Pediatric multicenter cohort comparison of percutaneous endoscopic and non-endoscopic gastrostomy technique outcomes

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Accepted 19 September 2019
Published Online First 26 September 2019

To cite: Kumar AS, Bani Yaghoub M, Rekab K, *et al*. *J Investig Med* 2020;**68**:413–418.

ABSTRACT

Enteral access is one of the mainstays of nutritional support. Several different modalities for gastrostomy placement are established. In pediatrics, however, there is a limited evidence base supporting the choice of 1 modality over the others. We retrospectively compared elective percutaneous endoscopically placed gastrostomy (PEG) with surgical and interventional radiology-placed gastrostomy outcomes using the Pediatric Hospital Inpatient Sample multicenter administrative database (Pediatric Health Information System). Pediatric patients (<18 years) undergoing planned elective gastrostomy (2010–2015) were included. Coded gastrostomy procedure subtype, patient demographic characteristics, chronic comorbidities and subsequent related outcomes, mortality, readmission, length of stay and total cost of admission were analyzed. Univariate analysis differentiated among gastrostomy techniques. The effect of gastrostomy on mortality and 30-day readmission were determined using a forward, stepwise, binary logistic regression. Generalized linear models were used to estimate the effect of gastrostomy type on length of stay and total cost. During the study period, 11,712 children underwent gastrostomy, including PEG (27%). Patients with chronic comorbidities were more, or as likely to undergo non-PEG procedures. Postoperatively, PEG patients were less likely to require mechanical ventilation and total parenteral nutrition (TPN). Gastrostomy type was not predictive of mortality; predictors included non-White race and need for mechanically assisted ventilation. Readmission following gastrostomy was common (29.5%), and more likely in PEG patients (OR 1.31). Predictors of readmission included earlier TPN (OR 1.39), cardiovascular (OR 1.17) and oncology (OR 4.17) comorbidities. Our study suggests that PEG placement entails similar length of stay and cost as in non-PEG gastrostomy. Patients undergoing PEG were less likely to require mechanical ventilation and TPN postoperatively. Mortality is similar in both groups although more likely with specific comorbidities. Racial background appeared to be associated with choice of gastrostomy, length of stay and mortality.

Significance of this study

What is already known about this subject?

- Enteral access by percutaneous endoscopically placed gastrostomy (PEG) is a safe, cost-effective procedure in pediatric patients.
- Comparison of different modalities for enteral access shows comparable outcomes.
- Specific populations, including children with chronic cardiac comorbidity, appear to favor PEG over other modalities.

What are the new findings?

- For elective gastrostomy placement in children there is no difference in mortality between gastrostomy types.
- Children undergoing PEG gastrostomy have a higher 30-day readmission rate.
- Overall, readmission was higher in cardiovascular and oncology comorbidities.

How might these results change the focus of research or clinical practice?

- Patient clinical characteristics need to be factored during planning and during discussion on the choice of gastrostomy with caregivers.

INTRODUCTION

Percutaneous endoscopically placed gastrostomy (PEG) has become an established modality for enteral access in both adult and more recently pediatric patients with low perioperative complication rates, favorable cost, and overall good outcomes in select populations. More recently alternative techniques ranging from fluoroscopically guided or laparoscopic gastrostomy are providing comparable or arguably superior outcomes, albeit still poorly defined in the pediatric population. The percutaneous endoscopic approach has been reported to be associated with good patient satisfaction and long-term outcomes; one study reports 94%–98% of parents viewing the procedure positively.[1] Improved nutritional status following PEG has been proven in children with

chronic comorbidities including cystic fibrosis[2] and Crohn's disease[3].

Evidence comparing gastrostomy techniques in the pediatric population has been largely limited to single-center retrospective studies[4] including studies using historical comparators.[5] Single-center studies suggest PEG placement entails higher complication rates than laparoscopic placement especially in younger patients,[6 7] but that it is superior to surgical techniques in infants with congenital heart disease by virtue of less anesthesia requirement.[8]

An initial study by Goldin and colleagues represents the largest analysis to date, of the risk factors related to emergency room presentation and subsequent hospitalization within a month of gastrostomy (surgically, interventional radiology placed or PEG) in children. Gastrostomy-related events resulting in admission were reported in 4% of patients, mainly relating to infection. Complications were more likely in patients with multiple chronic comorbidities.[9] On further analysis of this cohort, Akay and colleagues showed that across all modalities, readmission rate was inversely proportionate to the hospital-specific gastrostomy tube (GT) placement rate per 1000 discharges.[10]

A subsequent study analyzed a national sample of inpatient admissions including gastrostomy placement, surgical compared with PEG in infants and neonates and did not show significant differences in adverse outcomes between the 2 groups in this cohort.[11]

Herein, based on a nationwide, tertiary referral center-based multicenter database analysis, we present the most robust comparison to date, between percutaneous endoscopic gastrostomy and surgical or interventional radiology alternative modalities in the pediatric population.

METHODS

This retrospective data analysis study used data from the Pediatric Hospital Inpatient Sample (PHIS) database; an administrative database that includes inpatient, emergency department, ambulatory surgery, and observation encounter-level data from 49 not-for-profit, tertiary care pediatric hospitals in the USA.[1] All pediatric patients (aged 0–17) who received gastrostomy placement in the first or second day of inpatient stay during the study period (2010–2015) were included for analysis (figure 1). International Classification of Diseases, Ninth Revision (ICD-9) Procedure Coding System was used to define gastrostomies as either PEG (43.11) or non-PEG (43.0 or 43.19). Non-PEG gastrostomies included those using an open, fluoroscopy-guided, or laparoscopic approach. Specific gastrostomy placement techniques were categorized as PEG and non-PEG. Data were collected on patient characteristics (age, sex, race, insurance status); inpatient interventions (total parenteral nutrition 'TPN', extracorporeal membrane oxygenation 'ECMO', mechanical ventilation); and patient comorbidities.

Four outcomes of interest, including mortality, 30-day readmission, length of stay (LOS) and total cost of admission, were analyzed. Both mortality and readmission were defined as all-cause outcomes, and LOS covered the entire admission, including time spent in intensive care unit. Statistical analysis was performed with SPSS statistical software (Version 24.0). Univariate analysis was used to characterize differences among gastrostomy techniques using χ^2 test for categorical variables and Student's t-test for interval variables, with significance set at $p<0.05$. The effect of gastrostomy on all-cause mortality and 30-day readmission were determined using a forward, stepwise, binary logistic regression, retaining variables with $p<0.05$. Generalized linear models using simple main effects analysis with maximum likelihood estimate were used to estimate the effect of gastrostomy type on LOS and total cost.

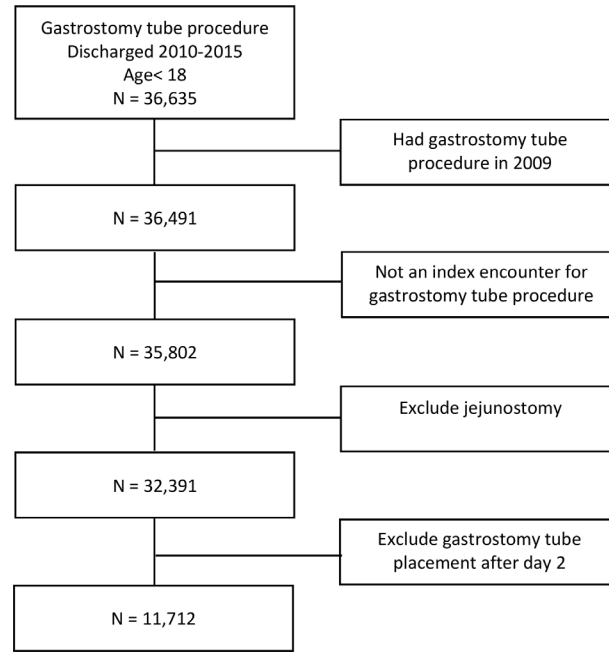

Figure 1 Consolidated Standards of Reporting Trials (CONSORT) diagram—study cohort selection.

RESULTS

Of the 11,712 pediatric gastrostomy patients during the study period, 3160 (27%) underwent PEG placement. A total of 248 (2%) patients underwent open gastrostomy, while 8304 (71%) patients underwent other non-PEG types of gastrostomy. Univariate statistics are reported in table 1.

Patients receiving PEG tended to be older (age group 10–17; 16.7% vs 13.8%, $p<0.001$), compared with non-PEG patients. The relative frequency of PEG decreased during the study period (21.4% in 2010 vs 11.5% in 2015). Further, patients receiving PEG were more likely to have neuromuscular (34.6% vs 31.8%, $p=0.004$) and malignancy (6.4% vs 4.4%, $p<0.001$), but were less likely to have cardiovascular (11.8% vs 16.0%, $p<0.001$) and renal (5.3% vs 8.3%, $p<0.001$) comorbidities.

PEG patients were no more likely than non-PEG patients to have hematologic ($p=0.903$), metabolic ($p=0.679$), or transplant-related ($p=0.406$) comorbidities. However, there was no significant difference in the average aggregate number of comorbidities (PEG 2.04 ± 0.86 vs non-PEG 2.13 ± 1.02; $p=0.513$). Patients who underwent PEG were less likely to require mechanical ventilation (6.7% vs 16.8%, $p<0.001$) and TPN (3.5% vs 14.0%). Multivariate predictors of mortality are reported in table 2. A total of 100 patients (0.85%) died during hospitalization, 7 (0.2%)

Table 1 Univariate analysis—non-PEG compared with PEG

	Non-PEG		PEG		
Variable	**n**	**%**	**n**	**%**	**p value**
Total	8552	73.00	3160	27.00	
Demographics					
Age					<0.001
0	3078	36.0	806	25.5	
1–3	2876	33.6	1174	37.2	
4–9	1415	16.5	651	20.6	
10–17	1183	13.8	529	16.7	
Gender					<0.001
Male	4535	53.0	1709	54.1	
Female	4017	47.0	1451	45.9	
Race					<0.001
White	4820	56.4	1836	58.1	
Black	1194	14.0	372	11.8	
Hispanic	1480	17.3	532	16.8	
Other	1058	12.4	420	13.3	
Insurance					<0.001
Government	4744	55.5	1754	55.5	
Private	3498	40.9	1350	42.7	
Other	310	3.6	56	1.8	
Comorbidities					
Neuromuscular disease	2719	31.8	1093	34.6	0.004
Cardiovascular disease	1366	16.0	374	11.8	<0.001
Respiratory disease	1019	11.9	331	10.5	0.03
Renal disease	709	8.3	166	5.3	<0.001
Hematologic/immune	283	3.3	106	3.4	0.903
Metabolic disorders	661	7.7	237	7.5	0.679
Congenital/genetic disorders	2153	25.2	617	19.5	<0.001
Malignancy	375	4.4	201	6.4	<0.001
Neonatal	627	7.3	147	4.7	<0.001
Transplant	172	2.0	56	1.8	0.406
Outcomes					
Mechanical ventilation	1440	16.8	211	6.7	<0.001
ECMO flag	18	0.2	2	0.1	0.087
TPN flag	1195	14.0	111	3.5	<0.001
Mortality	93	1.1	7	0.2	<0.001
Readmit 30 days	2682	31.4	778	24.6	<0.001
LOS (mean±SD)	11.4 (±31.2)	8552	4.42 (±10.3)	3160	<0.001

ECMO, extracorporeal membrane oxygenation; LOS, length of stay; PEG, percutaneous endoscopically placed gastrostomy; TPN, total parenteral nutrition.

underwent PEG, although in multivariable analysis, gastrostomy type was not a significant predictor of mortality (OR 1.78, 95% CI 0.77 to 4.08; p=0.177). Significant predictors of mortality included racial demographic: Black (OR 0.45, 95% CI 0.25 to 0.78; p=0.005), Hispanic (OR 0.38, 95% CI 0.18 to 0.78; p=0.008) and mechanical ventilation during hospitalization (OR 47.08, 95% CI 17.7 to 125.1; p<0.001). Additionally, mortality was more likely with neuromuscular (OR 1.72, 95% CI 1.05 to 2.83; p=0.032), cardiovascular (OR 2.44, 95% CI 1.53 to 3.90; p<0.001), genetic (OR 1.98, 95% CI 1.25 to 3.13; p=0.003), and malignancy-related (OR 2.99, 95% CI 1.01 to 8.86; p=0.047) comorbidities.

A total of 3460 patients (29.5%) were readmitted within 30 days, of which 778 (24.6%) underwent PEG. In multivariable analysis (table 3), PEG gastrostomy was associated with a higher risk of readmission (OR 1.31, 95% CI 1.17 to 1.47; p<0.001). Variations in patient sex, race, and insurance status were not predictive of readmission. Additionally, whereas mechanical ventilation was not predictive of readmission (OR 0.90, 95% CI 0.77 to 1.07; p=0.228), use of total parental nutrition during admission was (OR 1.39, 95% CI 1.18 to 1.65, p<0.001). Of the clinical comorbidities, only cardiovascular (OR 1.17, 95% CI 1.02 to 1.34; p=0.022) and oncologic (OR 4.17, 95% CI 3.46 to 5.03; p<0.001) were predictive of 30-day readmission.

Median LOS was 3 days (IQR 2–5 days). Gastrostomy type did not significantly affect LOS (p=0.665). Black race (p<0.001), mechanical ventilation (p<0.001), TPN (p<0.001), and renal comorbidity (p=0.001) were associated with increased LOS, while private insurance

Table 2 Multivariate predictors of mortality in pediatric gastrostomy patients

Variable	OR	95% CI	p value
Age			
0	Reference		
1–3	0.889	0.375 to 2.107	0.789
4–9	0.485	0.171 to 1.370	0.172
10–17	0.837	0.277 to 2.525	0.752
Sex			
Male	Reference		
Female	1.110	0.719 to 1.718	0.640
Race			
White	Reference		
Black	0.445	0.253 to 0.783	0.005
Hispanic	0.375	0.182 to 0.776	0.008
Other	0.701	0.344 to 1.428	0.328
Insurance			
Government			
Private	4.043	0.531 to 30.780	0.177
Other	4.725	0.615 to 36.320	0.136
Procedure year			
2010	Reference		
2011	2.160	0.898 to 5.193	0.085
2012	3.015	1.310 to 6.938	0.009
2013	2.060	0.855 to 4.962	0.107
2014	1.109	0.444 to 2.771	0.825
2015	2.157	0.981 to 4.745	0.056
Complications			
Mechanical ventilation	47.083	17.723 to 125.083	<0.001
ECMO	8.556	2.810 to 26.047	<0.001
TPN	1.455	0.851 to 2.489	0.171
Comorbidities			
Neuromuscular	1.720	1.046 to 2.829	0.032
Cardiovascular	2.444	1.534 to 3.895	<0.001
Respiratory	1.095	0.674 to 1.780	0.714
Renal	1.162	0.661 to 2.042	0.602
Hematologic/immune	1.261	0.511 to 3.110	0.615
Metabolic	0.621	0.269 to 1.431	0.263
Congenital/genetic	1.981	1.253 to 3.131	0.003
Malignancy	2.997	1.014 to 8.857	0.047
Neonatal	3.713	2.275 to 6.060	<0.001
Transplant	1.264	0.231 to 6.901	0.787
Gastrostomy type			
Non-PEG	Reference		
PEG	1.774	0.771 to 4.081	0.177

ECMO, extracorporeal membrane oxygenation; PEG, percutaneous endoscopically placed gastrostomy; TPN, total parenteral nutrition.

Table 3 Multivariate predictors of 30-day readmission in pediatric gastrostomy patients

Variable	OR	95% CI	p value
Age			
0	Reference		
1–3	1.233	1.047 to 1.452	0.012
4–9	1.281	1.099 to 1.494	0.002
10–17	0.962	0.808 to 1.145	0.664
Sex			
Male	Reference		
Female	1.012	0.984 to 1.402	0.801
Race			
White	Reference		
Black	1.093	0.941 to 1.271	0.245
Hispanic	1.126	0.934 to 1.358	0.212
Other	1.175	0.984 to 1.402	0.075
Insurance			
Government			
Private	0.922	0.707 to 1.202	0.550
Other	0.744	0.569 to 0.973	0.031
Procedure year			
2010	Reference		
2011	0.818	0.691 to 0.967	0.19
2012	0.882	0.744 to 1.047	0.151
2013	0.942	0.798 to 1.113	0.482
2014	0.836	0.710 to 0.985	0.032
2015	0.904	0.771 to 1.061	0.216
Complications			
Mechanical ventilation	0.903	0.765 to 1.066	0.228
ECMO	0.732	0.240 to 2.229	0.583
TPN	1.392	1.175 to 1.649	<0.001
Comorbidities			
Neuromuscular	1.057	0.951 to 1.176	0.305
Cardiovascular	1.172	1.023 to 1.342	0.022
Respiratory	1.008	0.866 to 1.173	0.920
Renal	1.174	0.991 to 1.391	0.063
Hematologic/immune	1.068	0.828 to 1.377	0.613
Metabolic	1.113	0.936 to 1.322	0.226
Congenital/genetic	0.975	0.870 to 1.093	0.663
Malignancy	4.168	3.457 to 5.025	<0.001
Neonatal	0.797	0.651 to 0.977	0.029
Transplant	0.746	0.531 to 1.047	0.091
Gastrostomy type			
Non-PEG	Reference		
PEG	1.392	1.175 to 1.649	<0.001

ECMO, extracorporeal membrane oxygenation; PEG, percutaneous endoscopically placed gastrostomy; TPN, total parenteral nutrition.

status (p<0.001), cardiovascular (p=0.006), respiratory (p<0.001) and hematologic (p=0.006) comorbidities were associated with reduced LOS. Median cost of admission was $10,434 (IQR $6949–$18,303). Gastrostomy type did not significantly affect total cost (p=0.186). All comorbidities except hematologic (p=0.445) were associated with increased cost. Complicated cases, including those involving mechanical ventilation, TPN, mortality, and readmission, all led to increased cost (all p<0.001).

DISCUSSION

Since its introduction in the early 1980s,[2] PEG has become the standard for artificial long-term enteral nutrition replacing the then-prevalent Stamm gastrostomy. Subsequently, competing modalities including laparoscopic gastrostomy, laparoscopic-assisted PEG, and interventional radiology-placed gastrostomies have emerged. Limited anesthetic exposure, reduced placement time, cost savings, and fewer in-hospital complications have become the driving considerations in choice of gastrostomy placement.[3 4]

In the pediatric population, several studies have compared PEG with other gastrostomy placement methods, mostly in the form of major (bowel perforation, wound dehiscence, GT dislodgement) and minor (surgical site infection, GT leak) complications.[5] Published studies corroborate that PEG has a higher rate of major complications compared with laparoscopic gastrostomy, but no significant difference in major complications compared with open or percutaneous fluoroscopically guided gastrostomy placement.[8] There appear to be no differences in minor complications, readmission, or time to refeeding between PEG and all other techniques.[9] Factors continuing to favor PEG in the pediatric population include markedly reduced operating time and procedure cost.[10] Nevertheless, definitive conclusions regarding superiority of one modality are difficult to support given the lack of randomized controlled trials and prospective studies as well as the limited sample sizes of the existing single-center retrospective studies.[11] Differences in outcomes between PEG and non-PEG modalities need to be understood in the broader context of pediatric care, including centers with relatively lower case volume and patient complexity. A clearer understanding of relative superiority would have substantial impact on current pediatric gastroenterology training and practice.[12] Our study is the first to focus on the difference in outcome between PEG and non-PEG gastrostomy modalities using a well-established, extensively adopted coding database that reflects the experience of the major pediatric tertiary centers in the USA. Our analysis obviates institutional bias toward particular modalities that may have influenced prior studies.

Our study found no significant association between mortality and gastrostomy type. Early outcome studies in the adult population similarly found no differences in mortality between PEG and open gastrostomy only.[3 4] Gastrostomy is generally indicated in conditions with high morbidity, including neurological disease, reduced level of consciousness and cancer among others.[13] Mortality during hospitalization is most likely related to these underlying disease processes for which the need of gastrostomy placement is an indicator of condition severity. Mechanical ventilation during hospitalization was found to be a significant predictor of mortality, an expected finding given its indication in patients with overall worsening respiratory status. Prior literature supports our finding that patients with neuromuscular and oncologic-related comorbidities are more likely to undergo PEG compared with laparoscopy.[7] The preference for laparoscopic gastrostomy in patients with cardiac, respiratory and renal comorbidities may reflect practitioner preference to defer to the surgical referral, potentially complicated cases, even when factoring the longer time under anesthesia.

Our study found that PEG gastrostomy predicted a lower rate of 30-day readmission compared with other types of gastrostomy. This finding has not been uniformly observed in prior adult or pediatric literature. Another study of hospital practice patterns surrounding gastrostomy using the PHIS database found significant variation in readmission rates following gastrostomy, although it primarily focused on differences between hospitals, rather than placement type. This reflects that complication rates, enteral feeding practices, and preoperative care which are determinants of outcome and cost may in part be due to institutional characteristics rather than consequences of gastrostomy placement modality. Several studies have identified the potential for significant reductions in postgastrostomy readmission, regardless of placement type, through the use of postoperative interventions such as patient education, home care, and creation of a dedicated hospital dietary service.[14 15] These reductions in readmission, which can be as much as 10-fold, are heavily dependent on institutional and departmental practices. Given that different gastrostomy placements are performed by different divisions (PEG by gastroenterology, laparoscopic and open by surgery, fluoroscopy guided by interventional radiology) and that the predominant choice of gastrostomy placement in the pediatric population, given the lack of clear guidelines, is often dictated by operator preference, significant interinstitutional variation in readmission might be expected.[15]

We found no significant effect of gastrostomy placement technique on LOS or cost, which correlates with findings in the adult population.[9] Non-PEG procedures were however more likely followed by mechanical ventilation or TPN use suggesting a postoperative complication. However, analogous to postoperative mortality,[16] patients undergoing gastrostomy tend to represent a much sicker cohort of the overall hospitalized population, and their duration of stay and total cost are more likely to be dictated by underlying disease and secondary procedures performed during the hospitalization.[17] Although PEG has long been considered the cheapest of the gastrostomy techniques due to its shorter operating time and non-surgical approach, this difference is lost when considering total cost of hospital stay.

This study relies on data from a large, multicenter database, which is associated with several limitations.[18] Our study population reflects patients cared for in tertiary pediatric referral centers and an urban practice setting; consequently our observations may not be generalizable to the entire pediatric population. Identification of gastrostomy type and comorbidities come from coding and billing data, which are not primarily collected for research purposes, and are thus subject to coding and reporting error and bias. The ICD-9 procedure codes for gastrostomy are not sufficiently granular in separating beyond PEG and other types of gastrostomy. Preliminary analysis exploring the use of Current Procedural Terminology (CPT) codes to better classify gastrostomy types led to many missing values. However, methodology from several pediatric gastrostomy papers suggests that PEG and laparoscopic gastrostomy are the most commonly used methods, with open, fluoroscopy guided, and other techniques reserved for specific institutions or patient cohorts.[11 19] Other limitations of this study include analyzing only all-cause, rather than gastrostomy-specific, outcomes; the inability to account for institutional differences in procedures and outcomes; and secondary events that occurred during the same hospitalization as the gastrostomy. The observed differences in mortality based on race (Black/Hispanic compared with White) require further study including factoring a more granular clinical profile and socioeconomic categorization that are not accessible through our study design. Our methodology also constrained us to comparing the outcomes of PEG with both open and laparoscopically placed gastrostomy which

introduces the potential for bias with case selection in that population.

CONCLUSION

This is the first large-scale database study focused on outcomes between endoscopic and non-endoscopic gastrostomy placement techniques in the pediatric population. Choice of gastrostomy is not significantly associated with mortality, LOS, or total cost of care, while PEG is associated with a slightly lower rate of 30-day readmission compared with other gastrostomy types. These outcomes are largely influenced by severity of underlying disease processes and other patient comorbidities. Further randomized, prospective studies are needed to definitively identify a gold standard gastrostomy technique in the pediatric population.

Contributors ASK, TMA: inception, coordination-query PHIS, results review, manuscript writing. MBY, KR: statistical analysis. MH: PHIS query design, results interpretation.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient consent for publication Not required.

Provenance and peer review Not commissioned; internally peer reviewed.

Data availability statement Data are available upon reasonable request. All data relevant to the study are included in the article or uploaded as supplementary information.

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