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Investigating rates of reoperation or postsurgical gastroparesis following fundoplication or paraesophageal hernia repair in New York State

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Abstract

Background Little is known of the natural history of fundoplication or paraesophageal hernia (PEH) repair in terms of reoperation or the incidence treatment of postsurgical gastroparesis (PSG) in large series. Repeat fundoplications or PEH repairs, as well as pyloroplasty/pyloromyotomy operations, have proven to be effective in the context of PSG or recurrence. In this study, we analyzed the incidences of PSG and risk factors for these revisional surgeries following fundoplication and PEH repair procedures in the state of New York.

Methods The New York State Planning and Research Cooperative System (NY SPARCS) database was utilized to examine all adult patients who underwent fundoplication or PEH repair for the treatment of GERD between 2005 and 2010. The primary outcome was the incidence of each type of reoperation and the timing of the follow-up procedure/diagnosis of gastroparesis. Generalized linear mixed models were used to examine the risk factors for follow-up procedures/diagnosis.

Results A total of 5656 patients were analyzed, as 3512 (62.1%) patients underwent a primary fundoplication procedure and 2144 (37.9%) patients underwent a primary PEH repair. The majority of subsequent procedures ($n=254$, 65.5%) were revisional procedures (revisional fundoplication or PEH repair) following a primary fundoplication. A total of 134 (3.8%) patients who underwent a primary fundoplication later had a diagnosis of gastroparesis or a follow-up procedure to treat gastroparesis, while 95 (4.4%) patients who underwent a primary PEH repair were later diagnosed with gastroparesis or underwent surgical treatment of gastroparesis.

Conclusion The results revealed low reoperation rates following both fundoplication and PEH repairs, with no significant difference between the two groups. Additionally, PEH repair patients tended to be older and were more likely to have a comorbidity compared to fundoplication patients, particularly in the setting of hypertension, obesity, and fluid and electrolyte disorders. Further research is warranted to better understand these findings.

Keywords Fundoplication · Paraesophageal hernia repair · Gastroparesis · Pyloroplasty · Pyloromyotomy

Gastroesophageal reflux disease (GERD) has become an increasingly common upper gastrointestinal disease seen largely in the Western world [1]. A systematic review found that 10–20% of the general population in USA and the UK

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experience weekly symptoms of GERD, including heartburn and/or regurgitation [2]. In patients that have symptoms refractory to medical treatment with proton pump inhibitors (PPI) and physiological testing of pathological acid reflux, surgical intervention may be indicated. Procedures may include Nissen fundoplication, sphincter augmentation procedures such as LINX [3], and possibly paraesophageal hernia (PEH) repair if present [4]. These procedures provide an effective treatment with long-term alleviation of GERD-related symptoms and improvement in quality of life [5, 6].

Although most cases of gastroparesis are classified as idiopathic, postsurgical gastroparesis (PSG) is recognized as a consequence following vagal nerve injury in upper gastrointestinal surgery. A study of 146 patients diagnosed with gastroparesis found that 13% of these patients developed gastroparesis following gastric surgery [7]. PSG was frequently seen in patients undergoing a vagotomy for the treatment of peptic ulcer disease [8]. Despite this surgery falling out of popularity among surgeons in place of PPIs, PSG is still documented in patients undergoing other surgical procedures, such as Roux-en-Y gastric bypass (RYGB) and fundoplication [9].

The development of PSG in patients undergoing surgical procedures for the treatment of GERD, such as fundoplication as well as PEH repair, is not well studied and remains poorly understood. We have previously studied long-term outcomes of fundoplication [10], but have not compared outcomes with the more complex paraesophageal hernia repair procedure. We hypothesized that the added hiatal dissection required in paraesophageal hernia repair could lead to increased vagal nerve injury as well as an increased need for reoperation. This study aims to analyze the incidence of development of PSG following fundoplication and paraesophageal hernia repair (PEH) in New York State [9] and to identify the comorbidities that put such patients at risk of requiring reoperative surgery.

Methods

The New York State Planning and Research Cooperative System (NY SPARCS) database was utilized to examine all adult patients who underwent fundoplication or PEH repair for the treatment of GERD between 2005 and 2010. NY SPARCS is an extensive, longitudinal data reporting system that documents all New York State patients, including demographics, diagnoses, and treatments in centers that treat Medicaid and Medicare patients [11]. Using ICD-9, ICD-10, and CPT codes (see Supplemental Figure 1), all inpatient and outpatient records were extracted listing either fundoplication or PEH repair as a primary surgical operation. Exclusion criteria included age <21 years, in-hospital death ($n=62$), duplicated records, records with diagnosis of gastroparesis at initial procedure ($n=50$), or those without any follow-up records after fundoplication or PEH repair ($n=782$), and missing information. For patients with multiple fundoplication or PEH repair records found during the study period, only the first surgery records were used as initial surgery records.

Through the use of unique identifiers, each patient was followed through 2015 for all subsequent diagnoses of gastroparesis, as well as reoperation. This included procedure codes for pyloroplasty, pyloromyotomy, or gastroenterostomy procedures as treatments for gastroparesis (see Supplemental Figure 1). Follow-up fundoplication or PEH repair procedures were also recorded. If the patient had a record of a fundoplication following the primary operation, this would indicate that they had a repeat or revision of the initial fundoplication or a conversion of an initial primary PEH repair. For any patients with a primary fundoplication or PEH repair procedure, they were only counted as having a redo fundoplication/PEH repair if they never had a follow-up pyloroplasty/gastroenterostomy/pyloromyotomy/diagnosis of gastroparesis. Similarly, any patients with a diagnosis of gastroparesis or follow-up surgery to treat gastroparesis were only counted if they never had a redo fundoplication/pyloroplasty.

Univariate generalized linear mixed models (GLMM) were fit to estimate the marginal association between whether the patients had follow-up procedures/diagnoses with possible risk factors (age group, insurance, race, gender, comorbidities and complications, operating surgeon's yearly volume). Facilities and operating physicians were considered as two random effects to take into account clustering of patients from the same facilities or same physician. Factors that were significant based on univariate tests and having at least 10 patients carrying that comorbidity or complication were further considered in corresponding multivariable GLMMs. In multivariable regression analysis, an $OR>1$ indicated that one category had more risk of having a follow-up surgery/diagnosis than the reference category, and $OR<1$ indicated that one category had less risk of having a follow-up surgery/diagnosis event than the reference category. Univariate generalized linear mixed models (GLMM) were also used to compare the difference between fundoplication and paraesophageal hernia repair patients in terms of patients' characteristics and comorbidities where both facilities and operating surgeons were treated as two random effects. Statistical analysis was performed using SAS 9.4, and significance level was set at 0.05 (SAS Institute Inc., Cary, NC).

This study was approved by the Institutional Review Board. As the SPARCS database is de-identified, no written consent is possible.

Results

After application of the inclusion and exclusion criteria, a total of 5656 patients were analyzed, as 3512 (62.1%) patients underwent a primary fundoplication procedure and 2144 (37.9%) patients underwent a primary PEH repair. Of those patients who underwent a primary fundoplication, 388 (11.1%) had a follow-up procedure. The majority of these procedures ($n = 254$, 65.5%) were revisional procedures [revisional fundoplication or PEH repair]. A total of 134 (3.8%) patients who underwent a primary fundoplication later had a diagnosis of gastroparesis or a follow-up procedure to treat gastroparesis. For patients who underwent a primary PEH repair procedure, 116 (5.4%) of these patients underwent a follow-up revisional PEH repair or redo fundoplication, while 95 (4.4%) were diagnosed with gastroparesis or underwent surgical treatment of gastroparesis. Table 1 summarizes the number of patients with follow-up procedures per year, following their initial surgery. There was no significant difference in having any follow-up procedure between the two surgery groups after adjusting for other confounding factors ([OR = 1.22, 95% CI 0.95–1.55, p value = 0.1149] and [OR = 1.02, 95% CI 0.79–1.30, p value = 0.8932] for revisional procedures and diagnosis/treatment of gastroparesis, respectively).

The average time to any subsequent procedure for patients that underwent a primary fundoplication procedure or PEH repair was 1088.6 days and 935.4 days, respectively. This is shown in Table 2.

The patient characteristics and comorbidities differ significantly between fundoplication patients and PEH repair patients (Table 3). Not surprisingly, of the patients who underwent a primary PEH repair, a larger proportion was 65 years or older compared to patients who underwent a primary fundoplication (44.22% vs 27.36%, p value < 0.0001). Additionally, patients were more likely to have one or more of any of the comorbidities listed in Table 3 if they underwent a primary PEH repair compared to a fundoplication (84.42% vs 72.12%, p value < 0.0001). The two patient groups differed most notably in the setting of hypertension, obesity, and fluid and electrolyte disorders. In each case, there was a greater proportion of patients that had any of these comorbidities present in the PEH repair group (48.79% vs 37.22%, 17.72% vs 8.29%, and 13.39% vs 5.47%, respectively). There were also significant differences in other patient demographics, notably in the region of the hospital where patients were treated and the insurance type, particularly toward Medicare.

Tables 4 and 5 describe the risk factors in patients who underwent a primary fundoplication procedure that make them more likely to undergo a follow-up procedure or diagnosis. Table 4 shows that female fundoplication patients (OR = 1.88, 95% CI 1.39–2.55, p value < 0.0001) and fundoplication patients with chronic pulmonary disease (OR = 1.43, 95% CI 1.07–1.91, p value = 0.0146) were more likely to have a follow-up fundoplication/PEH repair after adjusting for fluid and electrolyte disorders and any complication. Fundoplication patients with hemorrhage (OR = 4.42, 95% CI 1.57–12.48, p value = 0.0050) and diabetes (with and without chronic complications) ([OR = 5.45, 95% CI 1.12–26.47, p value = 0.0357] and [OR = 1.80, 95% CI 1.14–2.84, p value = 0.0119], respectively) were more likely to have a follow-up gastroparesis diagnosis or procedure for gastroparesis after adjusting for other possible confounding factors in Table 5.

Table 1 Number of patients with follow-up procedures/diagnoses by initial surgery types per year

Initial surgery type	Year	# of initial procedures	Fundo/PEH repair*	Pyloroplasty*	Gastroenterostomy*	Pyloromyotomy*	Gastroparesis*
Fundoplication	2005	609	49 (8.05%)	6 (0.99%)	9 (1.48%)	3 (0.49%)	22 (3.61%)
	2006	617	50 (8.10%)	12 (1.94%)	7 (1.13%)	2 (0.32%)	16 (2.59%)
	2007	617	41 (6.65%)	4 (0.65%)	7 (1.13%)	3 (0.49%)	26 (4.21%)
	2008	542	47 (8.67%)	3 (0.55%)	2 (0.37%)	1 (0.18%)	25 (4.61%)
	2009	533	34 (6.38%)	1 (0.19%)	11 (2.06%)	1 (0.19%)	12 (2.25%)
	2010	594	33 (5.56%)	4 (0.67%)	7 (1.18%)	0 (0.00%)	28 (4.71%)
PEH repair	2005	84	4 (4.76%)	2 (2.38%)	1 (1.19%)	0 (0.00%)	4 (4.76%)
	2006	91	3 (3.30%)	0 (0.00%)	2 (2.20%)	0 (0.00%)	3 (3.30%)
	2007	107	6 (5.61%)	0 (0.00%)	2 (1.87%)	1 (0.93%)	9 (8.41%)
	2008	247	14 (5.67%)	2 (0.81%)	3 (1.21%)	0 (0.00%)	8 (3.24%)
	2009	689	44 (6.39%)	10 (1.45%)	16 (2.32%)	0 (0.00%)	32 (4.64%)
	2010	926	45 (4.86%)	5 (0.54%)	13 (1.40%)	1 (0.11%)	33 (3.56%)

*Patients with multiple times of procedures and/or multiple times of diagnoses may be double counted

Table 2 Time interval (days) of secondary procedures/diagnosis after initial fundoplication/ PEH repair surgeries

Initial surgery type	Follow-up procedure/diagnosis	*N*	Mean	Median	Max	Min	SD	$Q1^b$	$Q3^b$
Fundoplication	Fundoplication	209	1050	796	3911	0[a]	902	315	1565
	Paraesophageal hernia repair	113	1496	1379	3911	13	996	683	2270
	Fundoplication/ PEH repair	254	1076	798	3911	0[a]	917	341	1610
	Pyloroplasty	30	819	552	3255	8	874	115	1288
	Gastroenterostomy	43	1205	1012	3432	3	887	408	1995
	Pyloromyotomy	10	1028	633	2471	43	859	392	1784
	Gastroparesis	129	946	709	3640	3	865	257	1427
Paraesophageal hernia repair	Fundoplication	55	856	666	3494	35	751	244	1172
	Paraesophageal hernia repair	88	1018	907	3494	7	755	288	1437
	Fundoplication/ PEH repair	116	940	804	3494	7	742	270	1356
	Pyloroplasty	19	820	594	3371	16	922	59	1324
	Gastroenterostomy	37	816	770	2230	10	532	391	1083
	Pyloromyotomy	2	1405	1405	1696	1113	412	1113	1696
	Gastroparesis	89	693	417	2739	9	692	149	1229

[a]There were 3 patients who had their repeat fundoplication procedure on the same admission dates as their respective initial surgery dates. This suggests a likely miscoding error

[b]$Q1$ and $Q3$: first and third quartile, respectively

Similarly, Tables 6 and 7 describe the risk factors in patients who previously underwent a primary PEH repair procedure that were associated with their likelihood of undergoing a follow-up procedure or diagnosis. Patients with deficiency anemias (OR = 1.84, 95% CI 1.02–3.33, p value = 0.0424) and patients between the ages 45–54 (e.g., 45–54 vs ≥ 65: OR = 1.93, 95% CI 1.03–3.64, p value = 0.0251) were more likely to undergo a revisional procedure following the initial PEH repair procedure after adjusting for other factors in Table 6. Patients with a hypothyroid disease (OR = 1.94, 95% CI 1.24–3.05, p value = 0.0039) and patients between the ages 45–54 (e.g., 45–54 vs ≥ 65: OR = 2.21, 95% CI 1.38–3.55, p value = 0.0072) were more likely to be diagnosed or be treated for gastroparesis following the initial procedure after adjusting for other confounding factors in Table 7. Unsurprisingly, the presence of diabetes was strongly correlated with the diagnosis of gastroparesis.

Discussion

Our analysis through the NY SPARCS database suggests that the incidence of PSG development following a primary PEH repair procedure in New York is not significantly greater than the incidence in those who underwent a fundoplication alone (4.4% vs 3.8%, respectively). However, the patient population that underwent a primary PEH repair was proportionally older than those of the fundoplication group and were more likely to have a comorbidity. This is especially true in the setting of hypertension, obesity, and fluid and electrolyte disorders, and in each case the PEH repair group was more likely to have the comorbidity compared to the fundoplication group (48.79% vs 37.22%, 17.72% vs 8.29%, and 13.39% vs 5.47%, respectively). Additionally, both groups had differing comorbidities (diabetes and hypothyroidism) that may have predisposed each patient population to developing PSG [12, 13].

The results of this study show a markedly lower reoperation rate for patients who underwent an initial PEH repair, with only 211 (9.84%) of these patients undergoing any revisional surgery or developing a new diagnosis of gastroparesis. These results are consistent with those from a study performed by Zhou et al. who utilized a state-wide database to follow the rates of redo antireflux surgery in California from 1995 to 2010. Their study of 13,050 patients found only a 6.9% reoperation rate over 10 years, being highest 1 year postoperatively (1.7%) [14].

Interestingly, studies report a relatively high recurrence rate of paraesophageal hernias following PEH repair, despite a low reoperation rate. One meta-analysis by Rathore et al. measures the true incidence of recurrence following a laparoscopic PEH repair as high as 25.5% [15]. However, it failed to include data on which of these patients had a revisional surgery to treat these recurrences.

Other studies have examined the rate of reoperation following PEH repair. One study of 126 patients who underwent a primary laparoscopic repair of a large

Table 3 Descriptive table comparing fundoplication vs PEH repair patients

Variable	Level	Total	PEH repair	Fundoplication	*p* value*
Patients' characteristics					
Age group	21–45	1239 (21.9%)	352 (16.4%)	887 (25.3%)	< 0.0001
	45–54	1174 (20.8%)	349 (16.3%)	825 (23.5%)	
	55–64	1334 (23.6%)	495 (23.1%)	839 (23.9%)	
	≥65	1909 (33.8%)	948 (44.2%)	961 (27.4%)	
Gender	Female	3684 (65.1%)	1446 (67.4%)	2238 (63.7%)	0.0091
	Male	1972 (34.9%)	698 (32.6%)	1274 (36.3%)	
Race/ethnicity	White	4410 (78.0%)	1720 (80.2%)	2690 (76.6%)	< 0.0001
	Black	310 (5.5%)	119 (5.6%)	191 (5.4%)	
	Asian	26 (0.5%)	10 (0.5%)	16 (0.5%)	
	Hispanic	374 (6.6%)	147 (6.9%)	227 (6.5%)	
	Other	536 (9.5%)	148 (6.9%)	388 (11.1%)	
Region	West	1271 (22.5%)	373 (17.4%)	898 (25.6%)	0.0025
	Mid/North	1634 (28.9%)	541 (25.2%)	1093 (31.1%)	
	Close to NYC	342 (6.1%)	174 (8.1%)	168 (4.8%)	
	NYC area	1663 (29.4%)	718 (33.5%)	945 (27.0%)	
	Long island	746 (13.2%)	338 (15.8%)	408 (11.6%)	
Insurance	Medicaid	225 (4.0%)	70 (3.3%)	155 (4.4%)	< 0.0001
	Medicare	1805 (31.9%)	882 (41.1%)	923 (26.3%)	
	Commercial	3303 (58.4%)	1161 (54.2%)	2142 (61.0%)	
	Other/unknown	323 (5.7%)	31 (1.5%)	292 (8.3%)	
Length of stay	2144 vs 3512	4.47 ± 7.92	6.45 ± 10.97	3.26 ± 4.87	< 0.0001
Facility type	Community	2224 (39.3%)	876 (40.9%)	1348 (38.4%)	0.7705
	Academic	3432 (60.7%)	1268 (59.1%)	2164 (61.6%)	
Surgeons' volume[a]	Low volume (≤ 40 cases/year)	2900 (51.3%)	1250 (58.3%)	1650 (47.0%)	0.0005
	High volume (> 40 cases/year)	2756 (48.7%)	894 (41.7%)	1862 (53.0%)	
Comorbidities					
Any Comorbidity	No	1313 (23.2%)	334 (15.6%)	979 (27.9%)	< 0.0001
	Yes	4343 (76.8%)	1810 (84.4%)	2533 (72.1%)	
Congestive heart failure	No	5510 (97.4%)	2050 (95.6%)	3460 (98.5%)	< 0.0001
	Yes	146 (2.6%)	94 (4.4%)	52 (1.5%)	
Valvular disease	No	5425 (95.9%)	2045 (95.4%)	3380 (96.2%)	0.1627
	Yes	231 (4.1%)	99 (4.6%)	132 (3.8%)	
Pulmonary circulation disease	No	5590 (98.8%)	2106 (98.2%)	3484 (99.2%)	0.0048
	Yes	66 (1.2%)	38 (1.8%)	28 (0.8%)	
Peripheral vascular disease	No	5599 (99.0%)	2105 (98.2%)	3494 (99.5%)	< 0.0001
	Yes	57 (1.0%)	39 (1.8%)	18 (0.5%)	
Hypertension	No	3303 (58.4%)	1098 (51.2%)	2205 (62.8%)	< 0.0001
	Yes	2353 (41.6%)	1046 (48.8%)	1307 (37.2%)	
Paralysis	No	5594 (98.9%)	2117 (98.7%)	3477 (99.0%)	0.8552
	Yes	62 (1.1%)	27 (1.3%)	35 (1.0%)	
Other neurological disorders	No	5470 (96.7%)	2050 (95.6%)	3420 (97.4%)	0.0002
	Yes	186 (3.3%)	94 (4.4%)	92 (2.6%)	
Chronic pulmonary disease	No	4384 (77.5%)	1646 (76.8%)	2738 (78.0%)	0.4752
	Yes	1272 (22.5%)	498 (23.2%)	774 (22.0%)	
Diabetes w/o chronic complications	No	5147 (91.0%)	1904 (88.8%)	3243 (92.3%)	0.0007
	Yes	509 (9.0%)	240 (11.2%)	269 (7.7%)	
Diabetes w/ chronic complications	No	5636 (99.7%)	2135 (99.6%)	3501 (99.7%)	0.6285
	Yes	20 (0.4%)	9 (0.4%)	11 (0.3%)	

Table 3 (continued)

Variable	Level	Total	PEH repair	Fundoplication	*p* value*
Hypothyroidism	No	4993 (88.3%)	1842 (85.9%)	3151 (89.7%)	< 0.0001
	Yes	663 (11.7%)	302 (14.1%)	361 (10.3%)	
Renal failure	No	5555 (98.2%)	2091 (97.5%)	3464 (98.6%)	0.0002
	Yes	101 (1.8%)	53 (2.5%)	48 (1.4%)	
Liver disease	No	5578 (98.6%)	2102 (98.0%)	3476 (99.0%)	0.0259
	Yes	78 (1.4%)	42 (2.0%)	36 (1.0%)	
Peptic ulcer Disease × bleeding	No	5649 (99.9%)	2141 (99.9%)	3508 (99.9%)	0.9602
	Yes	7 (0.1%)	3 (0.1%)	4 (0.1%)	
Acquired immune deficiency syndrome	No	5656 (100.0%)	2144 (100.0%)	3512 (100.0%)	
Lymphoma	No	5633 (99.6%)	2133 (99.5%)	3500 (99.7%)	0.3813
	Yes	23 (0.4%)	11 (0.5%)	12 (0.3%)	
Metastatic cancer	No	5644 (99.8%)	2133 (99.5%)	3511 (100.0%)	0.0001
	Yes	12 (0.2%)	11 (0.5%)	1 (0.0%)	
Solid tumor w/out metastasis	No	5626 (99.5%)	2131 (99.4%)	3495 (99.5%)	0.8884
	Yes	30 (0.5%)	13 (0.6%)	17 (0.48%)	
Rheumatoid arthritis/collagen vas	No	5525 (97.7%)	2096 (97.8%)	3429 (97.6%)	0.6894
	Yes	131 (2.3%)	48 (2.2%)	83 (2.36%)	
Coagulopathy	No	5594 (98.9%)	2105 (98.2%)	3489 (99.4%)	0.0006
	Yes	62 (1.1%)	39 (1.8%)	23 (0.7%)	
Obesity	No	4985 (88.1%)	1764 (82.3%)	3221 (91.7%)	< 0.0001
	Yes	671 (11.9%)	380 (17.7%)	291 (8.3%)	
Weight loss	No	5552 (98.2%)	2077 (96.7%)	3475 (98.9%)	< 0.0001
	Yes	104 (1.8%)	67 (3.1%)	37 (1.1%)	
Fluid and electrolyte disorders	No	5177 (91.5%)	1857 (86.6%)	3320 (94.5%)	< 0.0001
	Yes	479 (8.5%)	287 (13.4%)	192 (5.5%)	
Chronic blood loss anemia	No	5636 (99.7%)	2134 (99.5%)	3502 (99.7%)	0.1722
	Yes	20 (0.3%)	10 (0.5%)	10 (0.3%)	
Deficiency anemias	No	5315 (94.0%)	1962 (91.5%)	3353 (95.5%)	< 0.0001
	Yes	341 (6.0%)	182 (8.5%)	159 (4.5%)	
Alcohol abuse	No	5605 (99.1%)	2114 (98.6%)	3491 (99.4%)	0.0030
	Yes	51 (0.9%)	30 (1.4%)	21 (0.6%)	
Drug abuse	No	5617 (99.3%)	2128 (99.3%)	3489 (99.4%)	0.6311
	Yes	39 (0.7%)	16 (0.7%)	23 (0.6%)	
Psychoses	No	5541 (98.0%)	2093 (97.6%)	3448 (98.2%)	0.3051
	Yes	115 (2.0%)	51 (2.4%)	64 (1.8%)	
Depression	No	5045 (89.2%)	1892 (88.3%)	3153 (89.8%)	0.1562
	Yes	611 (10.8%)	252 (11.7%)	359 (10.2%)	
Tobacco use	No	4691 (82.9%)	1803 (84.1%)	2888 (82.2%)	0.8000
	Yes	965 (17.1%)	341 (15.9%)	624 (17.8%)	

**p* value was based on univariate generalized linear mixed model accommodating the correlation within the same facility or same physician

[a]Surgeons' yearly volumes were defined based on the surgeons' yearly volume including both fundoplication and paraesophageal hernia repair surgeries. The cutoff was chosen such that the # of patients in low or high volume groups were similar

paraesophageal hernia showed that, of the 19 (15.1%) patients that showed recurrence of the hernia, only 6 (4.8%) required reoperation for symptomatic recurrence or dysphagia [16]. This is consistent with our study, which found that only 5.41% of patients who underwent a primary PEH repair procedure underwent a reoperation or conversion to fundoplication later on.

Our study showed that patients with deficiency anemias were more likely to undergo a revisional procedure following the initial PEH repair procedure after adjusting for other

Table 4 Estimated ORs and corresponding 95% CIs of risk factors for having follow-up fundoplication/PEH repair among fundoplication patients

Variable	Level	Odds ratio	95% CI	*p* value*
Chronic pulmonary disease	Yes vs no	1.43	1.07–1.91	0.0146
Fluid and electrolyte disorders	Yes vs no	0.44	0.19–1.03	0.0583
Gender	Female vs male	1.88	1.39–2.55	< 0.0001
Any complication	Yes vs no	0.70	0.46–1.07	0.0998

**p* value was based on multivariable generalized linear mixed model accommodating the correlation within the same facility or same physician

Table 5 Estimated ORs and corresponding 95% CIs of risk factors for having follow-up pyloroplasty/gastroenterostomy/pyloromyotomy/gastroparesis among fundoplication patients

Variable	Level	Odds ratio	95% CI	*p* value*
Length of stay of initial fundoplication	Every step = 10 increase	1.05	0.75–1.46	0.7753
Chronic pulmonary disease	Yes vs no	1.40	1.00-1.96	0.0506
Collapsed	Yes vs no	1.17	0.55–2.51	0.6816
Depression	Yes vs no	1.34	0.86–2.09	0.1903
Diabetes w/o chronic complications	Yes vs no	1.80	1.14–2.84	0.0119
Diabetes w/ chronic complications	Yes vs no	5.45	1.12–26.47	0.0357
Other neurological disorders	Yes vs no	1.86	0.91–3.78	0.0866
Pneumonia	Yes vs no	1.33	0.59–2.98	0.4948
Ventilation	Yes vs no	1.70	0.31–9.29	0.5393
Weight loss	Yes vs no	1.53	0.52–4.54	0.4419
Gender	Female vs male	1.40	1.00-1.97	0.0521
Hemorrhage	Yes vs no	4.42	1.57–12.48	0.0050
Intestinal	Yes vs no	1.60	0.70–3.66	0.2637
Insurance	Medicaid vs commercial	2.24	1.27–3.95	0.0502
	Medicare vs commercial	1.11	0.78–1.57	
	Other/unknown vs commercial	1.01	0.53–1.91	

**p* value was based on multivariable generalized linear mixed model accommodating the correlation within the same facility or same physician

Table 6 Estimated ORs and corresponding 95% CIs of risk factors for having follow-up fundoplication/PEH repair among PEH repair patients

Variable	Level	Odds ratio	95% CI	*p* value*
Deficiency anemias	Yes vs no	1.84	1.02–3.33	0.0424
Depression	Yes vs no	1.62	0.95–2.74	0.0741
Obesity	Yes vs no	1.49	0.90–2.45	0.1181
Age	21–45 vs ≥ 65	0.78	0.37–1.65	0.0251
	45–54 vs ≥ 65	1.93	1.03–3.64	
	55–64 vs ≥ 65	1.14	0.62–2.11	
Digestive	Yes vs no	1.79	0.95–3.39	0.0725
Insurance	Medicaid vs commercial	1.14	0.44–2.91	0.2691
	Medicare vs commercial	0.57	0.32–1.02	
	Other/unknown vs commercial	1.22	0.26–5.64	

**p* value was based on multivariable generalized linear mixed model accommodating the correlation within the same facility or same physician; weight loss was excluded from the multivariable model due to its zero count in the "with fundoplication/paraesophageal hernia repair follow-up" group

factors. One consideration is that patients who underwent an initial PEH repair that developed gastroparesis may have developed a deficiency anemia due to inadequate diet intake. Parkman et al. found that patients with diabetic or idiopathic gastroparesis took significantly less calories and were vitamins A, B6, C, K, iron, potassium, and zinc compared to the

Table 7 Estimated ORs and corresponding 95% CIs of risk factors for having follow-up pyloroplasty/gastroenterostomy/pyloromyotomy/gastroparesis among PEH repair patients

Variable	Level	Odds ratio	95% CI	*p* value*
Length of stay of initial PEH repair	Every step = 10 increase	1.04	0.90–1.19	0.6149
Hypothyroidism	Yes vs no	1.94	1.24–3.05	0.0039
Age	21–45 vs ≥ 65	1.21	0.69–2.13	0.0072
	45–54 vs ≥ 65	2.21	1.38–3.55	
	55–64 vs ≥ 65	1.06	0.65–1.72	
Any complication	Yes vs no	1.78	1.21–2.61	0.0034

**p* value was based on multivariable generalized linear mixed model accommodating the correlation within the same facility or same physician

control, with consultation more likely in patients with longer duration of symptoms [17].

Also, hypothyroidism was associated with an increased likelihood of treatment for gastroparesis. Some studies have found that hypothyroidism significantly increases the mean esophageal transit time as well as gastric emptying time [18]. Therefore, it is possible that those patients who had been treated or diagnosed with gastroparesis following their initial procedure were likely to have a preexisting hypothyroidism diagnosis. More research would need to be conducted to better understand why fluid and electrolyte disorders were associated with a reduced risk of a follow-up fundoplication/PEH repair.

The NY SPARCS database helped to provide all patient records in every New York State hospital for the given study time, allowing us to collect a large amount of data that may otherwise be unattainable. In order to most accurately establish the recurrence and reoperation rate of fundoplication and PEH repair patients in New York, we excluded patients under age 21, patients with recorded in-hospital deaths, duplicated records, records with diagnosis of gastroparesis at the time of the initial procedure, and those patients without follow-up records after fundoplication or PEH repair or with missing information. Although we tried to eliminate patients who may have had their redo surgery in another state, there is still a chance that patients may have gone out of state for their redo surgery. Thus, it may be an underestimate of true rates.

The New York Department of Health trains employees in various hospitals to diagnose diseases and conditions consistently within NY SPARCS. However, due to the lack of the clinical information present in the database, it is not possible to determine how the diagnosis was reached, making it a limitation of the study. Additionally, some procedures that were classified under the codes that we considered for PEH repair, for example, may not have been for the treatment of large diaphragmatic hernias. Our study also may not capture all patients with recurrence. For example, those patients that are asymptomatic but have a radiographic recurrence may opt not to undergo reoperation and will be underrepresented in our study.

Other factors such as surgeon training and hospital volumes between each of the hospitals were not taken into consideration and may have contributed to differences in incidence rates of PSG for each patient. Table 3 shows there was a significant difference in surgeon volume for an initial fundoplication vs PEH repair (41.70% vs 53.02%, $p = 0.0005$), with PEH repairs being performed more frequently by doctors with higher patient volume.

Additionally, only recurrences requiring reoperation were identified in our study. This may exclude asymptomatic recurrences, otherwise symptomatic patients that have a high operative risk, or those that choose not to pursue repair for other reasons. Such inconsistencies provide a challenge in standardizing across all studies of paraesophageal hernia repairs and rates of recurrence.

It should be noted that, while gastroenterostomy surgeries have been performed for several reasons, such as the treatment of peptic ulcer disease and to bypass the duodenum in the setting of duodenal blockage, it is also used in the treatment of gastroparesis refractory to other treatments. Gastroenterostomy procedures may be subsequently converted to gastric bypass; however, such patient records were not considered in this study.

Conclusion

The incidence of diagnosis and treatment of gastroparesis following PEH repair in New York State is not significantly higher than that of fundoplication alone and is seen in under 5% of patients. However, PEH repair patients tended to be older and have a greater number of comorbidities prior to initial surgery. This is particularly true in setting of hypertension, obesity, and fluid and electrolyte disorders. Additionally, there is a relatively low reoperation rate for PEH repairs despite a purportedly high recurrence rate. However, the data on PEH repairs are limited, and further research

much be conducted to better understand the concerns and management of this patient population.

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Compliance with ethical standards

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