecht, H. et al. Computed tomography-guided percutaneous jejunostomy for feeding and decompression. Nutri. Clin. Pract. 32, 212–218 (2017).

28. Lopes, G., Salcone, M. & Neff, M. Laparoscopic-assisted percutaneous endoscopic gastrostomy tube placement. J. Soc. Laparoendosc. Surg. 14, 66–69 (2010).

29. Tsujimoto, H. et al. Laparoscopy-assisted percutaneous gastrostomy tube placement along with laparoscopic gastropexy. Dig. Surg. 28, 163–166 (2011).

30. Richter, J. A. et al. Bleeding after percutaneous endoscopic gastrostomy is linked to serotonin reuptake inhibitors, not aspirin or clopidogrel. Gastrointest. Endosc. 74, 22–34 (2011).

31. Sohail, U. et al. Bleeding risk with clopidogrel and percutaneous endoscopic gastrostomy. World J. Gastrointest. Endosc. 8, 553–557 (2016).

32. Ruthmann, O. et al. Percutaneous endoscopic gastrostomy. Complications with and without anticoagulation. Chirurg 81, 247–254 (2010).

33. Tang, S.-J. & Wu, R. Percutaneous endoscopic gastrostomy (pull method) and jejunal extension tube placement. Video J. Encycl. GI Endosc. 2, 40–45 (2014).

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Competing interests
The authors declare no competing interests.

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