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Original Article

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Outcomes and Complications of Radiological Gastrostomy vs. Percutaneous Endoscopic Gastrostomy for Enteral Feeding: An Updated Systematic Review and Meta-Analysis

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Abstract

Background: Percutaneous endoscopic gastrostomy (PEG) and percutaneous radiological gastrostomy (PRG) are commonly utilized to establish access to enteral nutrition. However, data comparing the outcomes of PEG vs. PRG are conflicting. Therefore, we aimed to conduct an updated systemic review and meta-analysis comparing PRG and PEG outcomes.

Methods: Medline, Embase, and Cochrane library databases were searched until February 24, 2023. Primary outcomes included 30-day mortality, tube leakage, tube dislodgement, perforation, and peritonitis. Secondary outcomes included bleeding, infectious complications, and aspiration pneumonia. All analyses were conducted using Comprehensive Meta-Analysis Software.

Results: The initial search revealed 872 studies. Of these, 43 of these studies met our inclusion criteria and were included in the final meta-analysis. Of 471,208 total patients, 194,399 received PRG and 276,809 received PEG. PRG was associated with higher odds of 30-day mortality when compared to PEG (odds ratio (OR): 1.205, 95% confidence interval (CI): 1.015 - 1.430, I^2 = 55%). In addition, tube leakage and tube dislodgement were higher in the PRG group than in PEG (OR: 2.231, 95% CI: 1.184 - 4.2 and OR: 2.602, 95% CI: 1.911 - 3.541, respectively). Perforation, peritonitis, bleeding, and infectious complications were higher with PRG than PEG.

Conclusion: PEG is associated with lower 30-day mortality, tube leakage, and tube dislodgement rates than PRG.

Keywords: Percutaneous endoscopic gastrostomy; Percutaneous radiological gastrostomy; Enteral feeding

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Introduction

Enteral feeding is a common strategy to maintain nutritional status when oral feeding is unfeasible, high risk, or requires supplementation. Gastrostomy feeding is favored over nasogastric tube feeding when medium and long-term enteral nutrition is indicated [1]. Enteral nutrition is superior to parenteral nutrition in terms of nutritional outcome, morbidity reduction, and gut function preservation [2]. Head and neck cancers, motor neuron disorders, cerebral vascular accidents, and malnutrition are the most common indications for gastrostomy tube placement [3]. The two most common placement techniques are percutaneous endoscopic gastrostomy (PEG) and percutaneous radiological gastrostomy (PRG) [4]. While PEG is the preferred approach at many centers, PRG and surgical gastrostomy are still frequently performed, especially in patients unable to undergo PEG [5, 6].

Current literature regarding adverse event rates of different gastrostomy tube placement approaches presents conflicting findings. Some studies have found that PRG leads to fewer

adverse events than PEG [7], while some suggest that PEG is safer than PRG in select patients. Other studies have found no significant difference between the various approaches [8, 9]. Several systematic reviews and meta-analyses comparing PEG and PRG have previously been published [10-12]. However, these meta-analyses have certain drawbacks because they mainly focus on a single outcome or include only a small number of studies. Therefore, we aimed to conduct an updated systematic review of the literature and a comprehensive meta-analysis comparing PEG and PRG outcomes.

Materials and Methods

A comprehensive search strategy to identify reports of studies comparing radiologically and endoscopically guided placement of gastrostomy tubes was constructed using truncated keywords, phrases, and database subject headings developed in Embase by an experienced health sciences librarian (WL-S). This strategy was translated to MEDLINE (PubMed platform, NCBI), Cochrane Central Register of Controlled Trials, the Web of Science Core Collection, Korean Citation Index, SciELO (Web of Science platform, Clarivate) and the regional indexes of the Global Index Medicus (World Health Organization) with all searches performed on December 21, 2021 and subsequently updated on February 24, 2023 (Supplementary Material 1, www.gastrores.org). No publication date or language limits were used. All results were exported to EndNote 20 citation management software (Clarivate, Philadelphia, PA, USA) and duplicates were removed by successive iterations of EndNote's duplicate detection algorithms and manual inspection.

Screening and data collection

The studies were screened by two independent reviewers (ZA and UI). The initial screening was based on titles and abstracts, with the full-text screening of relevant publications following. Next, two independent reviewers extracted the data (ZA and JB). Any discrepancies in study selection and data extraction were resolved through mutual discussion and consensus between the authors. Finally, data on demographics (age, gender), indications for the procedure, and outcomes (30-day mortality, tube leakage, tube dislodgement, perforation, peritonitis, bleeding, infections, and aspiration pneumonia) were collected and summarized using Microsoft Excel (Microsoft, Redmond, Washington, USA).

Data synthesis and statistical analysis

Statistical analysis was conducted utilizing Comprehensive Meta-analysis Software. We used both fixed and random-effects model for this meta-analysis, with point estimates, variance, and weights for each study based on study size and the number of events. When there was significant statistical heterogeneity, we used the random effects model. In outcomes with low or no statistical heterogeneity, we used the fixed effects model. Pooled odds ratios (ORs) with 95% confidence intervals (CIs) were calculated for all the outcomes. An I^2 test was used to evaluate the heterogeneity of the studies. An I^2 value of 0-25% represented insignificant heterogeneity, and > 75% represented significant heterogeneity. To assess the robustness of our study results, we performed a sensitivity analysis after removing one study at a time. This meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines [13]. The PRISMA checklist is provided in Supplementary Material 2 (www.gastrores.org).

Quality assessment

Methodological Index for Non-Randomized Studies (MINORS) was used to assess study quality [14]. Non-comparative studies are graded on eight MINORS criteria, with each item ranging from 0 to 2 (0 if not reported; 1 if reported but inadequate; 2 if reported and adequate). A global score of 16 for non-comparative studies and 24 for comparative studies is considered ideal. Two authors (ZA and UF) independently carried out the quality assessment, and disagreements were handled by a third reviewer (JB).

Bias assessment

The risk of bias within each individual study was determined using the MINORS scale for cohort studies and the Cochrane risk of bias tool for randomized controlled trials (RCTs) [14, 15]. Publication bias was assessed qualitatively by funnel plot visualization and quantitatively by Egger's regression analysis.

Results

The initial search revealed 872 studies. Of these, 43 studies including 471,208 patients met our inclusion criteria and were included in the final meta-analysis [6, 16-57]. There was one RCT, five non-randomized prospective studies, and 37 retrospective studies. Figure 1 elaborates our systematic literature search process. A total of 194,350 patients underwent PRG placement, and 276,741 patients underwent PEG placement. Baseline characteristics, including patient demographics and indications for gastrostomy tube placement, are reported in Table 1. The quality and bias assessment of studies is summarized in Table 2 and 3. There was no publication bias as assessed by the funnel plot diagram and Egger's regression test (two-tailed P-value = 0.72259) (Fig. 2).

Primary outcomes

30-day mortality

PRG was associated with higher odds of 30-day mortality when compared to PEG (OR: 1.205, 95% CI: 1.015 - 1.430, $I^2 = 55\%$) on primary analysis (Fig. 3a). Sensitivity analysis revealed con-

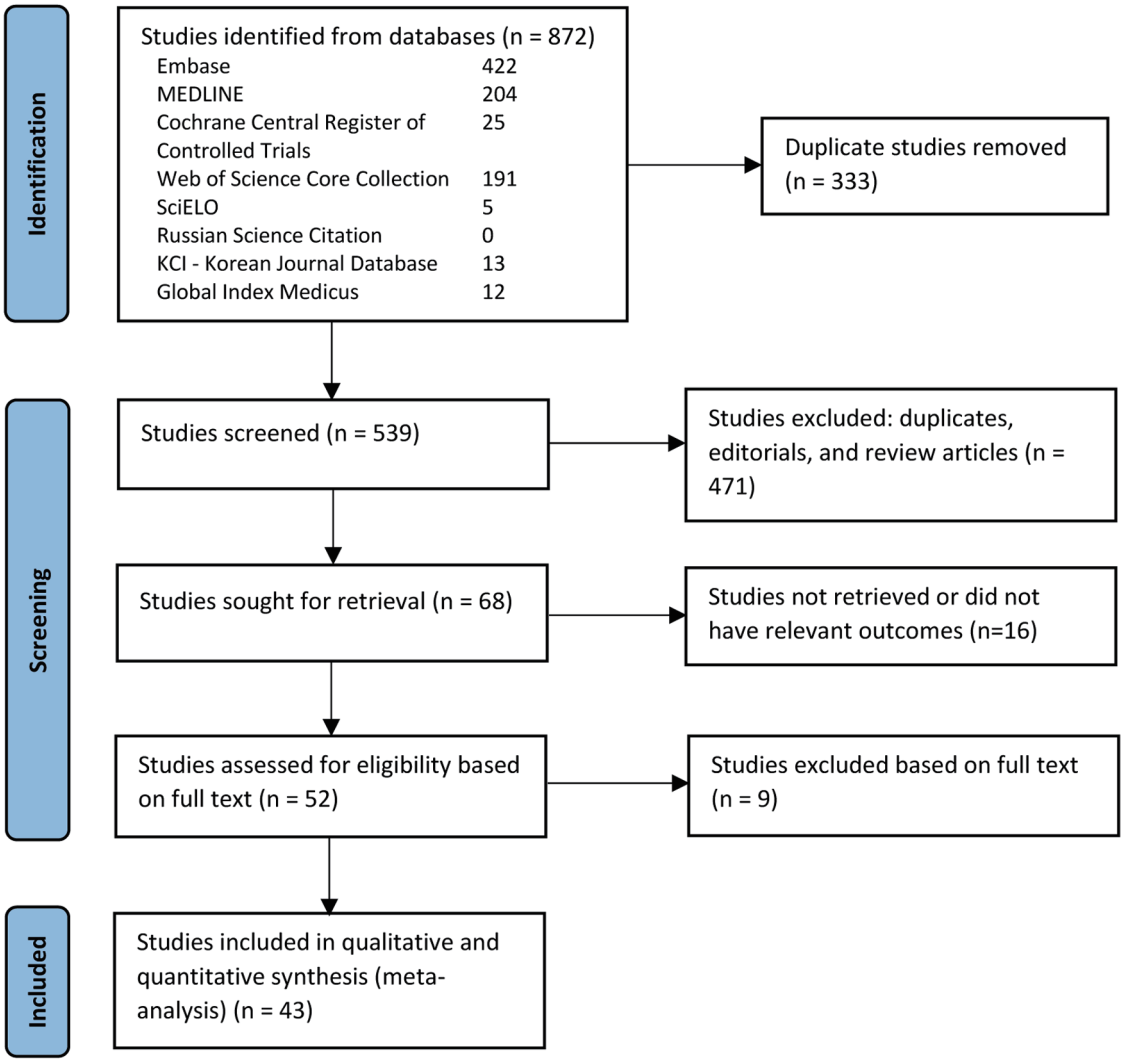

Figure 1. PRISMA flow diagram of the literature review process.

sistent results, with PRG being associated with a higher risk of 30-day mortality when compared to PEG placement. We performed a subgroup analysis after removing the three studies with the largest sample sizes, which confirmed consistent results without their influence (OR = 1.352, 95% CI = 1.001 - 1.826).

Tube leakage

PRG was associated with higher odds of tube leakage when compared to PEG (OR: 2.231, 95% CI: 1.184 - 4.2, I^2 = 76%) on primary analysis (Fig. 3b). Sensitivity analysis revealed consistent results, with PRG associated with higher odds of leakage compared to PEG.

Tube dislodgement

PRG was associated with higher odds of tube dislodgement when compared to PEG (OR: 2.602, 95% CI: 1.911 - 3.541, I^2 = 94%) on primary analysis (Fig. 3c). Sensitivity analysis confirmed these results. On subgroup analysis without the three largest studies, results were again consistent (OR = 2.927, 95% CI = 1.755 - 4.882).

Perforation

PRG was associated with higher odds of perforation when compared to PEG (OR: 1.758, 95% CI: 1.45 - 2.31, I^2: 33.13%) on primary analysis. However, this did not achieve statistical significance in the sensitivity analysis (OR: 1.306, 95% CI: 0.971 - 1.755).

Peritonitis

PRG was associated with higher odds of peritonitis when com-

Table 1. Study Characteristics

Study	Year	Demographics	Study design	Total	PRG	PEG	Indications
Allen et al [16]	2013	Mean age in PRG = 61 (SD ± 10.4); Mean age in PEG = 62 (SD ± 11.3); Male in PRG = 30 (57%); Male in PEG = 35 (61%)	Retrospective	108	51	57	ALS
Alvarez-Alvarez et al [17]	2022	Mean age overall: 66; Male overall: 41%	Retrospective	25	4	21	ALS
Bazarah et al [18]	2002	Mean age in PRG = 51; Mean age in PEG = 65; Male in PRG = 16 (48%); Male in PEG = 14 (73%)	Retrospective	52	33	19	Neurological disorders (60%); HNC (21.2%); other
Blondet et al [19]	2010	Mean age in PRG = 66 (SD ± 12); Mean age in PEG = 66 (SD ± 11.2); Male in PRG = 11 (50%); Male in PEG = 6 (33%)	Retrospective	43	22	21	ALS
Carey et al [20]	2004	NR	Retrospective	182	96	86	NR
Chandran et al [21]	2017	Median age in PRG = 64; Median age in PEG = 65; Male in PRG = 34 (65.4%); Male in PEG = 54 (63.5%)	Retrospective	137	52	85	HNC (37.2%); CVA (27.7%); NMDs (6.6%); trauma (6.6%); esophageal cancer (5.8%); other (16.1%)
Cherian et al [22]	2019	Median age in PRG = 65 (35 - 89); Median age in PEG = 62 (18 - 91); Male in PRG = 65 (68%); Male in PEG = 242 (61%)	Retrospective	403	95	308	HNC (62.9%); non-HNC malignancy (11%); other (26.1%)
Chio et al [23]	2004	Mean age in PRG = 69 (SD ± 9.5); Mean age in PEG = 65 (SD ± 10.3); Male in PRG = 12 (48%); Male in PEG = 13 (52%)	Retrospective	25	25	50	ALS
Clayton et al [24]	2019	Mean age in PRG = 62 (SD ± 16.4); Mean age in PEG = 66 (SD ± 17.3); Male in PRG = 82 (54%); Male in PEG = 90 (61%)	Retrospective	297	150	147	Gastrointestinal disorders (59.9%); neurological disorders (19.5%); other (17.8%)
Cosentini et al [25]	1998	Median age in PRG = 57 (20 - 84); Median age in PEG = 55 (10 - 90); Male in PRG = 28 (63%); Male in PEG = 16 (66%)	Retrospective	68	44	24	HNC (66%); neurological disorders (19%); esophageal perforation (4%); cachexia (4%); esophageal cancer (3%); gastric cancer/decompression (3%)
Desport et al [26]	2005	Mean age in PRG = 66 (SD ± 9.7); Mean age in PEG = 65 (SD ± 10.3); Male in PRG = 5 (25%); Male in PEG = 21 (70%)	Retrospective	50	20	30	ALS
El Chaarani et al [27]	2014	Mean age in PRG = 69; Mean age in PEG = 72; Male in PRG = 111 (60%); Male in PEG = 87 (42%)	Retrospective	394	186	208	NR
Elliot et al [28]	1996	NR	Prospective (non-randomized controlled trial (non-RCT))	78	45	33	CVA (42%); cystic fibrosis (22%); malignancy (8%); chest disease (4%); other (24%)
Galaski et al [29]	2009	Mean age in PRG = 65 (SD ± 19); Mean age in PEG = 55 (SD ± 21); Male in PRG = 31 (71%); Male in PEG = 19 (63%)	Retrospective	74	44	30	Neurological disorders (31.1%); trauma (17.6%); HNC (10.8%); coronary artery disease (10.8%); other

Table 1. Study Characteristics - *(continued)*

Study	Year	Demographics	Study design	Total	PRG	PEG	Indications
Grant et al [30]	2009	Mean age in PRG = 65 (36 - 95); Mean age in PEG = 61 (28 - 97); Male in PRG = 39 (77%); Male in PEG = 79 (65%)	Prospective (non-RCT)	172	51	121	HNC
Hazratjee et al [31]	2012	NR	Retrospective	267	70	197	NR
Hoffer et al [32]	1999	Mean age in PRG = 58 (18 - 93); Mean age in PEG = 52 (18 - 89); Male in PRG = 36 (55%); Male in PEG = 41 (59%)	Prospective (RCT)	135	66	69	Neurological impairment (80.7%); HNC (11.9%); gastrointestinal decompression (3%); other (4.4%)
Kim et al [33]	2014	Mean age overall = 60 (SD ± 17.5); Male overall = 102 (74%)	Retrospective	138	48	90	Unable to eat (67.4%); recurrent aspiration (18.1%); esophageal stricture (10.1%)
Kohli et al [34]	2021	Mean age in PRG = 70 (SD ± 9.7); Mean age in PEG = 71 (SD ± 10.2); Male in PRG = 9,432 (97.1%); Male in PEG = 22,989 (97.6%)	Retrospective (Nationwide Veterans Affairs Database)	33,281	9,715	23,566	Dysphagia/aphagia (86%); malignancy (65%); other non-malignant disorders including neurological diseases and aspiration pneumonia
Kohli et al [35]	2021	Mean age in PRG = 67 (SD ± 17.5); Mean age in PEG = 54 (SD ± 29); Male in PRG = 86,262 (56%); Male in PEG = 8,855 (54%)	Retrospective (Nationwide Readmissions Database)	170,391	154,007	16,384	Dysphagia/aphagia (48%); malignancy including HNC; non-malignant disorders including neurological diseases, aspiration pneumonia, and sepsis
Kohli et al [36]	2022	Mean age in PRG = 68.6 (SD ± 8.23); Mean age in PEG = 68.3 (SD ± 7.13); Male in PRG = 100%; Male in PEG = 100%	Prospective (non-RCT)	92	45	47	HNC; esophageal cancer; other cancer; critical illness/ALS
La Nauze et al [37]	2012	Median age in PRG = 61 (16 - 92); Median age in PEG = 61 (16 - 94); Male in PRG = 69 (71%); Male in PEG = 53 (66%)	Retrospective	177	97	80	HNC (27%); trauma (25%); stroke (23%); neuromuscular diseases/ dementia (10%); other
Laasch et al [38]	2003	Mean age in PRG = 68 (27 - 86); Mean age in PEG = 73 (19 - 96); Sex = NR	Retrospective	100	50	50	Neurological disorders; malignancy; nutritional support; other
Laskaratos et al [39]	2012	Mean age in PRG = 76.2 (48 - 93); Mean age in PEG = 69.4 (21 - 93); Male in PRG = 20 (50%); Male in PEG = 24 (45%)	Retrospective	93	40	53	CVA (31.2%); NMDs (30%); HNC (18.3%); other (22.6%)
Leeds et al [40]	2010	Mean age in PRG = 63; Mean age in PEG = 62; Male in PRG = 119 (70%); Male in PEG = 146 (64%)	Retrospective	403	170	233	HNC (43%); neurological diseases (29%); dysphagic stroke (9%); other
Maasarani et al [41]	2020	Age = NR; Male in PRG = 14,416 (54.4%); Male in PEG = 110,933 (47.8%)	Retrospective	258,641	26,477	232,164	NR
MacLean et al [42]	2007	Mean age in PRG = 57 (SD ± 19); Mean age in PEG = 51 (SD ± 21); Male in PRG = 113 (42%); Male in PEG = 74 (67%)	Retrospective	378	110	268	Gastrointestinal surgery (21%); trauma and burns (12%); head and neck surgery (9%); gastrointestinal obstruction (7%); other
McAllister et al [43]	2013	NR	Retrospective	110	89	21	HNC
McDermott et al [44]	2015	Mean age in PRG = 63.6 (SD ± 9.8); Mean age in PEG = 64.2 (SD ± 11.7); Male in PRG = 62 (51%); Male in PEG = 90 (55%)	Retrospective	284	121	163	ALS

Table 1. Study Characteristics - *(continued)*

Study	Year	Demographics	Study design	Total	PRG	PEG	Indications
Moller et al [45]	1999	Median age in PRG = 64 (20 - 92); Median age in PEG = 48 (29 - 73); Male in PRG = 49 (52%); Male in PEG = 6 (50%)	Retrospective	106	94	12	Neurological disorders (42%); malignancy (38%); other (20%)
Neeff et al [46]	2003	Mean age in PRG = 66 (SD ± 12); Mean age in PEG = 65 (SD ± 10.5); Male in PRG = 13 (72%); Male in PEG = 43 (77%)	Retrospective	74	18	56	HNC
Pannick et al [47]	2019	Median age overall = 64; Sex = NR	Retrospective	155	132	33	Dysphagia (45.2%); HNC (36.8%); stroke (12.3%)
Park et al [6]	2019	Mean age in PRG = 66 (SD ± 13.3); Mean age in PEG = 67 (SD ± 14.8); Male in PRG = 58 (62%); Male in PEG = 234 (72%)	Retrospective	418	94	324	Neurological diseases (70.8%); HNC (14.6%); esophageal cancer (6.5%); other
Pinar-Gutierrez et al [48]	2021	NR	Retrospective	896	330	896	NR
Abd Rahim et al [49]	2014	NR	Retrospective	244	168	76	Intracranial events; HNC; dysphagia
Righetti et al [50]	2020	Mean age in PRG = 64.1 (SD ± 12.6); Mean age in PEG = 63.0 (SD ± 15.0); Male in PRG = 340 (65.5%); Male in PEG = 134 (49.6%)	Retrospective	789	519	270	Neurological indications (29%); cancer (36%); chronic aspiration (4.4%); malnutrition (22%); gastric outlet obstruction (8.4%); other (5.7%)
Rio et al [51]	2010	Mean age overall = 62 (SD ± 12); Sex = NR	Retrospective	142	121	21	Motor neuron disease
Rustom et al [52]	2006	Mean age in PRG = 64.8; Mean age in PEG = 63.6; Male in PRG = 15 (53.6%); Male in PEG = 24 (60%)	Retrospective	68	28	40	HNC
Silas et al [53]	2005	Mean age in PRG = 63 (SD ± 14); Mean age in PEG = 68 (SD ± 15); Male in PRG = 114 (59.1%); Male in PEG = 100 (56.5%)	Retrospective	370	193	177	Nutrition/dysphagia (93%); decompression (7%); neurological disorders (34%); malignancy (47%)
Strijbos et al [54]	2019	Mean age in PRG = 62 (SD ± 15); Mean age in PEG = 63 (SD ± 11); Male in PRG = 305 (65%); Male in PEG = 173 (60%)	Retrospective	760	469	291	HNC (58%); ALS (7%); CVA (7%); Neurological disorders (7%); other including gastrointestinal and muscular diseases
Tan et al [55]	2019	Mean age overall = 66 (21 - 102); Male overall = 134 (54%)	Retrospective	248	90	158	Altered mental status (37%); cognitive impairment (16%); malignancy (15%); dysphagia (14%); other (18%)
Vashi et al [56]	2015	Mean age in PRG = 56 (SD ± 9.1); Mean age in PEG = 54 (SD ± 10.7); Male in PRG = 30 (57.7%); Male in PEG = 45 (55.6%)	Retrospective	133	52	81	Malignancy causing dysphagia, malnutrition, or need for decompression
Wollman et al [57]	1997	Mean age in PRG = 54 (15 - 89); Mean age in PEG = 55 (12 - 94); Male in PRG = 38 (56%); Male in PEG = 71 (62%)	Retrospective	182	68	114	Neurological impairment (59.9%); HNC (20.9%); decompression (6.6%); other (12.6%)

ALS: amyotrophic lateral sclerosis; CVA: cerebrovascular accident; HNC: head and neck cancers; NR: not reported; NMDs: neuromuscular disorders; PEG: percutaneous endoscopic gastrostomy; PRG: percutaneous radiological gastrostomy; SD: standard deviation.

Table 2. Quality Assessment of Non-Randomized Studies via Methodological Index for Non-Randomized Studies (MINORS)

Studies	Clearly stated aim	Consecutive patient inclusion	Prospective data collection	Appropriate end-points	Unbiased study end-point assessment	Appropriate follow-up period	Attrition bias (< 5%)	Sample size	Adequate control group	Contemporary groups	Baseline equivalence of groups	Statistical analysis	Total score
Allen et al [16]	2	2	2	2	0	2	2	0	2	2	2	2	20
Alvarez-Alvarez et al [17]	2	2	2	2	0	2	2	0	2	2	1	1	18
Bazarah et al [18]	2	2	2	2	0	2	2	0	2	2	2	2	20
Blondet et al [19]	2	2	2	2	0	2	2	0	2	2	2	2	20
Carey et al [20]	2	2	2	2	0	2	2	0	2	2	1	1	18
Chandran et al [21]	2	2	2	2	0	2	2	0	2	2	1	2	19
Cherian et al [22]	2	2	2	2	0	2	2	0	2	2	1	2	19
Chio et al [23]	2	2	2	2	0	2	2	0	2	2	2	2	20
Clayton et al [24]	2	2	2	2	0	2	2	0	2	2	1	2	19
Cosentini et al [25]	2	2	2	2	0	2	2	0	2	2	0	2	18
Desport et al [26]	2	2	2	2	0	2	2	0	2	2	2	2	20
El Chaarani et al [27]	2	2	2	2	0	0	2	0	2	2	1	2	17
Elliot et al [28]	2	2	2	2	0	2	2	0	2	2	0	2	18
Galaski et al [29]	2	2	2	2	0	2	2	0	2	2	1	2	19
Grant et al [30]	2	2	2	2	0	2	2	0	2	2	1	2	19
Hazratjee et al [31]	2	2	2	2	0	2	2	0	2	2	1	2	19
Kim et al [32]	2	2	2	2	0	2	2	0	2	2	0	1	17
Kohli et al [33]	2	2	2	2	0	0	2	0	2	2	0	2	18
Kohli et al (divyanshu) [34]	2	2	2	2	0	2	2	0	2	2	0	2	18
Kohli et al [35]	2	2	2	2	0	2	2	0	2	2	2	2	20
La Nauze et al [36]	2	2	2	2	0	2	2	0	2	2	2	2	20
Laasch et al [37]	2	2	2	2	0	1	2	0	2	2	1	2	18
Laskaratos et al [38]	2	2	2	2	0	2	2	0	2	2	1	2	19
Leeds et al [39]	2	2	2	2	0	2	2	0	2	2	1	2	19
Maasarani et al [40]	2	2	2	2	0	2	2	0	2	2	2	2	20
MacLean et al [41]	2	2	2	2	0	1	2	0	2	2	0	2	17
McAllister et al [42]	2	2	2	2	0	2	2	0	2	2	0	2	18
McDermott et al [43]	2	2	2	2	0	2	2	0	2	2	1	2	18
Moller et al [44]	2	2	2	2	0	2	2	0	2	2	1	1	18
Neeff et al [45]	2	2	2	2	0	2	2	0	2	2	0	1	17
Pannick et al [46]	2	2	2	2	0	2	2	0	2	2	0	2	18
Park et al [6]	2	2	2	2	0	2	2	0	2	2	2	2	20
Pinar-Gutierrez et al [48]	2	2	2	2	0	1	2	0	2	2	0	2	17
Abd Rahim et al [49]	2	2	2	2	0	2	2	0	2	2	0	0	12
Righetti et al [50]	2	2	2	2	0	0	2	0	2	2	1	2	17
Rio et al [51]	2	2	2	2	0	2	2	0	2	2	2	2	20

Table 2. Quality Assessment of Non-Randomized Studies via Methodological Index for Non-Randomized Studies (MINORS) - *(continued)*

Studies	Clearly stated aim	Consecutive patient inclusion	Prospective data collection	Appropriate end-points	Unbiased study end-point assessment	Appropriate follow-up period	Attrition bias (< 5%)	Sample size	Adequate control group	Contemporary groups	Baseline equivalence of groups	Statistical analysis	Total score
Rustom et al [52]	2	2	2	2	0	2	2	0	2	2	0	0	16
Silas et al [53]	2	2	2	2	0	2	2	0	2	2	1	2	19
Strijbos et al [54]	2	2	2	2	0	2	2	0	2	2	1	2	19
Tan et al [55]	2	2	2	2	0	2	2	0	2	2	0	2	18
Vashi et al [56]	2	2	2	2	0	2	2	0	2	2	1	2	19
Wollman et al [57]	2	2	2	2	0	2	2	0	2	2	1	2	19

Table 3. Risk of Bias Assessment of the Included RCTs

Study	Random sequence generation (selection bias)	Allocation concealment (selection bias)	Blinding of participants and personal (performance bias)	Blinding of outcome assessment (detection bias)	Incomplete outcome data (attrition bias)	Selective reporting (reporting bias)	Other bias
Hoffer et al [32]	Low	Low	Low	Low	Low	Low	Low

RCTs: randomized controlled trials.

pared to PEG (OR: 1.369, 95% CI: 1.81 - 1.586, I^2 = 0%) on primary analysis. However, this did not achieve statistical significance in sensitivity analysis (OR: 1.066, 95% CI: 0.653 - 1.742).

Secondary outcomes

Bleeding

PRG was associated with a greater risk of bleeding than PEG (OR: 1.376, 95% CI: 1.257 - 1.507, I^2 = 72%). However, this did not achieve statistical significance on sensitivity analysis (OR: 0.883, 95% CI: 0.74 - 1.051).

Infectious complications

PRG was associated with higher odds of infectious complications than PEG (OR: 1.193, 95% CI: 1.136 - 1.253, I^2 = 23.3%). However, this did not achieve statistical significance on sensitivity analysis (OR: 1.124, 95% CI: 0.996 - 1.268).

Aspiration pneumonia

There was no significant difference in risk of aspiration pneumonia when comparing PRG with PEG (OR: 0.931, 95% CI: 0.654 -1.324, I^2 = 15%). Sensitivity analysis confirmed these results.

Discussion

This systematic review and meta-analysis comparing PRG and PEG outcomes found higher odds of 30-day mortality, tube leakage, and tube dislodgement with PRG compared to PEG. Rates of bleeding, perforation, infectious complications, and peritonitis were significantly higher with PRG than PEG, but these results did not achieve statistical significance in a sensitivity analysis.

The odds of 30-day mortality after PRG was significantly higher than PEG, which is consistent with the results of previously published meta-analyses. Strijbos et al [12] reported a 30-day mortality rate of 7% for PEG vs. 11% for PRG in their 2017 meta-analysis of 2,027 patients. Lim et al also reported a lower 30-day mortality rate of 5.5% for PEG vs. 10.5% for PRG (OR: 0.6, CI 0.38 - 0.94, P = 0.026) in their 2016 meta-analysis of 2,183 patients [11]. The lower 30-day mortality rate in the PEG group could be attributed to several factors. First, prophylactic antibiotics are widely used and recommended among patients undergoing PEG placement [58], while present data on the use of antibiotics before PRG are conflicting. Clements et al reported no significant difference with antibiotic prophylaxis in early peristomal infection rate in their retrospective analysis [59]. In contrast, in an RCT, Ingraham et al reported early infection rate was 11.8% in the placebo arm and 0.0% in the antibiotic arm [60]. Currently, prophylactic

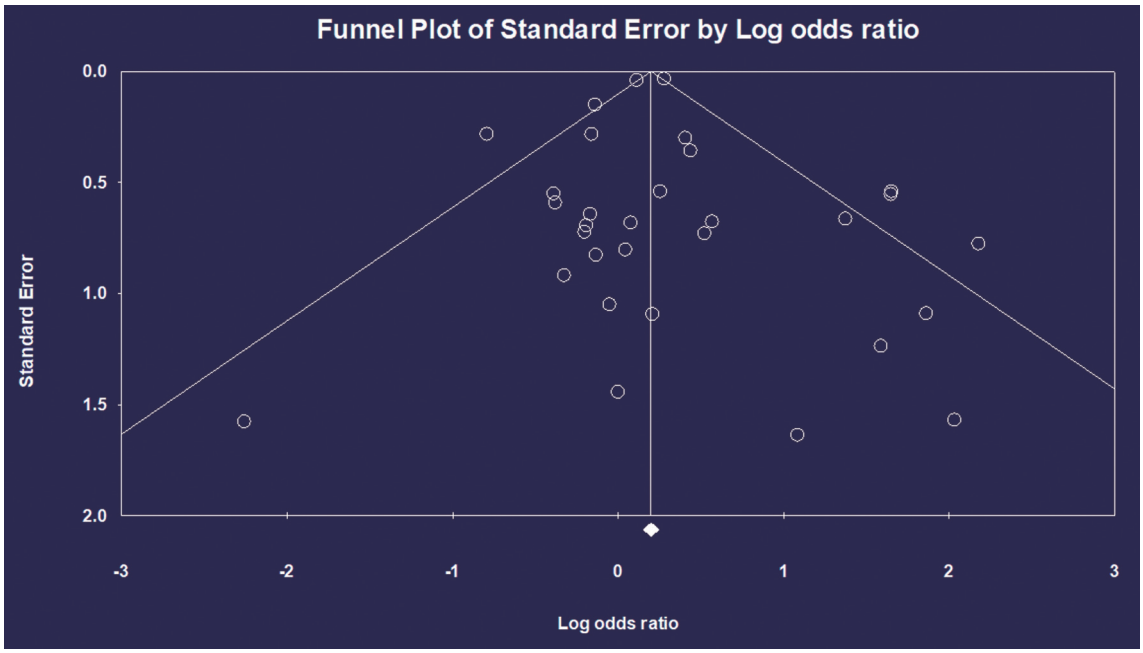

Figure 2. Publication bias assessed by funnel plot diagram.

antibiotics are not widely recommended for patients undergoing PRG, as the procedure avoids the oropharyngeal bacterial contamination of the endoscope as it traverses through the mouth and pharynx that occurs during PEG [61]. Second, PEG and PRG often use gastrostomy tubes of different sizes. PRG tubes are thinner in diameter (10 - 14 French) than PEG tubes (20 French), which could affect rates of tube blockage and result in aspiration pneumonia, increasing risk of respiratory decompensation and mortality [62]. In addition, because PRG tubes are secured using a balloon retention system, they are typically less secure than PEG tubes, resulting in greater risk of peristomal leakage and tube displacement, potentially leading to peritonitis and bowel perforation [63]. Furthermore, the two groups differed in terms of indication for gastrostomy tube placement. PEG patients had a higher prevalence of neurological disorders, whereas PRG patients had a higher prevalence of head and neck malignancy. These distinctions could have influenced our study's findings.

Tube-related complications, tube leakage, and tube dislodgement were more common among patients undergoing PRG than PEG. Strijbos et al reported the rate of tube-related complications to be 16% for PRG vs. 6% for PEG [12]. Failure of equipment, particularly balloon failure, has been identified as a primary cause of tube dislodgment in PRG [22]. Additionally, the smaller diameter of PRG tubes compared to PEG tubes may increase the chance of blockage, as well as risk of tube dislodgement. Contrary to our results, a meta-analysis by Wollman et al reported a higher rate of tube-related complications in PEG patients (16%) than PRG patients (12%) ($P \leq 0.001$) [10].

To assess whether any single study had a dominant effect on the meta-analysis, we excluded one study at a time and analyzed its impact on the primary summary estimate. We found that after removing certain studies from the analysis one at a time, some results were no longer significant. For example, overall results indicated that PRG is associated with a higher rate of infections than PEG. However, this was not significantly different based on our sensitivity analysis, which is consistent with previous studies.

Despite being associated with higher 30-day mortality rates and tube-related complications, PRG is still an important option for patients requiring gastrostomy tubes. In contrast to PEG, PRG can be placed without requiring sedation. PRG can also be used in patients with severe esophageal stenosis or malignant esophageal and oropharyngeal cancers that are poor candidates for PEG [64].

We compared our study to the meta-analysis by Strijbos et al [12] published in 2018. The limitations of their meta-analysis included a low number of studies, failure to include all available studies that met inclusion criteria, and lack of reporting on all outcomes. Our meta-analysis has the following strengths: systematic literature search with well-defined inclusion criteria, inclusion of all available studies in the current literature, careful exclusion of redundant studies, high-quality studies with detailed data extraction, and rigorous study quality evaluation. Our pooled rates are calculated from 471,091 patients, a very robust figure. However, our study has some limitations, many of which are inherent to any meta-analysis. Most of the studies included are retrospective, which likely contributed to selection bias. Although 30-day mortality is high with PRG, it should be highlighted that the underlying comorbid illnesses that required the patient to have a gastrostomy tube were likely the cause of mortality, rather than procedural complications. Because we were unable to account for comorbidities, it is plausible that individuals who received PRG were sicker than those who received PEG, which could explain the higher mortality rate. Furthermore, because our meta-analysis

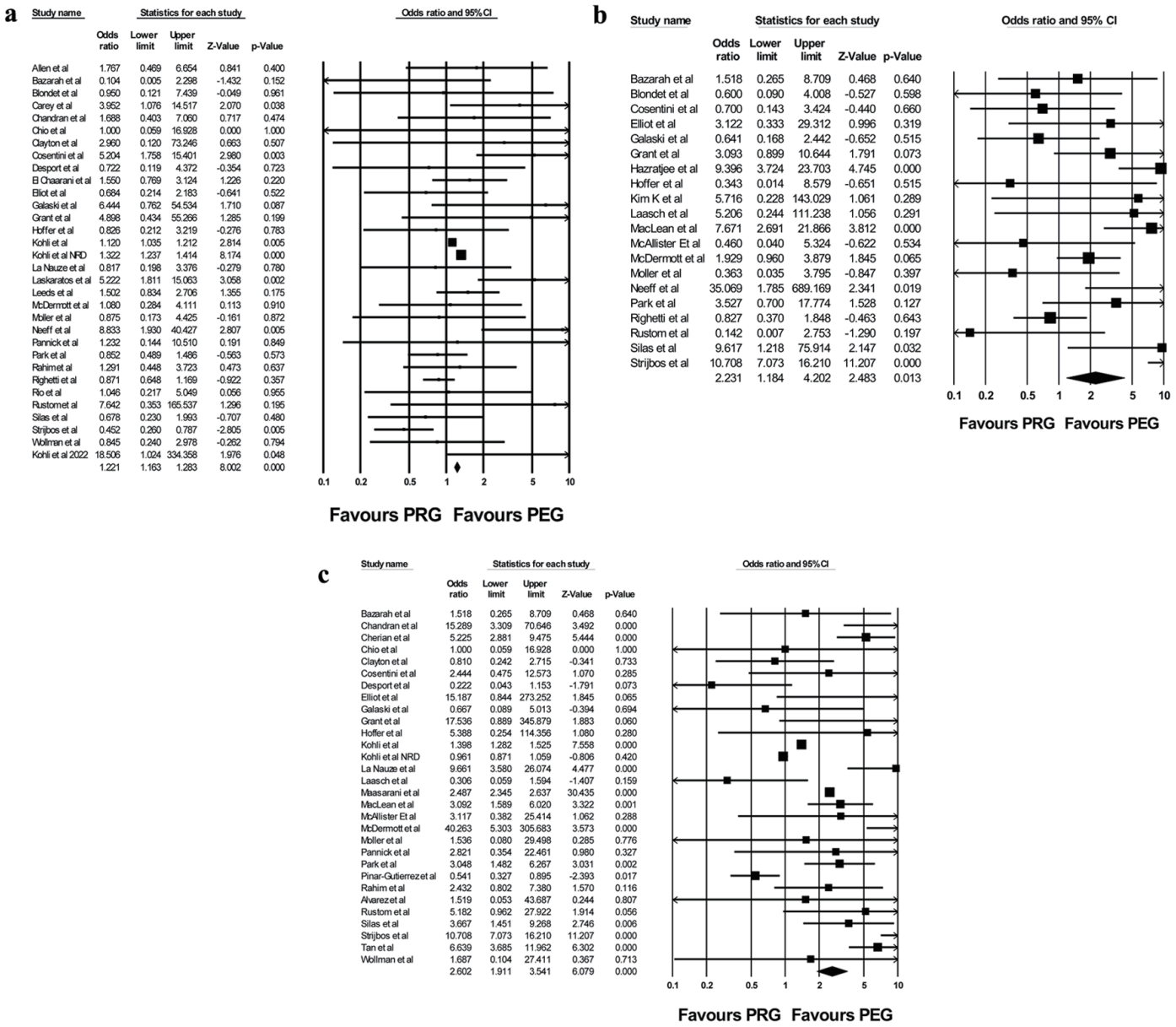

Figure 3. Forest plot of (a) 30-day mortality, (b) tube leakage, and (c) tube dislodgement between PRG and PEG. PEG: percutaneous endoscopic gastrostomy; PRG: percutaneous radiological gastrostomy.

identified studies from various databases, there is a chance of patient overlap. However, our sensitivity analysis for each outcome bolsters our meta-analysis findings. Nonetheless, our study represents the best estimate of PRG and PEG clinical outcomes currently available in the literature.

In summary, PRG is associated with higher 30-day mortality and gastrostomy tube-related complications than PEG. Additional studies, particularly large RCTs, are warranted.

Supplementary Material

Suppl 1. Search strategy.

Suppl 2. PRISMA checklist.

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Conflict of Interest

The authors declare no conflict of interest.

Informed Consent

Not applicable.

Author Contributions

Zohaib Ahmed contributed to study planning and conduction, data collection and interpretation, manuscript drafting and revision. Umair Iqbal contributed to study planning, statistical analysis, manuscript drafting and revision. Muhammad Aziz contributed to statistical analysis, manuscript drafting. Syeda Faiza Arif, Joyce Badal, and Umer Farooq contributed to data collection, manuscript drafting. Faisal Kamal contributed to data interpretation, manuscript drafting and revision. Wade Lee-Smith contributed to study search strategy, data collection, manuscript drafting. Asif Mahmood contributed to manuscript revision. Abdallah Kobeissy, Harshit S. Khara, Ali Nawras, Bradley Confer, and Douglas G. Adler contributed to study design and conception, and critical manuscript revision.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Abbreviations

ALS: amyotrophic lateral sclerosis; CI: confidence interval; CVA: cerebrovascular accident; HNC: head and neck cancers; MINORS: Methodological Index for Non-Randomized Studies; OR: odds ratio; PEG: percutaneous endoscopic gastrostomy; PRG: percutaneous radiological gastrostomy

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