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A systematic review and meta-analysis of gastrostomy insertion techniques in children

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ABSTRACT

Background: Gastrostomy tubes are inserted via multiple techniques to provide a route for enteral feeding in the pediatric population. This review compares the rate of major complications and resource utilization associated with the various insertion techniques.

Methods: Major electronic databases were queried for comparative studies of two or more insertion techniques, including open, laparoscopic, percutaneous endoscopic, or fluoroscopic guided. Major complications were defined as reoperation within 1 year or death. Screening of eligible studies, data extraction, and assessment of methodological quality were conducted independently by two reviewers. Forest and funnel plots were generated for outcomes using Revman 5.1, with $p < 0.05$ considered significant.

Results: Twenty-two studies with a total of 5438 patients met inclusion criteria. No differences in major complications were noted in studies comparing open versus laparoscopic approaches or open versus PEG. Studies comparing laparoscopic gastrostomy and PEG revealed a significantly increased risk in major complications with PEG ($n = 10$ studies, OR 0.29, 95% CI: 0.17–0.51, $p < 0.0001$). The number needed to treat to reduce one major complication by abandoning PEG is 45.

Conclusions: PEG is associated with an increased risk of major complications when compared to the laparoscopic approach. Advantages in operative time appear outweighed by the increased safety profile of laparoscopic gastrostomy insertion.

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The placement of a gastrostomy feeding tube (GT) is one of the most commonly performed operative procedures for children. These feeding tubes are offered to a wide spectrum of pediatric patients that cannot meet their long-term nutritional needs without supplementation, including patients with neurodevelopmental delay (NDD), intractable gastroesophageal reflux disease (GERD), or other cases of failure to thrive (FTT). Gastrostomy tubes are typically well tolerated and provide improved quality of life compared to parenteral and nasogastric feeding for patients unable to maintain adequate oral nutrition [1].

The GT device can be positioned using one of four different technical approaches: surgically using the Stamm or open technique (OPEN), using the percutaneous-endoscopic approach (PEG), guided by interventional-radiology (IRG) or by laparoscopic (LAP) minimally invasive surgery. The original description of the surgical technique of placing a GT was provided in 1984 by Stamm [2]. While this approach continues to be employed in certain circumstances, the original technique mandated a considerable operative incision affiliated with significant postoperative pain [3]. Evolving technology gave rise to a less invasive approach described by Gauderer et al. [4] involving an endoscopic technique to place the feeding tube: the percutaneous-endoscopic gastrostomy (PEG). Shortly after its introduction, PEG gained popularity owing to its minimally invasive nature, speed, low cost, high patient tolerability and early postoperative feeding. However, lack of direct visualization of the intraabdominal cavity and inadvertent injury to surrounding structures have tempered initial enthusiasm with the technique [5,6]. Shortly following the introduction of PEG, Ho [7] described a percutaneous image-guided alternative to surgical and endoscopic gastrostomy placement. In contrast to the OPEN and PEG approaches, it obviates a laparotomy incision or gastroscope, respectively, and is therefore considered the least invasive gastrostomy insertion technique [8]. Despite being less invasive, this relatively blind approach has been associated with unique complications including placement of the catheter through a lobe of the liver and fistulation into the small bowel [9,10]. In 1990, laparoscopic gastrostomy placement was introduced, combining the minimally invasive advantages of PEG with the safety of the OPEN procedure allowing for tube placement under direct visualization. Two laparoscopic variations have been reported and studied, including both a laparoscopic (LAP) and a laparoscopic-assisted percutaneous endoscopic approach (LA-PEG) [11,12].

The approach to gastrostomy placement has undergone considerable evolution since first described. However, the literature

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reporting the supremacy of one technique to another is conflicting and there are no reports comparing all four techniques. An early meta-analysis evaluating effectiveness and safety of IRG, PEG and OPEN gastrostomy, inclusive of pediatric and adult populations, documented the superiority of IRG (major complications 5.9% versus 9.4% for PEG and 19.9% for surgery, $p < 0.05$; thirty-day procedure-related mortality 0.3% versus 0.53% for PEG and 2.5% for surgery) [13]. However, 6 years later, a single-center retrospective review investigating the same 3 techniques reported no significant difference between complication rates ($n = 147$) [14]. Following the introduction of laparoscopy GT insertion, 3 single-center retrospective reviews have been conducted comparing various outcomes following OPEN, PEG and LAP gastrostomy in a pediatric population, reporting varying results [15–17].

There is currently no consensus as to the optimal technique of gastrostomy insertion in the pediatric population, and there remains a paucity of well-designed trials to answer the question. The PEG, IRG and LAP techniques are the most commonly preformed and widely accepted approaches today but there has yet to be a systemic review of the literature critically comparing these approaches. This report evaluates the available literature summarizing complication rates and resource utilization for gastrostomy techniques in children. Given that gastrostomy tube placement remains one of the most commonly preformed elective procedures, summary recommendations on relative advantages and disadvantages of each technique should inform future practice for many children with nutritional deficiencies in need of long-term enteral access.

1. Materials & methods

1.1. Guideline

The PRISMA statement, checklist and flowchart were referenced to achieve the highest standard in reporting items for a systematic review and meta-analysis [18,19].

1.2. Literature search

A systematic search of electronic databases was performed to identify all relevant studies comparing two or more gastrostomy insertion techniques in children reporting procedural-related complication rates. A reference librarian was consulted to assist with the development of database-specific search strategies. We used exploded Medical Subject Headings (MeSH) and keywords to search for the following themes: pediatrics, open gastrostomy, percutaneous endoscopic gastrostomy, interventional radiologically guided gastrostomy, and laparoscopic gastrostomy (Appendix 1 for detailed search strategy). We applied the search strategy to the following databases: MEDLINE (PubMed, PubMEd in Process and Ovid), EMBASE, Cumulative Index of Nursing and Allied Health Literature (CINAHL), Scopus and Cochrane Library. The search was restricted temporally from 1993 to 2013, with no linguistic restriction. Reference lists from the retrieved articles were then hand searched to identify additional potentially relevant articles.

Table 1
Studies that met inclusion criteria, segregated by procedure. Complication rates and MINORS score are displayed.

Study	Intervention A		Intervention B		MINORS score
	n	Incidence of major complication (%)	n	Incidence of major complication	
LAP versus open	LAP		Open		
Collins et al. (1995)	46	0	52	0	14
Ruangtrakool and Ong (2000)	18	NA[b]	51	NA[b]	16
Wadie and Lobe (2002)	56	3 (5.36%)	74	5 (6.76%)	16
Conlon et al. (2004)	247	10 (4.05%)	754	36 (4.78%)	13
Fraser et al. (2009)	695	1 (0.15%)	557	5 (0.90%)	11
Naiditch et al. (2010)	65	NA[a]	94	NA[a]	16
Thatch et al. (2010)	25	0	32	0	16
Liu et al. (2013)	260	1 (0.38%)	23	0	14
Total	1412	15 (1.13%)	1637	46 (2.81%)	
LAP versus PEG	LAP		PEG		
Lee et al. (2002)	51	0	8	0	10
Steyaert et al. (2003)	14	0	19	5 (26.32%)	13
Conlon et al. (2004)	247	10 (4.05%)	41	7 (17.08%)	13
Zamakhshary et al. (2005)	26	1 (3.85%)	93	8 (8.61%)	16
Fraser et al. (2009)	695	1 (0.15%)	282	6 (2.13%)	11
Vervloessem et al. (2009)	19	0	448	9 (2.01%)	14
Akay et al. (2010)	104	9 (8.66%)	134	26 (19.41%)	15
Peters et al. (2010)	98	0	16	2 (12.5%)	14
Villalona et al. (2011)	85	2 (2.36%)	34	3 (8.82%)	14
Liu et al. (2013)	260	0	86	1 (1.17%)	14
Total	1599	23 (1.44%)	1161	67 (5.77%)	
OPEN versus PEG	OPEN		PEG		
Cameron et al. (1995)	33	3 (9.09%)	30	0	16
Stylianos and Flanigan (1995)	17	0	15	0	12
Day et al. (2001)	18	0	34	0	10
Conlon et al. (2004)	754	36 (4.77%)	41	3 (7.32%)	13
Lindmayer et al. (2006)	30	NA[c]	2	NA[c]	
Fraser et al. (2009)	557	5 (0.90%)	282	6 (2.13%)	11
Ackroyd et al. (2011)	75	0 (0%)	85	2 (2.36%)	15
Lintula et al. (2012)	13	1 (7.69%)	56	4 (7.15%)	16
Liu et al. (2013)	23	0	86	4 (4.66%)	14
Total	1520	45 (2.96%)	631	19 (3.01%)	
PEG versus IR	PEG		IR		
Nah et al. (2010)	136	6 (4.42%)	195	1 (0.51%)	16

[a] Complications not segregated by procedure, total of 3 major complications reported.
[b] Total of 2 major complications.
[c] Results uninterpretable as presented.

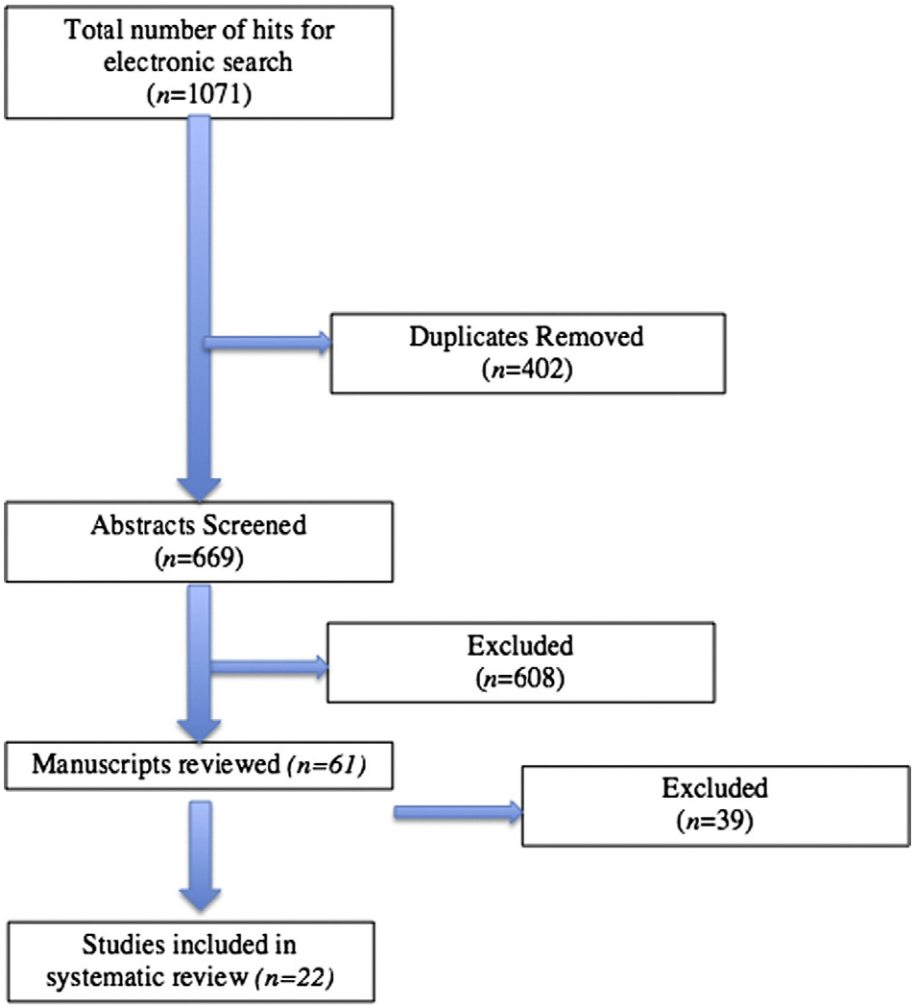


Fig. 1. Consort diagram of articles included in review.

1.3. Inclusion/exclusion criteria

All studies that compared postoperative outcomes in two or more gastrostomy placement techniques in a pediatric population were included. The primary outcome of interest was postoperative complication resulting in death or requiring operative management within one year — our working definition of a major complication. Secondary outcomes included: other reported complications and a comparison of resource utilization between the techniques (including operative time and cost). The pediatric population was defined as patients 0–18 years of age. If a study included data of both pediatric and adult populations, the study was included in our review if the pediatric data could be extracted and analyzed separately. The different gastrostomy techniques of interest included OPEN, PEG, IRG and LAP (inclusive of LAP-PEG). Patients that underwent concomitant fundoplication were included in this review, but excluded from some aspects of the meta-analysis. Complications requiring operative management included visceral injury (defined as perforation of surrounding intraabdominal organs), peritonitis, early dislodgement, excessive leakage (defined as significant loss of enteral feeding >10%), migration of gastrostomy site (defined as cephalad migration of the gastrostomy site toward the ribs or caudal migration of the ribs causing significant discomfort) and malposition

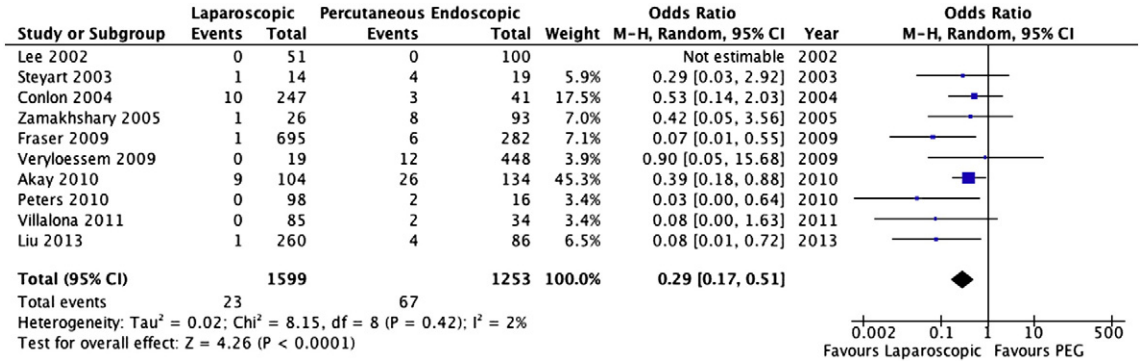


Fig. 2. Forest plot of major complications after laparoscopic gastrostomy versus PEG.

Table 2
Comparison of studies investigating laparoscopic gastrostomy versus percutaneous endoscopic gastrostomy.

Study	n		Death		Visceral injury		Infection		Mechanical		Other		Total		Failed procedure	
	L	PEG	L	PEG	L	PEG	L	PEG	L	PEG	L	PEG	L	PEG	L	PEG
Lee et al. (2002)	51	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Steyaert et al. (2003)	14	19	0	0	0	1	0	3	0	1	0	0	0	5	0	1
Conlon et al. (2004)	247	41	0	0	0	5	0	0	7	2	3	0	10	7	0	0
Zamakhshary et al. (2005)	26	93	0	0	0	3	1	1	0	4	0	0	1	8*	0	2
Fraser et al. (2009)	695	282	0	0	0	0	0	1	1	3	0	2	1	6	0	0
Vervloessem et al. (2009)	19	448	0	1	0	6	0	0	0	0	0	2	0	9	0	0
Akay et al. (2010)	104	134	0	0	1	2	0	0	0	13	8	11	9	26*	5	5
Peters et al. (2010)	98	16	0	0	0	2**	0	0	0	0	0	0	0	2	1	0
Villalona et al. (2011)	85	34	0	0	0	0	0	1	2	2	0	0	2	3	0	0
Liu et al. (2013)	260	86	0	0	0	1	0	0	0	0	0	0	0	1	2	2
Total	1599	1161	0	1	1	20	1	6	10	25	11	15	23	67	8 (0.5%)	10 (0.9%)

L = laparoscopic gastrostomy.
PEG = percutaneous endoscopic gastrostomy.
Mechanical: dislodgement, "excessive leakage," prolapse of stomach through gastrostomy tract, "disruption of gastrostomy tract," gastric separation from abdominal wall.
Infection: stomal infection or peritonitis requiring operative management.
Other: migration of the gastrostomy site (referring to cephalad migration of the gastrostomy site toward the ribs or caudal migration of the ribs toward the gastrostomy site), malposition of the gastrostomy site (unplanned construction of the gastrostomy tract near the pylorus with secondary obstruction of the pylorus or dumping syndrome), pain, necrosis (PEG migration), gastrocutaneous fistula, significant stomal complication (granulation tissue, erosion, ulceration, nonhealing skin, foreign body reaction).
* L was shown to result in fewer complications requiring operative management compared to PEG ($p < 0.05$).
** There was a statistically significant decrease in gastrocolic fistula reported in the LAP group compared to PEG ($p < 0.05$).

of the gastrostomy tract (construction of the gastrostomy tract near the pylorus with secondary obstruction of the pylorus or dumping syndrome). These complications requiring reoperation within one year of initial insertion were included as major complications. If timing relative to insertion was not specified, the event was included. Our review included both retrospective and prospective comparative studies. To date, there have been no randomized control trials comparing interventions of interest. Only published data were included in our study.

Exclusion criteria included irrelevant publications (animal studies, basic science papers) and inappropriate patient populations (patients older than 18 years of age). Articles that did not compare two or more of the above interventions nor report the primary study outcome of procedural-related complications following GT placement were also excluded.

1.4. Study selection

All titles and abstracts identified in the electronic database were independently screened for relevance and categorized as relevant, possibly relevant or irrelevant, based on our inclusion criteria. Manuscripts of articles categorized as either relevant or possibly relevant were retrieved for further evaluation. Uncertainty regarding the inclusion or exclusion of a study was resolved through a discussion with the senior author (RB).

1.5. Data extraction

Data extraction was conducted by 2 reviewers (LB & AB) using a predefined data extraction worksheet. The following information was extracted from each article: title, authors, number of centers involved, geographical location, patient demographics, the interventions being compared, complications assessed, markers of resource utilization, as well as the reported findings of the study. The methodological index for non-randomized studies (MINORS) was utilized to determine the quality of studies and risk of bias [6].

1.6. Statistical analysis

Meta-analysis was preformed for primary and secondary outcomes using RevMan 5.1 (Copenhagen) [20]. Postoperative morbidity necessitating operative management or resulting in mortality was analyzed as dichotomous data, with odds ratios calculated. The fixed effect model (Mantel–Haenszel approach) was used to create forest plots, with significance and effect size also investigated using the random effects model when moderate heterogeneity existed. Publication bias was evaluated through the generation of a funnel plot of standard error against the log odds ratio. $P < 0.05$ was considered statistically significant for all analyses.

2. Results

2.1. Description of identified studies

The search strategy for the review resulted in 22 studies meeting inclusion criteria, with 5346 participants overall (Table 1) [3,11,15–17,21–37]. The results of the search strategy are detailed in Fig. 1. Of the 22 studies identified, the median MINORS score of all studies was 14 (range 10–16), max = 24.

Three studies identified compared three or more techniques (Conlon et al. [16], Fraser et al. [17] & Liu et al. [15]), and there was one

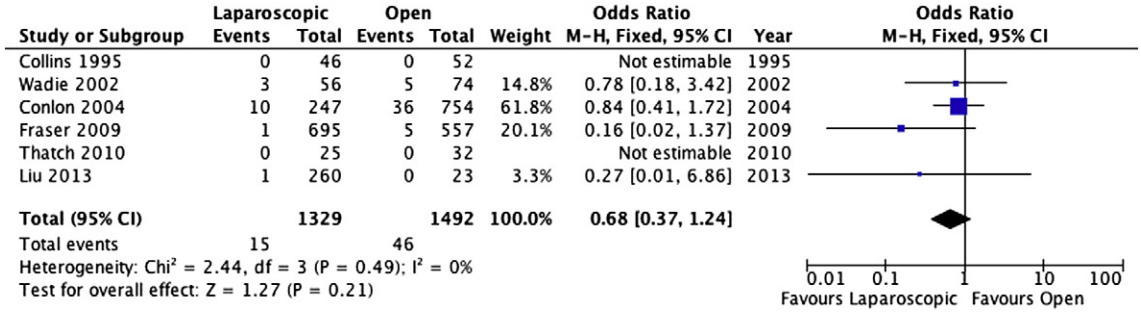


Fig. 3. Forest plot of major complications after laparoscopic gastrostomy versus open.

multiinstitutional investigation (Fraser et al. [17]). Eight studies compared a laparoscopic-assisted gastrostomy insertion with an open approach and 10 studies compared laparoscopic gastrostomy to PEG. There were no comparative studies involving LAP and IRG. Nine studies were identified comparing PEG and OPEN and 1 study comparing PEG and IRG. Studies were of variable size (mean patient number: 243; range 32–1534). A total of 1823 patients underwent OPEN gastrostomy insertion (within 14 comparative studies), 1382 in the PEG group (within 17 comparative studies), 195 underwent IR (one study), and 1809 LAP cases (within 15 comparative studies).

2.2. Results of the studies

2.2.1. Patient demographics:

Children undergoing PEG were reported as older than those undergoing LAP gastrostomy tube placement in 3 out of the 10 studies comparing these two techniques ($p < 0.05$). In two of the 10 studies, children undergoing PEG were also reported as heavier. There was otherwise no significant difference noted between sex, age, weight and indication for gastrostomy tube placement. However, it should be noted that only 6 of the 22 studies commented on no significant difference in age or weight. Seven documented no significant difference in gender. Five commented on no significant difference between indications for gastrostomy tube placement. The studies not described either failed to report a statistical analysis or did not comment on the above patient demographics.

2.2.2. Major complication rates:

Studies comparing laparoscopic gastrostomy and PEG revealed a significant increase in major complications with PEG (n = 10, OR 0.29, 95% CI: 0.17–0.51, $p < 0.0001$) (Fig. 2). These complications are further enumerated in Table 2, which demonstrates that much of this significant difference is owing to the improved visceral perforation rate in the LAP technique when compared to PEG. The number needed to treat to avoid one major complication with PEG is 45 (38–65). No differences in major complications were noted in studies comparing laparoscopic versus open approaches, see Fig. 3 (n = 6 studies, OR: 0.68 95%CI: 0.37–1.24, p = 0.49) or open versus PEG, see Fig. 4 (n = 8 studies, OR: 0.75 95%CI: 0.38–1.48, p = 0.26). Study heterogeneity was low in all cases and the funnel plot of LAP versus PEG GT procedures revealed an absence of significant asymmetry — suggesting no important publication bias (Fig. 5).

2.2.3. Secondary outcomes:

Two studies directly evaluated postprocedural length of stay after OPEN versus LAP GT insertion. Wadie and Lobe [37] demonstrated no difference (13.1 days versus 11.2, n = 56) while Collins et al. [3] demonstrated an earlier time to discharge in the LAP group (6.8 days versus 10.7 days, n = 98). A single study comparing OPEN and PEG demonstrated no difference in length of stay after procedure (3.2 days v 2.4 days, n = 69) [29].

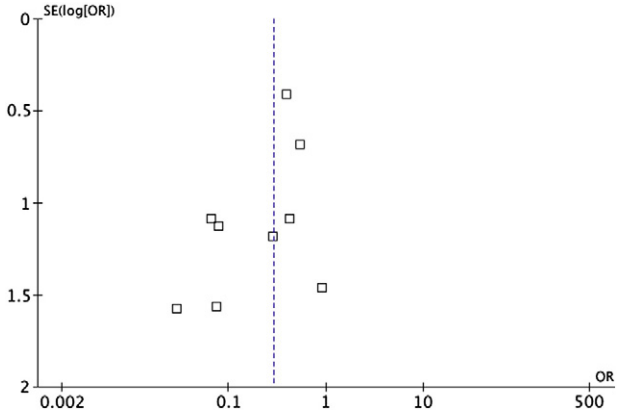


Fig. 5. Funnel plot of major complications after laparoscopic gastrostomy versus PEG.

Considerable variation existed in reporting practices of enteral feeding after gastrostomy insertion. Five studies evaluated this outcome, with three studies demonstrating significantly improved feeding parameters when comparing lap to open GT insertion [3,21,33,34,37].

2.2.4. Resource utilization:

Only one study evaluated procedural-related direct costs [22], with LAP revealed to be nearly twice as costly when compared to PEG as a consequence of necessitating longer operative time ($2425 USD v $1375 USD, n = 16). This estimation did not take into account the cost of an additional endoscopy for change to a low-profile device in the PEG group.

One study evaluated operative time comparing the LAP and OPEN technique, revealing no significant difference (66.3 minutes versus 44.5 minutes, n = 56) [37]. Six studies compared the procedure-related times of LAP and PEG techniques (Fig. 6). This analysis revealed significant heterogeneity ($I^2 = 100\%$), although the reduction in operative time with PEG appears considerable and significant given the narrow confidence interval (19.25 minutes, 18.7–19.7, $p < 0.0001$).

3. Discussion

Gastrostomy tube placement remains a highly popular intervention with a number of indications, in both adult and pediatric populations. Since initially introduced in 1986 as an open surgical approach, it has evolved into a procedure performed using multiple different techniques by several different operators, including surgeons, gastrointestinal endoscopists and interventional radiologists. Over the past 30 years, outcomes following gastrostomy tube placement have been extensively investigated, however no definitive consensus regarding optimal practice has been described. This study reviews the incidence of major complications necessitating operative management following OPEN, PEG,

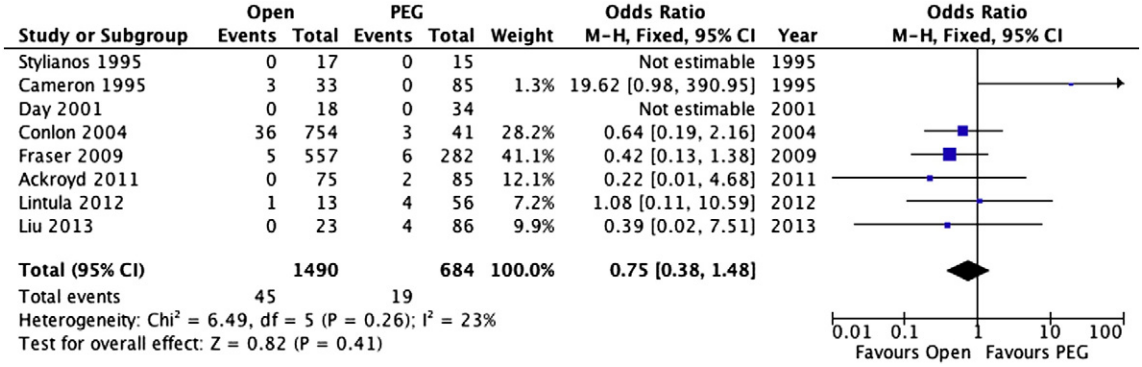


Fig. 4. Forest plot of major complications after open versus PEG.

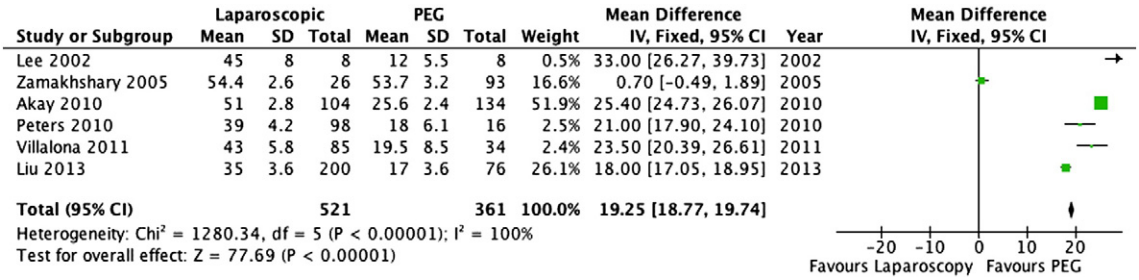


Fig. 6. Forest plot of procedural-related time for laparoscopy gastrostomy versus PEG.

IRG and LAP (or LAP-PEG) gastrostomy insertion in children. It summarizes 22 comparative studies, none of which was randomized control trials, involving 5346 pediatric patients who have undergone gastrostomy placement during the last 20 years.

This meta-analysis has revealed a significant increase in major complications with PEG when compared to the laparoscopic technique. No differences were noted in the major complication rate in the other reported comparative studies, although a paucity of literature regarding the IRG technique obviates the ability to render sound judgment about its performance. Postprocedural length of stay and resumption of enteral feeding were not well reported in the available literature, although unsurprisingly laparoscopy appeared to reduce length of stay and time to full feeds when compared to the traditional open approach. While markers of resource utilization were incompletely reported and highly variable between studies, PEG appeared associated with a reduction in procedural time and potentially a reduction in direct costs.

Selection of older, heavier children for PEG compared to LAP, as reported in 3 of 10 studies comparing these approaches, may be explained by the lack of evidence documenting safety of PEG in infants at the time of study conduction. The first large pediatric review reporting safety of PEG in small (<6 kg) neonates with failure to thrive was in 2011 [38]. As there is currently no literature supporting patient age or weight as a predictive factor for success and safety of tube placement, we are unable to draw conclusions on the influence of these discrepancies of baseline demographics on the results. Additionally, the other 7 studies failed to report patient demographic information. This paucity in reporting of patient demographics presents a limitation in our study.

One of the major advantages of the addition of laparoscopy in comparison to a percutaneous endoscopic approach is the improved visualization of the abdominal cavity, which aids in minimizing the risk of visceral injury. It also allows for immediate recognition of any possible inadvertent injury prior to completion of the procedure — operative correction can then be undertaken with minimal overall patient morbidity. In the articles reviewed comparing LAP to PEG gastrostomy insertion, the rate of visceral injury including colonic perforation, was found to be 1.72% (range: 0–12.2%) in PEG, compared to 0.06% in LAP (range: 0–0.96%). Akay et al. [21] suggested that reduction in visceral injury via the utilization of laparoscopy also helps decrease the rates of postoperative sepsis. In their study, they reported 4 cases of misplaced tubes in the PEG group that resulted in significant septic complications (no misplaced tubes in LAP). Although we did not document the occurrence of infection responsive to antibiotics, infection prompting operative management occurred in 0.52% (6/1161) of PEG cases, compared to 0.06% (1/1599) of LAP cases. Direct visualization also allows for optimal placement of the gastrostomy tube, in contrast to PEG, where placement is limited to areas with adequate transillumination. Lee et al. [22] suggests that inability to precisely identify the area of the stomach to be used as the gastrostomy site might be related to increased rates of gastroesophageal reflux or gastric outlet obstruction observed after PEG. Contrary to this hypothesis, a study by Conlon et al. [16] reported increased incidence of malpositioning of the GT, defined as unplanned construction of the GT near the pylorus resulting in pyloric obstruction or dumping syndrome, in LAP compared to PEG (2/247 versus 0/41). However, this finding was not reported to be of statistical significance [16]. Two independent comparative studies investigating the influence of GT insertion technique on long-term revision rates secondary to migration of the GT, defined as cephalad movement of the gastrostomy site toward the ribs or caudal migration of the ribs toward the gastrostomy site, found varying results. One group identified 2 patients requiring revision of the gastrostomy site for this reason following PEG placement, and intends to continue to follow these patients for long-term evaluation [17] The other group reported 1 case requiring reoperation secondary to tubal migration following LAP insertion [16].

The second major advantage of the LAP technique is the ability to securely transfix the stomach to the anterior abdominal wall. This has proven to be of benefit in both the short-term and long-term course following gastrostomy insertion. It provides an immediate postoperative advantage by preserving the GT insertion site and tract in the event of accidental dislodgement, potentially preventing the need for operative management [11,39]. Furthermore, data from our center report a reduction in emergency department visits, secondary to tube dislodgement, following laparoscopic placement compared to open [40]. In the comparative studies between PEG and LAP there was only 1 case of 1599 requiring operative management of tube dislodgement following early presentation, compared to 11 cases of 1161 following PEG insertion. There were 3 additional cases of dislodgement (2 LAP and 1 PEG) requiring reoperation; these resulted from delayed presentation with associated stenosis of the insertion site requiring reintervention. In addition to decreasing the incidence of early dislodgement, Lee et al. report that perfect fixation of the stomach to the abdominal wall prevents the possible development of peritonitis at the time of conversion to a low-profile button, if not placed primarily [22].

An additional advantage of LAP over PEG is the option of primary placement of a low-profile device. Rothenberg et al. [39] described this modification to the original LAP technique, which did not adversely influence complication rates. In fact, they report a significantly higher incidence of complications following PEG compared to LAP. Another advantage of primary placement of a low-profile device is that it negates the possible need for a second procedural anesthetic for subsequent conversion to a low-profile device.

The most commonly reported disadvantages of LAP over PEG are increased operative length and cost. Three of the 10 comparative studies commented on operative length, 2 of which reported a statistically significant decrease in operative time in the PEG group compared to LAP. However, Zamakhshary et al. [11] reported cumulative operative time (for the PEG group including conversion to low-profile button under general anesthesia) and reported no significant difference in operative length between the two techniques once this conversion was accounted for (54.4 minutes LAP versus 53.7 minutes PEG). Only one investigation commented on the discrepancy in direct costs between the two insertion techniques. On average, the procedure-related hospital charges during an LAP insertion visit were found to be $1050 higher than in PEG. Given that the study is single institutional and now 10 years out of date, these absolute cost numbers are likely inaccurate and hard to generalize. Increased operative time secondary to inexperience with laparoscopic equipment was the primary contributor to the increased

cost affiliated with LAP. Another possible disadvantage of LAP is the potential for visceral injury at the time of initial port placement as well as upon insertion of the Veress needle. However, this was not recognized as a cause of visceral injury in any of the comparative LAP versus PEG studies reviewed. Additionally, Lee et al. [22] report a history of introduction of Veress needles in more than 1000 procedures at their institution, with no reported cases of visceral injury.

Of importance, this review highlights the paucity of literature evaluating the safety of the radiologically guided approach in comparison to other techniques. In contrast to laparoscopy, it is a minimally invasive technique that does not require general anesthesia, making it an attractive option for patients unfit for sedation. Additionally, its instillation does not necessitate an operating room. Data from the adult literature support the supremacy of radiologically guided tube placement to PEG and OPEN in regards to safety [13]. However, the literature reporting its application in children is limited. Following a tube-related death, as well as several other serious complications, a large pediatric center recognized as a center of interventional radiology excellence reported their experience with radiologic placement of enterostomy tubes by retrograde percutaneous technique [41]. A major complication rate of 5% and a minor complication rate of 73% were reported in the more than 200 cases reviewed. At present, further evaluation is recommended in order to advise the medical community on the role of IR gastrostomy insertion in pediatrics.

Additional limitations to this review include the retrospective nature of the majority of the studies included. Only one of the ten comparative studies investigating PEG versus LAP was conducted in a prospective fashion; the study by Steyaert et al. [24] failed to demonstrate a significant difference in outcomes and was limited by a small sample size. Because of the retrospective nature of most of the included data, the potential for selection bias is significant. In addition, the relatively modest MINORS score of included studies and the relative heterogeneity of results (particularly with respect to resource utilization) suggest that individual-specific and/or institutional-specific factors likely influence outcomes and diminish the generalizability of the presented results.

The placement of a gastrostomy tube in a pediatric patient often represents a seminal moment for the child, his/her family and the medical team providing care. The implications of the procedure resonate for years to follow as care plans shift to outpatient management and nutritional needs become definitively addressed. Ultimately, the technique chosen for gastrostomy tube placement should rest with the implicated health care team, individualized for each unique patient circumstance and be based on individual/institutional expertise. Nonetheless, this review suggests that a laparoscopic approach is affiliated with decreased patient morbidity requiring reoperation when compared to an endoscopic gastrostomy insertion approach. While definitive, 'level one evidence' is lacking, these results suggest that any advantages in operative time and resource utilization associated with PEG appear outweighed by the increased safety profile of laparoscopic gastrostomy insertion. Further high-level evidence would continue to refine our appreciation of the associated risks and benefits of gastrostomy tube insertion for some of the most fragile pediatric patients.

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Appendix 1. Detailed search strategy for each database

Search done on May 17th, 2013 in the following databases: MEDLINE (PubMed, PubMEd in Process and Ovid), EMBASE, Cumulative Index of Nursing and Allied Health Literature (CINAHL), Scopus and Cochrane library.

The following search strategy was used in OVID and adapted as appropriate for other databases:

1. Gastroscopes/
2. Gastrostomy/
3. Intubation, gastrointestinal/
4. Enteral nutrition/
5. gastrostom*.tw.
6. ((Gastro* or G) adj tube*).tw.
7. ((Gastro* or GI) adj3 intubat*).tw.
8. ((Feed* or stomach) adj2 tube*).tw.
9. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10. Endoscopic gastrostom*.tw.
11. PEG.tw.
12. 10 or 11
13. Open gastrostom*.tw.
14. Stamm gastrostom*.tw.
15. Witzel gastrostom*.tw.
16. 13 or 14 or 15
17. Exp fluoroscopy/
18. Radiology, interventional/
19. (Radiolog* adj2 gastrostom*).tw.
20. 17 or 18 or 19
21. Exp laparoscopy/
22. Surgical procedures, minimally invasive/
23. Laparoscop*.tw.
24. Minimally invasive.tw.
25. 21 or 22 or 23 or 24
26. 9 and 12 and 16
27. 9 and 12 and 25
28. 9 and 12 and 20
29. 9 and 16 and 25
30. 9 and 16 and 20
31. 9 and 20 and 25
32. Exp child/
33. Child$.mp.
34. Exp pediatrics/
35. Pediatric$.mp.
36. Paediatric$.mp.
37. Or/32-36
38. Perinat$.mp.
39. Neonat$.mp.
40. Newborn$.mp.
41. Infan$.mp.
42. Bab$.mp.
43. Toddler$.mp.
44. Boy$.mp.
45. Girl$.mp.
46. Kid$1.mp.
47. School?age.mp.
48. Juvenil$.mp.
49. Under?age$.mp.
50. Teen$.mp.
51. Minor$.mp.
52. Pubescen$.mp.
53. Adolescen$.mp.
54. Or/38-53
55. Infan$.jw.
56. Child$.jw.
57. Pediatric$.jw.
58. Pediatric$.jw.
59. Adolescen$.jw.
60. Or/54-59
61. 37 or 54 or 60
62. 26 and 61
63. 27 and 61
64. 28 and 61
65. 29 and 61
66. 30 and 61
67. 31 and 61
68. 62 or 63 or 64 or 65 or 66 or 67

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