Safety of endoscopic gastrostomy tube placement compared with radiologic or surgical gastrostomy: nationwide inpatient assessment

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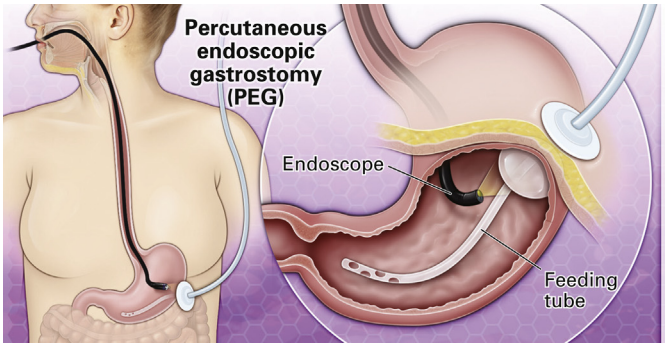
GRAPHICAL ABSTRACT



Adverse event	Surgical gastrostomy vs endoscopic PEG	IR gastrostomy vs endoscopic PEG	Surgical gastrostomy vs IR gastrostomy
Procedural			
Perforation of colon	6.65 (4.38 - 10.12; <.001)	1.90 (1.26 - 2.86; 0.002)	3.50 (2.81 - 4.37; <.001)
Hemorrhage requiring blood transfusion	1.09 (.64 - 1.86; 0.746)	1.84 (1.26 - 2.68; 0.002)	0.60 (0.40 - 0.89; 0.011)
Infection of gastrostomy	1.61 (1.29 - 2.01; <.001)	1.28 (1.07 - 1.53; .006)	1.25 (1.07 - 1.47; .005)
Disposition			
Discharge other than home	0.93 (0.88 - 0.99; 0.0272)	1.58 (1.51 - 1.65; <.0001)	0.59 (0.56 - 0.62; <.0001)
Nonelective 30-day readmission	1.13 (1.06 - 1.2; 0.0002)	1.07 (1.03 - 1.12; 0.0023)	1.05 (1 - 1.1; 0.04)
Death	1.55 (1.42 - 1.69; <.0001)	1.09 (1.02 - 1.17; 0.0114)	1.42 (1.33 - 1.5; <.0001)

Background and Aims: A gastrostomy tube is often required for inpatients requiring long-term nutritional access. We compared the safety and outcomes of 3 techniques for performing a gastrostomy: percutaneous endoscopic gastrostomy (PEG), fluoroscopy-guided gastrostomy by an interventional radiologist (IR-gastrostomy), and open gastrostomy performed by a surgeon (surgical gastrostomy).

Methods: Using the Nationwide Readmissions Database, we identified hospitalized patients who underwent a gastrostomy from 2016 to 2017. They were identified using the International Classification of Diseases, 10th Revision, Procedure Coding System. The selected patients were divided into 3 cohorts: PEG (0DH64UZ), IR-gastrostomy (0DH63UZ), and open surgical gastrostomy (0DH60UZ). Adjusted odds ratios for adverse events associated with each technique were calculated using multivariable logistic regression analysis.

Results: Of the 184,068 patients meeting the selection criteria, the route of gastrostomy tube placement was as follows: PEG, 16,384 (53.7 ± 29.0 years); IR-gastrostomy, 154,007 (67.2 ± 17.5 years); and surgical gastrostomy, 13,677 (57.9 ± 24.3 years). Compared with PEG, the odds for colon perforation using IR-gastrostomy and surgical gastrostomy, respectively, were 1.90 (95% confidence interval [CI], 1.26-2.86; $P = .002$) and 6.65 (95% CI, 4.38-10.12; $P < .001$), for infection of the gastrostomy 1.28 (95% CI, 1.07-1.53; $P = .006$) and 1.61 (95% CI, 1.29-2.01; $P < .001$), for hemorrhage requiring blood transfusion 1.84 (95% CI, 1.26-2.68; $P = .002$) and 1.09 (95% CI, .64-1.86; $P = .746$), for nonelective 30-day readmission 1.07 (95% CI, 1.03-1.12; $P = .0023$) and 1.13 (95% CI, 1.06-1.2; $P = .0002$), and for inpatient mortality 1.09 (95% CI, 1.02-1.17; $P = .0114$) and 1.55 (95% CI, 1.42-1.69; $P < .0001$).

Conclusions: Placement of a gastrostomy tube (PEG) endoscopically is associated with a significantly lower risk of inpatient adverse events, mortality, and readmission rates compared with IR-gastrostomy and open surgical gastrostomy. (Gastrointest Endosc 2021;93:1077-85.)

(footnotes appear on last page of article)

Gastrostomy tube placement is a common procedure for long-term enteral access in patients who are unable to maintain adequate volitional intake of food.[1] A gastrostomy procedure can be performed by 1 of 3 principal techniques: percutaneous endoscopic gastrostomy (PEG), typically performed by a gastroenterologist; fluoroscopy-guided gastrostomy performed by an interventional radiologist (IR-gastrostomy); and open or laparoscopic gastrostomy performed by a surgeon (surgical gastrostomy).[2] Some centers consider PEG to be the initial intervention of choice, but IR-gastrostomy and surgical gastrostomy are also commonly performed, especially in patients who are unable to undergo PEG.[3-6]

Gastrostomy creation is a high-risk procedure associated with risk of bleeding, aspiration, infection, perforation, and, rarely, death.[7,8] Furthermore, the procedure is often indicated and performed in older inpatients with multiple comorbidities who are vulnerable to adverse events.[9] Published studies have reported varying comparative rates of adverse events associated with various gastrostomy techniques. Some studies have demonstrated fewer major adverse events with IR-gastrostomy compared with PEG,[10] whereas others have suggested that PEG is safer than IR-gastrostomy in select patients.[11] Still other studies have demonstrated no difference between the different techniques.[12-14] The available literature is often limited to single-center, retrospective studies with relatively small sample sizes and varying indications for the gastrostomy.[2,5,15] Hence, the optimal technique for gastrostomy remains to be defined, and the selection is often per the discretion of physicians

Knowledge of associated adverse events and mortality for each technique is necessary to improve patient care. In this study, we analyzed the outcomes and adverse events associated with endoscopic, radiologic, and open surgical gastrostomy procedures using a large, nationwide readmission database.

METHODS

Study design

This is a retrospective analysis of hospitalized patients who underwent a gastrostomy. Patients were identified using the International Classification of Diseases, 10th Revision, Procedure Coding System (ICD-10-PCS) with a nationally representative database of hospitalized patients.

Description of the database

The Nationwide Readmissions Database was developed through a federal, state, and industry partnership sponsored by the Agency for Healthcare Research and Quality for the Healthcare Cost and Utilization Project.[16] It is a large, publicly available, all-payer inpatient healthcare database designed to produce U.S. regional and national estimates of inpatient utilization, readmissions, charges, quality, and outcomes. It is a unique and powerful database designed to support various types of analyses of national readmission rates for all patients, regardless of the expected payer for the hospital stay.[17] Beginning with data year 2016, the Nationwide Readmissions Database has been using the ICD-10-PCS and ICD-10-Clinical Modification (ICD-10-CM) coding systems and can be purchased online by a central distributor.[16]

Selection of the cohort

Inpatients who underwent a gastrostomy in 2016 and 2017 were selected using the ICD-10-PCS procedure codes for an endoscopic PEG (0DH64UZ: "Insertion of Feeding Device into Stomach, Percutaneous Endoscopic Approach"), IR-gastrostomy (0DH63UZ: "Insertion of Feeding Device into Stomach, Percutaneous Approach"), and open surgical gastrostomy (0DH60UZ: "Insertion of Feeding Device into Stomach, Open Approach"). The ICD ninth revision procedure codes were not used because both percutaneous and open approaches to gastrostomy are coded using the 43.19 code for "other gastrostomy." This precludes the differentiation of the type of gastrostomy performed. The ICD-10 codes 0DH68UZ and 0DH67UZ were excluded from the analysis because they refer to "placement of a feeding device into the stomach through a (pre-existing) natural or artificial opening" and convert to different ICD ninth revision codes that are inconsistent with creation of a gastrostomy. Bypass procedures were also excluded. Patients thus selected were divided into 3 cohorts based on the type of gastrostomy technique: PEG, IR-gastrostomy, and surgical gastrostomy.

Defining comorbidities

The Agency for Healthcare Research and Quality comorbidity measures were used to identify 29 coexisting medical conditions that were not directly related to the principal diagnosis or the main reason for admission and that originated before the index hospital stay. Comorbidities were identified using ICD-10-CM codes and the diagnosis-related group in effect on the discharge date.[18]

Indications for gastrostomy

The indications for gastrostomy were identified using the ICD-10-CM codes for common conditions that cause or may lead to dysphagia. The indications were subdivided into malignant and nonmalignant based on the presence or absence of upper GI or head and neck malignancies.

Defining adverse events

Readmission was defined as a nonelective admission within 30 days of discharge after index hospitalization and gastrostomy. Adverse events were identified using the ICD-10-CM codes for hemorrhage requiring blood transfusion, infection of gastrostomy, adverse event of gastrostomy (not specified), malfunction/mechanical adverse

TABLE 1. Details of patient- and hospital-related parameters

	Endoscopic PEG	Interventional radiologist gastrostomy	Open surgical gastrostomy	Total	*P* value
Total patients	16,384	154,007	13,677	184,068	<.001
Calendar year 2016	8488	75,065	6966	90,519	
Calendar year 2017	7896	78,942	6711	93,549	
Patient demographics					
Age at admission, y, mean ± standard deviation	53.7 ± 29.0	67.2 ± 17.5	57.9 ± 24.3	65.3 ± 19.8	<.001
Female	7529 (46)	67745 (44)	6328 (46)	81602 (44)	<.001
Location of hospital based on population					
Central counties of metropolitan areas ≥1 million	4834 (29.6)	51451 (33.5)	3636 (26.6)	59,921 (32.7)	<.001
Fringe counties of metropolitan areas ≥1 million	3888 (23.8)	38121 (24.8)	3200 (23.4)	45,209 (24.6)	
Counties in metropolitan areas of 250,000-999,999	3617 (22.1)	30,322 (19.8)	3210 (23.5)	37,149 (20.2)	
Counties in metropolitan areas of 50,000-249,999	1685 (10.3)	13,300 (8.7)	1404 (10.3)	16,389 (8.9)	
Micropolitan counties	1352 (8.3)	11,174 (7.3)	1237 (9.1)	13,763 (7.5)	
Not metropolitan or micropolitan counties	965 (5.9)	9153 (6.0)	963 (7.1)	11,081 (6.0)	
Missing	43	486	27	556	
Median household income national quartile for patient ZIP code					
1	4861 (30.1)	50,779 (33.5)	4241 (31.4)	59,881 (33.0)	<.001
2	4363 (27.0)	38,491 (25.4)	3739 (27.7)	46,593 (25.7)	
3	3984 (24.7)	34,316 (22.6)	3122 (23.1)	41,422 (22.8)	
4	2939 (18.2)	28,209 (18.6)	2385 (17.7)	33,533 (18.5)	
Missing	237	2212	190	2639	
Primary payer					
Medicare	8244 (50.4)	102,175 (66.4)	7335 (53.7)	117,754 (64.0)	<.001
Medicaid	3786 (23.1)	21,929 (14.3)	2615 (19.1)	28,330 (15.4)	
Private insurance	3681 (22.5)	23,137 (15.0)	3013 (22.1)	29,831 (16.2)	
Self-pay	190 (1.2)	2390 (1.6)	258 (1.9)	2838 (1.5)	
No charge	12 (.1)	241 (.2)	26 (.2)	279 (.2)	
Other	455 (2.8)	3983 (2.6)	414 (3.0)	4852 (2.6)	
Missing	16	152	16	184	
Hospital-related information					
Size of hospital based on number of beds					<.001
Small	1939 (11.8)	15,252 (9.9)	1540 (11.3)	18731 (10.2)	
Medium	3892 (23.8)	40,415 (26.2)	3229 (23.6)	47,536 (25.8)	
Large	10,553 (64.4)	98,340 (63.9)	8908 (65.1)	117,801 (64.0)	
Ownership of hospital					
Government	1843 (11.2)	20,629 (13.4)	1819 (13.3)	24,291 (13.2)	<.001
Private, not for profit	13,365 (81.6)	107,155 (69.6)	9909 (72.5)	130,429 (70.9)	
Private	1176 (7.2)	26,223 (17.0)	1949 (14.3)	29,348 (15.9)	
Teaching status of urban hospitals					
Metropolitan nonteaching	3227 (19.7%)	35,120 (22.8)	2794 (20.4)	41,141 (22.4)	<.001
Metropolitan teaching	12,659 (77.3)	112,622 (73.1)	10,276 (75.1)	135,557 (73.6)	
Nonmetropolitan	498 (3.0)	6265 (4.1)	607 (4.4)	7370 (4.0)	

Values are n (%) unless otherwise defined.

event of gastrostomy tube, other adverse events, nonoperative replacement of gastrostomy tube, perforation of colon, and others. Adverse events were subdivided into major or minor based on previously defined criteria.[6,19]

Statistics

Continuous variables were compared using 1-way analysis of variance and reported as mean ± standard deviation, whereas categorical variables were compared using the χ^2 or Fisher exact test and reported as counts and percentages. To determine predictors of adverse outcomes we developed a multivariable logistic regression model. The primary variable was procedure type, and we then adjusted for potential confounding variables, including age, gender, 29 comorbidity measures, hospital ownership, and hospital teaching status. For our 30-day readmission measure we excluded from the denominator those who died and had a December admission because the Nationwide Readmissions Database does not track readmission between calendar years.

Adjusted odds ratios were calculated for adverse events based on the type of gastrostomy and are reported as 95% confidence intervals (CI) with *P* value. Statistical analyses were performed using SAS, version 9.4 (SAS Institute Inc, Cary, NC, USA). All *P* values were 2-sided with a significance threshold of <.05.

RESULTS

A total of 184,068 patients (aged 65.3 ± 19.8 years; 44.3% women) met the selection criteria and included 16,384 patients who underwent a PEG (aged 53.7 ± 29.0 years, 46% women), 154,007 patients who underwent an IR-gastrostomy (aged 67.2 ± 17.5 years, 44% women), and 13,677 patients who underwent a surgical gastrostomy (aged 57.9 ± 24.3 years, 46.3% women). Demographics are shown in Table 1 and comorbidities in Supplementary Table 1 (available online at www.giejournal.org).

Description of hospital practices

Hospitals were often private not-for-profit organizations, with a large bed capacity, and located typically in the central counties of metropolitan areas with a population exceeding 1 million people. They were likely to be metropolitan teaching hospitals, and the most common payer for the inpatients was Medicare (Table 1).

Indication for gastrostomy

A total of 13,189 patients with malignancies of the head and neck or upper GI tract underwent a gastrostomy: 1199 patients (7.32%) who underwent an endoscopic PEG, 10,399 patients (6.75%) who underwent IR-gastrostomy, and 1591 patients (11.63%) who underwent surgical gastrostomy (Table 2). The most common nonmalignant indications for a gastrostomy were aspiration pneumonia (25%) and sepsis (16%).

Adverse events

Overall, 10,019 adverse events (5.4%) were recorded in 184,068 patients who underwent a gastrostomy: 957 (5.84%) in PEG, 7722 (5.01%) in IR-gastrostomy, and 1340 (9.8%) in surgical gastrostomy groups (Table 3). The most common adverse event was malfunction of the gastrostomy tube (52%) followed by infection of the gastrostomy site (19%).

Compared with PEG, the odds of perforation of the colon were 1.90 (95% CI, 1.26-2.86; $P = .002$) with IR-gastrostomy and 6.65 (95% CI, 4.38-10.12; $P < .001$) with surgical gastrostomy. Similarly, compared with PEG, the odds of infection of the gastrostomy were 1.28 (95% CI, 1.07-1.53; $P = .006$) for IR-gastrostomy and 1.61 (95% CI, 1.29-2.01; $P < .001$) for surgical gastrostomy. The odds of bleeding requiring blood transfusion were 1.84 (95% CI, 1.26-2.68; $P = .002$) for IR-gastrostomy versus PEG and 1.09 (95% CI, .64-1.86; $P = .746$) for surgical gastrostomy versus PEG.

Disposition

Among survivors we modeled nonhome discharge (skilled nursing facility/home health care) versus those with routine disposition (home or self-care). Overall, the most common disposition was to a nursing home (Table 4). The odds of being discharged to a skilled nursing home or needing home health care were .93 (95% CI, .88-.99; $P = .03$) for surgical gastrostomy versus endoscopic PEG, 1.58 (95% CI, 1.51-1.65; $P < .001$) for IR-gastrostomy versus endoscopic PEG, and .59 (95% CI, .56-.62; $P < .001$) for surgical gastrostomy versus IR-gastrostomy (Table 5).

Readmission

The overall 30-day nonelective readmission rate for all inpatients undergoing a gastrostomy was 22.6%. The 30-day readmission risk was calculated after adjusting for confounders. The adjusted odds for nonelective 30-day readmission were 1.13 (95% CI, 1.06-1.2; $P = .0002$) for surgical gastrostomy versus endoscopic PEG, 1.07 (95% CI, 1.03-1.12; $P = .0023$) for IR-gastrostomy versus endoscopic PEG, and 1.05 (95% CI, 1.002-1.1, $P = .044$) for surgical gastrostomy versus IR-gastrostomy (Table 5).

Death

When a multivariate logistic regression model predicting death was used, the odds of inpatient mortality were 1.55 (95% CI, 1.42-1.69; $P < .001$) for surgical gastrostomy versus endoscopic PEG, 1.42 (95% CI, 1.33-1.5; $P < .001$) for surgical gastrostomy versus IR-gastrostomy, and 1.09

TABLE 2. Indications for gastrostomy*

	Endoscopic PEG	Interventional radiologist gastrostomy	Open surgical gastrostomy	Total	*P* value
Dysphagia/aphagia	6465 (39.5)	74,960 (48.7)	3100 (22.8)	84,525 (45.8)	<.001
Nonmalignant					
Dysphagia because of stroke	486 (3.0)	6285 (4.1)	152 (1.1)	6923 (3.8)	<.001
Alzheimer disease	411 (2.5)	6151 (4.0)	173 (1.3)	6735 (3.7)	<.001
Aspiration pneumonia	3328 (20.3)	41,171 (26.7)	1923 (14.1)	46,422 (25.2)	<.001
Sepsis	2034 (12.4)	25,249 (16.4)	2558 (18.7)	29,841 (16.2)	<.001
Failure to thrive in adult	1256 (7.7)	14,840 (9.6)	731 (5.3)	16,827 (9.1)	<.001
Feeding difficulty	1265 (7.7)	2558 (1.7)	453 (3.3)	4276 (2.3)	<.001
Cachexia	708 (4.3)	8437 (5.5)	667 (4.9)	9812 (5.3)	<.001
Malignant					
Malignant neoplasm of base of tongue	130 (.8)	1212 (.8)	87 (.6)	1429 (.8)	.151
Malignant neoplasm of other parts of tongue	113 (.7)	1232 (.8)	87 (.6)	1432 (.8)	.045
Malignant neoplasm of larynx, supraglottis, glottis, subglottis	276 (1.7)	2564 (1.7)	287 (2.1)	3127 (1.7)	<.001
Malignant neoplasm of floor of mouth	44 (.3)	373 (.2)	24 (.2)	441 (.2)	.226
Malignant neoplasm of palate	15 (.1)	178 (.1)	16 (.1)	209 (.1)	.680
Malignant neoplasm of mouth not otherwise specified	58 (.4)	432 (.3)	33 (.2)	523 (.3)	.150
Malignant neoplasm of oropharynx	71 (.4)	757 (.5)	88 (.6)	916 (.5)	.025
Malignant neoplasm of hypopharynx	63 (.4)	419 (.3)	79 (.6)	561 (.3)	<.001
Malignant neoplasm of esophagus	322 (2.0)	2300 (1.5)	615 (4.5)	3237 (1.8)	<.001
Malignant neoplasm of stomach	107 (.7)	932 (.6)	275 (2.0)	1314 (.7)	<.001

Values are n (%).
*Some patients may have more than 1 indication for a gastrostomy tube placement.

(95% CI, 1.02-1.17; $P = .01$) for IR-gastrostomy versus endoscopic PEG (Table 5).

DISCUSSION

Gastrostomy creation is the most common intervention for long-term enteral access to facilitate a bolus feeding regimen.[9] A gastrostomy can also be used for multiple reasons other than nutrition, including retrograde intestinal access to the biliary system for facilitation of ERCP in surgically altered anatomy or other procedures.[9,20] Gastrostomy has evolved from an open surgical technique with high mortality to varying methodologies including endoscopic, fluoroscopic, and laparoscopic or open surgical methods.[21] Although many centers prefer PEG and IR-gastrostomy over surgical gastrostomy because of lower morbidity,[22,23] the optimal and safest technique for performing a gastrostomy remains unclear. Although each method can technically create a gastrostomy, the safety profile of each technique needs to be assessed.

This study assessed the safety and outcomes of endoscopic, IR-guided, and surgical gastrostomy using a large, nationwide database of hospitalized patients. We report that PEG is associated with significantly lower risks of adverse events like hemorrhage, peristomal infections, and colon perforation compared with IR-gastrostomy and surgical gastrostomy. Further, the rates of adverse outcomes such as inpatient mortality, readmission, nonhome discharge, and inpatient mortality are significantly lower with PEG.

Grant et al[6] categorized mortality, perforation, hemorrhage, and peristomal infection as major gastrostomy-related adverse events, whereas adverse events requiring minimal intervention, such as tube dislodgement, were classified as minor. In their prospective series of 172 patients, IR-gastrostomy was associated with a significantly higher incidence of major and minor adverse events. Similar results were reported from a single-center study that demonstrated lower rates of major and minor adverse events with PEG compared with IR-gastrostomy.[24] However, other investigators have reported better safety with IR-gastrostomy compared with PEG.[25] Compared with open surgical gastrostomy, PEG reduces operative time and expense and requires a shorter recovery time.[26] The above studies have significant limitations including small sample size, which precludes an adequately powered statistical analysis; risks of selection bias; restriction to specific indications; and often report data from single centers.[6,14,24,25,27] Our study, based on a large dataset, is able to overcome

TABLE 3. Adverse events of inpatient gastrostomy

	Endoscopic PEG	Interventional radiologist gastrostomy	Open surgical gastrostomy	Total	*P* value
Adverse event of gastrostomy					
Adverse event of gastrostomy (not specified)	2 (.0)	19 (.0)	7 (.1)	28 (.0)	.001
Hemorrhage requiring blood transfusion	29 (.2)	556 (.4)	26 (.2)	611 (.3)	<.001
Infection of gastrostomy	142 (.9)	1587 (1.0)	183 (1.3)	1912 (1.0)	<.001
Malfunction/mechanical adverse event of gastrostomy tube	459 (2.8)	4149 (2.7)	652 (4.8)	5260 (2.9)	<.001
Other adverse events	137 (.8)	863 (.6)	219 (1.6)	1219 (.7)	<.001
Other interventions					
Replacement of gastrostomy tube (nonoperative)	0 (.0)	0 (.0)	0 (.0)	0 (.0)	
Closure of gastrostomy	150 (.9)	198 (.1)	118 (.9)	466 (.3)	<.001
Perforation of colon	27 (.2)	298 (.2)	131 (1.0)	456 (.2)	<.001
Adjustment of appliance/device	11 (.1)	52 (.0)	4 (.0)	67 (.0)	.093

Values are n (%).

TABLE 4. Outcomes of inpatient gastrostomy

Outcome	Endoscopic PEG	Interventional radiologist gastrostomy	Open surgical gastrostomy	Total	*P* value
Length of stay, days, mean ± standard deviation	24.2 ± 31.9	22.7 ± 23.7	26.5 ± 34.5	23.1 ± 25.5	<.001
Disposition					
Home or self-care	4505 (27.5)	16,944 (11.0)	3393 (24.8)	24,842 (13.5)	<.001
Transfer to short-term hospital	359 (2.2)	3229 (2.1)	310 (2.3)	3898 (2.1)	
Transfer to other: SNF, ICF	7216 (44.1)	92,947 (60.4)	4803 (35.1)	104,966 (57.1)	
Home health care	3311 (20.2)	28,714 (18.7)	3742 (27.4)	35,767 (19.4)	
Died	988 (6.0)	12,045 (7.8)	1427 (10.4)	14,460 (7.9)	
Missing	5	128	2	135	
30-day nonelective readmission among eligible patients	2808 (19.9)	29,632 (22.9)	2469 (22.1)	34,909 (22.6)	<.001

Values are n (%) unless otherwise defined.
ICF, Intermediate care facility; *SNF*, skilled nursing facility.

these limitations and reports lower rates of adverse events with PEG compared with IR-gastrostomy and surgical gastrostomy.

A gastrostomy is considered a high-risk procedure for bleeding by the American Society for Gastrointestinal Endoscopy and the Society of Interventional Radiology.[28-30] Bleeding during gastrostomy is a well-characterized adverse event among all techniques.[31,32] This study demonstrates that the risk of significant hemorrhage is greater with IR-gastrostomy than PEG or surgical gastrostomy among hospitalized patients. This could possibly reflect the ability of endoscopists and surgeons to control local bleeding with easily available endoscopic or surgical tools. Indeed, among patients with hemorrhage after undergoing IR-gastrostomy, an upper endoscopy is often performed to localize and treat the bleeding site.[31]

The most common adverse event of PEG reported in the literature is wound or peristomal infection.[7] The American Society for Gastrointestinal Endoscopy recommends administration of antibiotics at the time of PEG to reduce the risk of peristomal infections. Data from randomized controlled trials involving IR-gastrostomy[33] and PEG[34] suggest that administration of antibiotics reduces the risk of peristomal infections. However, some studies suggest that performing a transabdominal gastrostomy without traversing the tube through the oropharynx (ie, IR-gastrostomy) has a lower risk of infections and obviates the need for antibiotics.[35] This study reported significantly lower odds of infection with PEG compared with surgical or IR-gastrostomy. Other investigators have also suggested a higher rate of adverse events, especially infectious adverse events, occurs more frequently in IR-gastrostomy compared

TABLE 5. Selected adjusted odds ratios (95% confidence interval; *P* value) for adverse events based on methods of placing a gastrostomy tube

Adverse event	Surgical gastrostomy vs endoscopic PEG	Interventional radiologist gastrostomy vs endoscopic PEG	Surgical gastrostomy vs interventional radiologist gastrostomy
Procedural			
Perforation of colon	6.65 (4.38-10.12; <.001)	1.90 (1.26-2.86; .002)	3.50 (2.81- 4.37; <.001)
Hemorrhage requiring blood transfusion	1.09 (.64-1.86; .746)	1.84 (1.26-2.68; .002)	.60 (.40-.89; .011)
Infection of gastrostomy	1.61 (1.29-2.01; <.001)	1.28 (1.07-1.53; .006)	1.25 (1.07-1.47; .005)
Disposition			
Discharge other than home	.93 (.88-.99; .0272)	1.58 (1.51-1.65; <.0001)	.59 (.56-.62; <.0001)
Nonelective 30-day readmission	1.13 (1.06-1.2; .0002)	1.07 (1.03-1.12; .0023)	1.05 (1-1.1; .04)
Death	1.55 (1.42-1.69; <.0001)	1.09 (1.02-1.17; .0114)	1.42 (1.33-1.5; <.0001)

with PEG.[27] This could reflect the lack of universal administration of antibiotics among patients undergoing IR-gastrostomy because of a perceived lower of risk of infections with a "push" gastrostomy that obviates oral passage of the gastrostomy tube.[11,33,36,37]

Perforation of the transverse colon during gastrostomy is a major adverse event that can result in peritonitis and often requires surgical intervention.[38] We report that although the incidence of colon perforation is low, the odds of colon perforation are significantly higher with IR-gastrostomy and surgical gastrostomy compared with PEG. Endoscopic techniques such as transillumination, finger indentation, and the "safe-tract" method can reduce the risk of colonic injury during PEG placement.[39] IR-gastrostomy uses imaging studies (US or CT) to assess for intervening viscera and often uses oral contrast administration to delineate the colon or outline gastric rugal folds during fluoroscopy.[37] However, other means of confirming the absence of intervening viscera may be needed to further improve the safety of the procedure. Because of a lack of operative details and patient-specific information in the database, we were unable to explain the incidence of colon perforation among patients undergoing open gastrostomy.

A salient outcome of the study is the lower adjusted odds of inpatient mortality with PEG compared with IR-gastrostomy and surgical gastrostomy. A pooled analysis of randomized and nonrandomized trials of PEG and IR-gastrostomy reported a significantly lower 30-day mortality rate with PEG compared with IR-gastrostomy.[40] Investigators have posited multiple explanations for the lower mortality associated with PEG, including the use of antibiotics and the preferential use of PEG in patients without malignancies.[40] Notably, this study also reported lowers odds of nonelective readmission and non-home discharge after PEG compared with IR-gastrostomy. We posit that this difference may reflect the lower incidence of infections, colon perforation, and bleeding in patients undergoing PEG.

We report that the most common adverse event of a gastrostomy, irrespective of technique, is malfunction or mechanical adverse event of the gastrostomy tube. This suggests that patients and caregivers should receive education and instructions regarding the management of gastrostomy tubes.[41] Use of multidisciplinary nutrition support teams may also result in reduced readmissions and improved clinical outcomes.[42]

The strengths of the study include a nationally representative large sample size, incorporation of hospitals of varying sizes and location, and inclusion of patients with diverse insurance coverage. Further, the large sample size facilitates control of multiple confounding variables including the presence of comorbidities and age, which can impact outcomes and adverse events. The study is limited by its retrospective design, constraints of possible coding errors in an administrative database, and lack of patient-specific data and other pertinent information such as medications, laboratory values, and follow-up beyond 30 days. The analysis did not include outpatient procedures because the database is restricted to inpatients. Further, despite our efforts to statistically adjust for covariates, other confounding variables may not have been accounted for. For example, the Nationwide Readmissions Database does not provide information about the clinical status of the patient at the time of procedure, periprocedure use of antibiotics, information about the gastrostomy tube, or details of the surgical interventions. This study found that among hospitalized patients, IR-gastrostomy is the most frequently performed technique. We speculate that this could reflect a selection bias because the study did not include outpatients.

In conclusion, this study demonstrates that endoscopic gastrostomy is associated with a lower risk of adverse events including infection, significant bleeding, perforation, need for readmission, and all-cause mortality compared with surgical or IR-gastrostomy. It may be prudent to consider PEG as a safe method for gastrostomy among inpatients who need long-term enteral access. Future prospective, multicenter, randomized trials are needed to explore causal relationships and investigate other associated factors to determine the optimal method of creation of a gastrostomy.

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Abbreviations: ICD-10-PCS, International Classification of Diseases, 10th Revision, Procedure Coding System; ICD-10-CM, International Classification of Diseases, Tenth Revision, Clinical Modification; IR, interventional radiologist.

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SUPPLEMENTARY TABLE 1. Agency for Healthcare Research and Quality comorbidity measures

	Endoscopic PEG	Interventional radiologist gastrostomy	Open surgical gastrostomy	Total	*P* value
Congestive heart failure	2511 (15.3)	31,622 (20.5)	1711 (12.5)	35,844 (19.5)	<.001
Valvular disease	928 (5.7)	9097 (5.9)	573 (4.2)	10,598 (5.8)	<.001
Pulmonary circulation disorders	344 (2.1)	3838 (2.5)	319 (2.3)	4501 (2.4)	.005
Peripheral vascular disorders	1073 (6.5)	12,485 (8.1)	1041 (7.6)	14,599 (7.9)	<.001
Hypertension (uncomplicated and complicated)	8172 (49.9)	94,589 (61.4)	6654 (48.7)	109,415 (59.4)	<.001
Paralysis	2644 (16.1)	30,062 (19.5)	1400 (10.2)	34,106 (18.5)	<.001
Other neurologic disorders	3589 (21.9)	34,938 (22.7)	2154 (15.7)	40,681 (22.1)	<.001
Chronic pulmonary disease	3315 (20.2)	34,913 (22.7)	2691 (19.7)	40,919 (22.2)	<.001
Diabetes, uncomplicated	1610 (9.8)	19,244 (12.5)	1262 (9.2)	22,116 (12.0)	<.001
Diabetes with chronic adverse events	2014 (12.3)	26,967 (17.5)	1415 (10.3)	30,396 (16.5)	<.001
Hypothyroidism	1896 (11.6)	19,507 (12.7)	1653 (12.1)	23,056 (12.5)	<.001
Renal failure	2129 (13.0)	28,068 (18.2)	1722 (12.6)	31,919 (17.3)	<.001
Liver disease	669 (4.1)	5941 (3.9)	720 (5.3)	7330 (4.0)	<.001
Peptic ulcer disease excluding bleeding	686 (4.2)	6236 (4.0)	676 (4.9)	7598 (4.1)	<.001
AIDS	35 (.2)	448 (.3)	26 (.2)	509 (.3)	.027
Lymphoma	133 (.8)	1639 (1.1)	95 (.7)	1867 (1.0)	<.001
Metastatic cancer	898 (5.5)	9194 (6.0)	1754 (12.8)	11,846 (6.4)	<.001
Solid tumor without metastasis	739 (4.5)	8114 (5.3)	977 (7.1)	9830 (5.3)	<.001
Rheumatoid arthritis/collagen vascular diseases	348 (2.1)	3965 (2.6)	329 (2.4)	4642 (2.5)	.001
Coagulopathy	1638 (10.0)	19,493 (12.7)	1693 (12.4)	22,824 (12.4)	<.001
Obesity	1613 (9.8)	15,868 (10.3)	1468 (10.7)	18,949 (10.3)	.039
Weight loss	5429 (33.1)	58,653 (38.1)	5609 (41.0)	69,691 (37.9)	<.001
Fluid and electrolyte disorders	8338 (50.9)	95,151 (61.8)	7606 (55.6)	111,095 (60.4)	<.001
Chronic blood loss anemia	172 (1.0)	1843 (1.2)	237 (1.7)	2252 (1.2)	<.001
Deficiency anemias	3842 (23.5)	43,768 (28.4)	3184 (23.3)	50,794 (27.6)	<.001
Alcohol abuse	786 (4.8)	9096 (5.9)	654 (4.8)	10,536 (5.7)	<.001
Drug abuse	505 (3.1)	4689 (3.0)	400 (2.9)	5594 (3.0)	.693
Psychoses	609 (3.7)	7160 (4.6)	454 (3.3)	8223 (4.5)	<.001
Depression	1776 (10.8)	18,322 (11.9)	1511 (11.0)	21,609 (11.7)	<.001

Values are n (%).