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# Surgery for benign esophageal disorders in the US: risk factors for complications and trends of morbidity

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## Abstract

**Background** Gastroesophageal reflux disease (GERD), paraesophageal hernia (PEH), and achalasia are the most frequent benign esophageal disorders that may need surgical treatment. We aimed to identify risk factors for postoperative complications and to characterize trends of morbidity for surgery for benign esophageal disorders in a national cohort.

**Methods** A retrospective population-based analysis was performed using the National Inpatient Sample for the period 2000–2013. Adult patients (≥ 18 years old) diagnosed with GERD, PEH, and achalasia, and who underwent fundoplication, PEH repair, and esophagomyotomy were included. The yearly incidence of complications, stratified by procedure, was calculated using Poisson regression, and multivariable logistic regression was used to determine risk factors for complications.

**Results** A total of 79,622 patients were included; 38,695 (48.6%) underwent PEH repair, 38,719 (48.6%) fundoplication, and 2208 (2.8%) esophagomyotomy. While the rate of postoperative complications dropped from 26.5 to 10.0% and from 16.1 to 12.2% for PEH repair and esophagomyotomy, respectively, the complication rate after fundoplication increased from 5.7 to 12.7% during the same period ($p < 0.0001$). Age, black race, diabetes, renal insufficiency, coronary artery disease, peripheral vascular disease, chronic obstructive pulmonary disease, and open surgery were independent risk factors for postoperative complications. The rate of laparoscopic procedures for PEH repair increased from 4.9 to 91.4%, while for fundoplication it increased from 24.2 to 78.3% ($p < 0.0001$).

**Conclusions** Opposite to PEH repair and esophagomyotomy, antireflux surgery has shown an increase in the morbidity rate in the last decade. Patient selection and embracement of laparoscopic techniques are critical to improve the perioperative outcome in surgery for benign esophageal disorders.

**Keywords** Gastroesophageal reflux · Fundoplication · Paraesophageal hernia repair · Achalasia · Myotomy · Morbidity

Gastroesophageal reflux disease (GERD) affects an estimated 20% of the population in the US, and its prevalence is increasing worldwide [1]. Paraesophageal hernias (PEH) are less common, accounting for 5% of all hiatal hernias, but given the progressive aging of the US population, their numbers are expected to increase in the future [2]. Achalasia is a rare primary motility disorder, but its incidence also increases with age [3]. These three diseases are the most frequent benign esophageal disorders that may need surgical treatment.

The most commonly performed antireflux operation is the Nissen fundoplication, which has long-term success in about 80–90% of patients [4–6]. Paraesophageal hernia repairs (PEHR) are challenging and associated with a high rate of recurrence [7, 8]. Achalasia has no curative treatment, and the esophagomyotomy aims to provide symptomatic relief. Identifying patients at increased risk of postoperative morbidity is valuable and useful during preoperative work-up. This information could be used to identify patients who would benefit from an operation or to select the most appropriate surgical approach. However, data on risk factors for

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postoperative morbidity in surgery for benign esophageal disorders are scarce.

We aimed to identify risk factors for postoperative complications and to characterize trends in postoperative complications after surgery for benign esophageal disorders in the US.

## Methods

### Study design and population

A cohort of patients was identified using the National Inpatient Sample (NIS) database between January 1, 2000 and December 31, 2013. The NIS is the largest publically available all-payer health care database in the United States and includes over 7 million hospitalizations from 1000 hospitals each year, representing a 20% stratified sample of all hospitals in the US. In 2012, the NIS redesigned the sampling strategy from a 20% stratified sample of hospitals to a 20% stratified random sample of all discharges. Eligible patients were identified using International Classification of Disease, 9th revision, Clinical Modification (ICD-9-CM) diagnostic and procedural codes.

Adult patients ($\geq 18$ years old) diagnosed with a paraesophageal hernia (ICD-9-CM 551.3, 552.3, and 553.3), gastroesophageal reflux disease (530.11, 530.81, and 530.85), or achalasia (530.0 and 530.5), and who underwent paraesophageal hernia repair (53.7–53.75, 53.80, and 53.83), fundoplication (44.66 and 44.67), or esophagomyotomy (42.7) during their inpatient hospitalization were eligible for inclusion. Patients undergoing more than one surgical procedure during their hospitalization ($n = 17{,}375$) were excluded. Laparoscopic procedures were identified using both specific procedure codes (44.66, 53.71, and 53.83) and non-specific laparoscopic/robot-assist procedural codes (17.42 and 54.21).

Surgical outcomes of interest was any postoperative complication, which included venous thromboembolism (415.11, 453.40–453.42, and V12.51), wound complications (998.13, 998.30–998.32, and 998.83), infection (54.91, 86.04, 567.22, 569.5, 995.9–995.99, 996.64, 998.5–998.59, and 999.3–999.39), esophageal perforation (42.82 and 530.4), bleeding (99.0–99.09, 998.11, and 998.12), shock (998.0–998.09), cardiac failure (410–410.9, 428–428.9), renal failure (38.95, 39.95, 584–584.9, 586, and V45.11), and respiratory failure (31.1–31.29, 96.04, 96.05, 96.7–96.72, and 799.1).

### Statistical analyses

Prevalence of patient demographics, hospital characteristics, and procedure type were compared between patients who had a complication to those who did not using Chi-square and Wilcoxon–Mann–Whitney tests, where appropriate. Comorbidities of interest included hypertension (401–401.9 and 402–402.91), primary and secondary diabetes (249–249.91 and 250–250.93), obesity (278–278.8), renal insufficiency (585–585.9), coronary artery disease (414–414.9), peripheral vascular disease (443–443.9), chronic obstructive pulmonary disease (COPD) (491–492.8), and sleep apnea (327.23).

The yearly incidence of complications, stratified by procedure, was calculated using Poisson regression. Complication rates in 2000 and 2013 were compared using Wald trend tests. Multivariable Poisson regression was used to assess whether there were changes in complication rates between 2000 and 2013, stratified by procedure, after adjusting for patient gender, age, race/ethnicity, comorbidities, primary insurance, household income, laparoscopic procedure, hospital volume, region, type, and size.

Potential risk factors included age, gender, race/ethnicity, comorbidities, primary insurance, household income, laparoscopic procedure, hospital size, type, and region. Patient age was modeled as linear variable as determined by functional form assessment and centered at 50 years old.

Multivariable logistic regression was used to estimate the direct effect of all potential risk factors on postoperative complications, irrespective of surgical procedure, after adjusting for all other factors, hospital volume, and admit year. Hospital volume was categorized into small, medium, and high volume as per prior analyses and described elsewhere [9–11]. Additionally, multivariable logistic regression with interaction terms to allow for effect measure modification by surgical procedure on each risk factors/postoperative complication was also performed. Likelihood ratio tests were used to assess whether the effect of each risk factor on complications was significantly different across surgery type.

All analyses were performed using SAS software version 9.4 (SAS Inc., Cary, NC). A $p$ value $< 0.05$ was considered significant.

## Results

A total of 79,622 patients were included, 38,695 (48.6%) underwent PEHR, 38,719 (48.6%) fundoplication, and 2,208 (2.8%) esophagomyotomy. Patient and hospital characteristics, stratified by surgery type, are described in Table 1.

Overall incidence of complications was 14.3% for PEHR, 8.9% for fundoplication, and 14.5% for esophagomyotomy ($p < 0.0001$). Specifically, PEHR had higher rates of postoperative infection, bleeding, cardiac failure, renal failure, and respiratory failure ($p < 0.0001$) (Table 2).

**Table 1** Distribution of patient and hospital characteristics among adult patients undergoing esophageal surgery between 2000 and 2013, stratified by surgery, $n = 79{,}622$

| | PEH repair 38,695 (48.6) | Fundoplication 38,719 (48.6) | Esophagomyotomy 2208 (2.8) |
|---|---|---|---|
| Gender, *n* (%) | | | |
| Female | 29,983 (77.5) | 24,819 (64.1) | 1121 (50.8) |
| Male | 8712 (22.5) | 13,900 (35.9) | 1087 (49.2) |
| Age, median (IQR) | 53 (42–65) | 54 (42–65) | 55 (42–68) |
| Race/ethnicity, *n* (%) | | | |
| Non-Hispanic White | 29,171 (75.4) | 33,390 (86.2) | 1628 (73.7) |
| Non-Hispanic Black | 4462 (11.5) | 1,886 (4.9) | 310 (14.0) |
| Hispanic | 3486 (9.0) | 2223 (5.7) | 161 (7.3) |
| Other | 1576 (4.1) | 1220 (3.2) | 109 (4.9) |
| Primary insurance, *n* (%) | | | |
| Private | 22,749 (58.8) | 22,437 (58.0) | 1137 (51.5) |
| Public | 13,248 (34.2) | 14,615 (37.8) | 956 (43.3) |
| Other/self-pay | 2698 (7.0) | 1667 (4.3) | 115 (5.2) |
| Household income[a], *n* (%) | | | |
| Low | 7912 (20.5) | 6871 (17.8) | 488 (22.1) |
| Medium | 9332 (24.1) | 10,558 (27.3) | 515 (23.3) |
| High | 10,271 (26.5) | 10,258 (26.5) | 544 (24.6) |
| Highest | 11,180 (28.9) | 11,032 (28.5) | 661 (29.9) |
| Comorbidities, *n* (%) | | | |
| Hypertension | 19,882 (51.4) | 12,914 (33.4) | 779 (35.3) |
| Diabetes | 7828 (20.2) | 2982 (7.7) | 230 (10.4) |
| Obesity | 25,959 (67.1) | 4212 (10.9) | 168 (7.6) |
| Renal insufficiency | 775 (2.0) | 342 (0.9) | 42 (1.9) |
| Coronary artery disease | 2636 (6.8) | 2296 (5.9) | 193 (8.7) |
| Peripheral vascular disease | 306 (0.8) | 266 (0.7) | 27 (1.2) |
| COPD | 375 (1.0) | 586 (1.5) | 43 (2.0) |
| Sleep apnea | 7724 (20.0) | 996 (2.6) | 53 (2.4) |
| Approach, *n* (%) | | | |
| Laparoscopic | 25,888 (66.9) | 21,700 (56.0) | 229 (10.4) |
| Open | 12,807 (33.1) | 17,019 (44.0) | 1979 (89.6) |
| Hospital bed size, *n* (%) | | | |
| Small | 7158 (18.5) | 4886 (12.6) | 162 (7.3) |
| Medium | 10,812 (27.9) | 9960 (25.7) | 391 (17.7) |
| Large | 20,725 (53.6) | 23,873 (61.7) | 1655 (75.0) |
| Hospital type, *n* (%) | | | |
| Urban, teaching | 19,690 (50.9) | 17,630 (45.5) | 1581 (71.6) |
| Urban, non-teaching | 17,286 (44.7) | 15,969 (41.2) | 539 (24.4) |
| Rural, non-teaching | 1719 (4.4) | 5120 (13.2) | 88 (4.0) |
| Hospital region, *n* (%) | | | |
| Northeast | 9285 (24.0) | 6373 (16.5) | 580 (26.3) |
| Midwest | 5448 (14.1) | 8636 (22.3) | 347 (15.7) |
| South | 15,845 (41.0) | 14,601 (37.7) | 798 (36.1) |
| West | 8117 (21.0) | 9109 (23.5) | 483 (21.9) |

*IQR* interquartile range, *COPD* chronic obstructive pulmonary disease, *PEH* paraesophageal hernia repair

Between 2000 and 2013, the rate of postoperative complications significantly changed across surgical procedures (Fig. 1). Among patients undergoing PEHR, the rate dropped from 26.5 to 10.0% and among patients undergoing esophagomyotomy, the rate dropped from 16.1 to 12.2%. In contrast, the complication rate after

**Table 2** Distribution of complications across surgical procedures among patients undergoing esophageal surgery

| | PEH repair 38,695 (48.6) | Fundoplication 38,719 (48.6) | Esophagomyotomy 2208 (2.8) | *p* Value |
|---|---|---|---|---|
| Postoperative complications, *n* (%) | | | | |
| Venous thromboembolism | 1071 (2.8) | 713 (1.8) | 44 (2.0) | < 0.0001 |
| Wound complications | 193 (0.5) | 117 (0.3) | < 11 | < 0.0001 |
| Infection | 917 (2.4) | 415 (1.1) | 31 (1.4) | < 0.0001 |
| Esophageal perforation | 162 (0.04) | 256 (0.7) | 70 (3.2) | < 0.0001 |
| Bleeding | 2059 (5.3) | 1272 (3.3) | 97 (4.4) | < 0.0001 |
| Cardiac failure | 1489 (3.9) | 792 (2.1) | 73 (3.3) | < 0.0001 |
| Renal failure | 1081 (2.8) | 426 (1.1) | 40 (1.8) | < 0.0001 |
| Respiratory failure | 1491 (3.9) | 699 (1.8) | 82 (3.7) | < 0.0001 |
| Shock | 73 (0.2) | 48 (0.1) | < 11 | 0.05 |
| Any complication, *n* (%) | 5530 (14.3) | 3459 (8.9) | 321 (14.5) | < 0.0001 |

*PEH* paraesophageal hernia

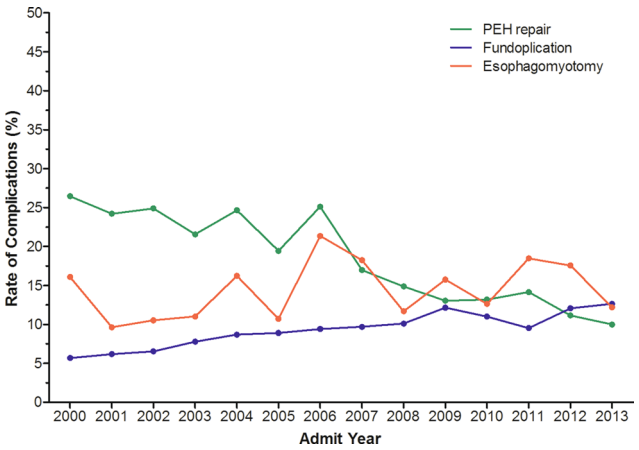


**Fig. 1** Rate of complications for paraesophageal hernia (PEH) repair, esophagomyotomy, and fundoplication between 2000 and 2013

fundoplication increased from 5.7 to 12.7% during the same period ($p < 0.0001$). Even after adjusting for patient demographics and hospital characteristics, the differences in the changes in complication rate over time across surgical procedure persisted ($p < 0.0001$).

After adjusting for patient and hospital characteristics, age (10-year increase), black race, diabetes, renal insufficiency, coronary artery disease, peripheral vascular disease, and COPD were strongly associated with postoperative complications ($p < 0.0001$). Patients with public health insurance and low household income were also more likely to have postoperative complications. In contrast, patients with laparoscopic surgery were significantly less likely to have complications (OR 0.41 95% CI 0.39, 0.44, $p < 0.0001$) (Table 3). The magnitude of the effects of gender, diabetes, obesity, coronary artery disease, and hospital type on postoperative complications was significantly different across each esophageal procedure (Table 4).

Between 2000 and 2013, the percentage of elderly patients and the use of laparoscopy changed differentially across the procedures. The rate of patients older than 60 years for PEHR declined from 74.2 to 49.9%, while for fundoplication and esophagomyotomy the rate increased from 45.0 to 71.2% and from 59.3 to 63.9%, respectively ($p < 0.0001$). The rate of laparoscopic procedures for PEH repair increased from 4.9 to 91.4%, while for fundoplication it increased from 24.2 to 78.3% ($p < 0.0001$).

## Discussion

In this analysis of a large national cohort of patients who underwent surgery for benign esophageal disorders, we found that age (10-year increase), black race, diabetes, renal insufficiency, coronary artery disease, peripheral vascular disease, COPD, and open surgery were associated with a higher rate of postoperative complications. In addition, we found that the complication rates dropped for both PEHR and esophagomyotomy, but increased for fundoplication.

Previous reports with smaller studies have searched for predictive factors of morbidity in benign esophageal surgery. Larusson et al. [12] analyzed 354 patients who underwent PEHR from the database of the Swiss Association for laparoscopic and thoracoscopic surgery, and found that age ≥ 70 years and American Society of Anesthesiologists (ASA) score ≥ 3 were independent predictors of morbidity. Similarly, Gangopadhyay et al. [13] reported higher incidence of postoperative complications in elderly patients after PEHR. For fundoplication, Hahnloser et al. [14] reported that patients with an increased body mass index were more likely to have postoperative complications. Interestingly, they found that the presence of comorbidities was not a predictive factor of complications. Opposite to these findings, Telem et al. [15] stated that increased ASA score and

**Table 3** Crude and adjusted odds ratios of risk factors on postoperative complications among patients undergoing esophageal surgery

| | Crude | | Adjusted[a] | |
|---|---|---|---|---|
| | OR (95% CI) | *p* Value | OR (95% CI) | *p* Value |
| Age, 10-year increase | 1.72 (1.70, 1.75) | **< 0.0001** | 1.37 (1.35, 1.40) | **< 0.0001** |
| Gender | | | | |
| Female | 0.82 (0.78, 0.86) | **< 0.0001** | 0.88 (0.84, 0.93) | **< 0.0001** |
| Male | Ref | – | Ref | – |
| Race/ethnicity | | | | |
| Non-Hispanic White | Ref | – | Ref | – |
| Non-Hispanic Black | 0.91 (0.84, 0.99) | **0.03** | 1.37 (1.25, 1.50) | **< 0.0001** |
| Hispanic | 0.75 (0.69, 0.82) | **< 0.0001** | 0.94 (0.85, 1.03) | 0.19 |
| Other | 0.74 (0.65, 0.84) | **< 0.0001** | 0.91 (0.80, 1.03) | 0.20 |
| Primary insurance | | | | |
| Private | Ref | – | Ref | – |
| Public | 3.82 (3.64, 4.00) | **< 0.0001** | 1.58 (1.48, 1.67) | **< 0.0001** |
| Other/self-pay | 1.44 (1.29, 1.60) | **< 0.0001** | 1.25 (1.11, 1.40) | **0.0002** |
| Household income | | | | |
| Low | 1.34 (1.26, 1.42) | **< 0.0001** | 1.10 (1.02, 1.18) | **0.01** |
| Medium | 1.21 (1.14, 1.28) | **< 0.0001** | 1.07 (1.00, 1.14) | **0.05** |
| High | 1.08 (1.02, 1.15) | **< 0.0001** | 1.01 (0.94, 1.08) | 0.79 |
| Highest | Ref | – | Ref | – |
| Comorbidities[b] | | | | |
| Hypertension | 1.29 (1.23, 1.34) | **< 0.0001** | 0.92 (0.87, 0.97) | **0.001** |
| Diabetes | 1.35 (1.28, 1.43) | **< 0.0001** | 1.22 (1.14, 1.30) | **< 0.0001** |
| Obesity | 0.45 (0.43, 0.47) | **< 0.0001** | 0.58 (0.54, 0.62) | **< 0.0001** |
| Renal insufficiency | 8.38 (7.46, 9.43) | **< 0.0001** | 4.00 (3.49, 4.59) | **< 0.0001** |
| Coronary artery disease | 3.31 (3.10, 3.54) | **< 0.0001** | 1.56 (1.44, 1.68) | **< 0.0001** |
| Peripheral vascular disease | 3.24 (2.71, 3.86) | **< 0.0001** | 1.48 (1.22, 1.81) | **0.0001** |
| COPD | 3.26 (2.84, 3.74) | **< 0.0001** | 1.99 (1.71, 2.31) | **< 0.0001** |
| Sleep apnea | 0.79 (0.74, 0.86) | **< 0.0001** | 1.25 (1.15, 1.37) | **< 0.0001** |
| Approach | | | | |
| Laparoscopic | 0.42 (0.40, 0.44) | **< 0.0001** | 0.41 (0.39, 0.44) | **< 0.0001** |
| Open | Ref | – | Ref | – |
| Hospital bed size | | | | |
| Small | 0.72 (0.67, 0.78) | **< 0.0001** | 0.86 (0.80, 0.93) | **< 0.0001** |
| Medium | 0.93 (0.88, 0.97) | **0.002** | 0.98 (0.93, 1.03) | 0.43 |
| Large | Ref | – | Ref | – |
| Hospital type | | | | |
| Urban, teaching | Ref | – | Ref | – |
| Urban, non-teaching | 0.93 (0.86, 1.01) | 0.07 | 0.80 (0.73, 0.88) | **0.002** |
| Rural, non-teaching | 0.92 (0.88, 0.97) | **0.0006** | 0.92 (0.87, 0.97) | **< 0.0001** |
| Hospital region | | | | |
| Northeast | 0.90 (0.85, 0.96) | **0.0006** | 0.85 (0.80, 0.91) | **< 0.0001** |
| Midwest | 1.01 (0.95, 1.07) | 0.76 | 0.98 (0.93, 1.03) | 0.98 |
| South | Ref | – | Ref | – |
| West | 0.86 (0.81, 0.91) | **< 0.0001** | 0.94 (0.88, 1.00) | 0.05 |

*p* values < 0.05 are given in bold

*OR* odds ratio, *CI* confidence interval, Ref reference, *NC* no constant effect, *PEH* paraesophageal repair

[a]Models were adjusted for gender, age, race/ethnicity, insurance type, income, comorbidities, procedure, approach, hospital bed size, location/teaching status, region, surgical volume, admit year, and interaction between procedure type and each potential risk factor; age was modeled as a linear variable

[b]Patients with each specific comorbidity were compared to patients without the comorbidity (i.e., yes vs. no [ref])

**Table 4** Adjusted assessment of potential effect measure modification by esophageal surgery

| | PEH repair OR (95% CI) | Fundoplication OR (95% CI) | Esophagomyotomy OR (95% CI) | *p* Value[a] |
|---|---|---|---|---|
| Age, 10-year increase | 1.37 (1.33, 1.41) | 1.37 (1.33, 1.40) | 1.36 (1.32, 1.39) | 0.18 |
| Gender | | | | |
| Female | 0.81 (0.75, 0.87) | 1.00 (0.93, 1.09) | 0.84 (0.65, 1.09) | **0.0003** |
| Male | Ref | Ref | Ref | – |
| Race/ethnicity | | | | |
| Non-Hispanic White | Ref | Ref | Ref | 0.16 |
| Non-Hispanic Black | 1.46 (1.30, 1.63) | 1.23 (1.04, 1.45) | 1.35 (0.93, 1.96) | – |
| Hispanic | 1.00 (0.88, 1.14) | 0.82 (0.69, 0.97) | 0.83 (0.48, 1.46) | – |
| Other | 0.94 (0.78, 1.13) | 0.96 (0.77, 1.20) | 0.46 (0.21, 0.99) | – |
| Primary insurance | | | | |
| Private | Ref | Ref | Ref | 0.63 |
| Public | 1.49 (1.37, 1.62) | 1.64 (1.49, 1.80) | 1.45 (1.06, 2.00) | — |
| Other/self-pay | 1.23 (1.07, 1.42) | 1.28 (1.06, 1.57) | 1.06 (0.55, 2.04) | |
| Household income | | | | |
| Low | 1.12 (1.02, 1.24) | 1.05 (0.93, 1.18) | 1.13 (0.78, 1.64) | 0.75 |
| Medium | 1.10 (1.00, 1.20) | 1.03 (0.92, 1.14) | 1.01 (0.70, 1.45) | – |
| High | 0.94 (0.78, 1.13) | 0.98 (0.88, 1.08) | 1.14 (0.76, 1.71) | – |
| Highest | Ref | Ref | Ref | – |
| Comorbidities[b] | | | | |
| Hypertension | 0.89 (0.83, 0.95) | 0.97 (0.89, 1.05) | 0.85 (0.64, 1.13) | 0.26 |
| Diabetes | 1.17 (1.08, 1.28) | 1.41 (1.26, 1.58) | 1.18 (0.82, 1.71) | **0.04** |
| Obesity | 0.44 (0.40, 0.48) | 1.17 (1.04, 1.32) | 1.10 (0.68, 1.77) | **< 0.0001** |
| Renal insufficiency | 3.86 (3.25, 4.59) | 4.29 (3.38, 5.44) | 3.26 (1.65, 6.45) | 0.66 |
| Coronary artery disease | 1.38 (1.25, 1.53) | 1.81 (1.61, 2.03) | 1.70 (1.17, 2.46) | **0.002** |
| Peripheral vascular disease | 1.46 (1.12, 1.91) | 1.45 (1.06, 1.99) | 1.55 (0.65, 3.73) | 0.99 |
| COPD | 1.99 (1.58, 2.49) | 1.91 (1.54, 2.37) | 2.23 (1.11, 4.46) | 0.91 |
| Sleep apnea | 1.36 (1.23, 1.50) | 1.15 (0.94, 1.41) | 1.84 (0.94, 3.57) | 0.22 |
| Approach | | | | |
| Laparoscopic | 0.44 (0.40, 0.47) | 0.42 (0.39, 0.45) | 0.69 (0.43, 1.09) | 0.11 |
| Open | Ref | Ref | Ref | – |
| Hospital bed size | | | | |
| Small | 0.87 (0.79, 0.96) | 0.87 (1.77, 0.98) | 1.14 (0.71, 1.83) | 0.75 |
| Medium | 0.99 (0.92, 1.07) | 0.99 (0.91, 1.08) | 1.17 (0.85, 1.61) | – |
| Large | Ref | Ref | Ref | – |
| Hospital type | | | | |
| Urban, teaching | Ref | Ref | Ref | **0.004** |
| Urban, non-teaching | 1.01 (0.94, 1.08) | 0.83 (0.76, 0.99) | 1.04 (0.77, 1.39) | – |
| Rural, non-teaching | 0.82 (0.71, 0.95) | 0.79 (0.70, 0.90) | 1.09 (0.61, 1.97) | – |
| Hospital region | | | | |
| Northeast | 0.84 (0.77, 0.92) | 0.88 (0.82, 1.01) | 0.94 (0.67, 1.32) | 0.16 |
| Midwest | 1.07 (0.98, 1.18) | 0.91 (0.82, 1.01) | 1.08 (0.745, 1.56) | – |
| South | Ref | Ref | Ref | – |
| West | 0.92 (0.84, 1.00) | 0.95 (0.86, 1.05) | 0.92 (0.64, 1.31) | – |

*p* values < 0.05 are given in bold

Models were adjusted for gender, age, race/ethnicity, insurance type, income, comorbidities, procedure, approach, hospital bed size, location/teaching status, region, surgical volume, admit year, and interaction between procedure type and each potential risk factor; age was modeled as a linear variable

*OR* odds ratio, *CI* confidence interval, Ref reference, *NC* no constant effect, *PEH* paraesophageal repair

[a]A likelihood ratio test was used to assess whether the effect of each risk factor (e.g., race) on complications was significantly different across surgery type; a *p* value < 0.05 was considered significant

[b]Patients with each specific comorbidity were compared to patients without the comorbidity (i.e., yes vs. no [ref])

diabetes were associated with higher rates of postoperative complications after fundoplication. Using the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) data, Ross et al. analyzed 1237 patients who underwent esophagomyotomy [16]. The authors found that major complications were associated with patient alcohol use, smoking, history of stroke, and longer operative times. In our analysis, comprising the largest national cohort of patients who underwent surgery for benign esophageal disorders to date, we found that elderly patients and patients with severe comorbidities were more likely to have postoperative complications. We strongly believe that the indication for surgery for these disorders should be carefully balanced against the patient's risks for postoperative morbidity.

We also found that patients who underwent laparoscopic surgery were significantly less likely to have postoperative complications. Previous studies have also shown the benefits of minimally invasive surgery for benign esophageal disorders. Kubasiak et al. [17] reported that laparoscopic PEHR was associated with a significant decrease in infections, respiratory and cardiac complications, transfusion requirements, episodes of sepsis and shock as compared to an open approach. We recently showed that laparoscopic antireflux surgery was associated with less postoperative morbidity and mortality, shorter length of hospital stay, and lower costs, as compared to open fundoplication [18]. Minimally invasive techniques for benign esophageal diseases were first reported in the early 1990s [19–21]. Almost 30 years later, a considerable number of procedures are still done through an open approach. Thus, minimally invasive surgery still needs to be fully embraced in the US in order to achieve better postoperative outcomes.

An interesting finding of our study was that the rate of complications dropped for PEHR and esophagomyotomy, but it increased for fundoplication. These results can be partially explained by the trend of two of the main risk factors of complications: age and open surgery. Embracement of laparoscopy was slower for fundoplication, and the rate of patients older than 60 years has significantly increased for antireflux surgery. We can also speculate that a fundoplication is somehow more a component of the general surgeon's armamentarium, and general surgeons without specific training in esophageal surgery may feel more comfortable performing a fundoplication rather than a PEHR or Heller myotomy, while these procedures are more often performed by more experienced surgeons. In addition, the use of medical therapy and the introduction of endoscopic treatment modalities for patients with reflux and Barrett's esophagus, contributed to a major surgical complexity in many patients that are now referred for fundoplication. Overall, the worsening outcomes after fundoplication are indeed preoccupying. In fact, the utilization of antireflux surgery has declined in the US in recent years [22, 23]. The obesity epidemic and the increase of bariatric procedures may have contributed to this decline. However, non-optimal surgical results may have led to an "under-referral" by gastroenterologists for antireflux surgery.

Limitations of this study include that there is potential for coding errors in a large administrative database; this may be especially problematic for identifying laparoscopic esophagomyotomy procedures, as only non-specific codes could be used. In addition, because NIS does not link hospital records, patients' outcomes, including complications, readmission, and mortality, occurring after the initial hospital discharge are unable to be measured. Although these procedures are often done concomitantly, we excluded patients undergoing combination procedures in order to determine a potential effect measure modification by procedure type. Finally, NIS does not provide information about the complexity of the cases (e.g., size of the hernia, prior abdominal operations, or redo surgery), and therefore we were not able to adjust for it. Despite these limitations, our study represents the largest series to date assessing risk factors for complications after surgery for benign esophageal disorders.

## Conclusions

In patients undergoing surgery for benign esophageal diseases, age (10-year increase), diabetes, renal insufficiency, coronary artery disease, peripheral vascular disease, COPD, and open surgery were associated with postoperative complications. Opposite to PEHR and esophagomyotomy, antireflux surgery has shown an increase in the morbidity rate in the last decade. Patient selection and embracement of laparoscopic surgery are critical to improve perioperative outcomes in surgery for benign esophageal disorders.

### Compliance with ethical standards

**Disclosures** Francisco Schlottmann, Paula Strassle, and Marco Patti have no conflict of interest or financial ties to disclose.

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