J Gastrointest Surg (2017) 21:1199–1205
DOI 10.1007/s11605-017-3469-z

SSAT QUICK SHOT PRESENTATION

Paraesophageal Hernia Repair in the USA: Trends of Utilization Stratified by Surgical Volume and Consequent Impact on Perioperative Outcomes

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Received: 27 April 2017 / Accepted: 29 May 2017 / Published online: 12 June 2017

Abstract
Background The impact of surgical volume on perioperative results after a paraesophageal hernia (PEH) repair has not yet been analyzed. We sought to characterize the trend of utilization of this procedure stratified by surgical volume in the USA, and analyze its impact on perioperative outcomes.
Methods A retrospective population-based analysis was performed using the National Inpatient Sample for the period 2000–2013. Adult patients (≥18 years old) who underwent PEH repair were included. Surgical volume was categorized as small (<6 operations/year), intermediate (6–20 operations/year), or high (>20 operations/year). Multivariable linear and logistic regression models were used to assess the effect of surgical volume on patient outcomes.
Results A total of 63,812 patients were included. Over time, the rate of procedures across high-volume centers increased from 65.8 to 94.4%. The use of the laparoscopic approach was significantly different among the groups (small volume 38.4%; intermediate volume 41.8%; high volume 67.4%; $p < 0.0001$). Patients undergoing PEH repair at high-volume hospitals were less likely to experience postoperative bleeding, cardiac failure, respiratory failure, and shock. On average, patients at low- and intermediate-volume hospitals stayed 0.8 and 0.6 days longer, respectively.
Conclusions A spontaneous centralization towards high-volume centers for PEH repair has occurred in the last decade. This trend is beneficial for patients as it is associated with higher rates of laparoscopic operations, decreased surgical morbidity, and a shorter length of hospital stay.

Keywords Paraesophageal hernia · Paraesophageal hernia repair · Surgical volume

Francisco Schlottmann, MD, Paula Strassle, MSPH, Marco E. Allaix, MD, and Marco G. Patti, MD, conceived the study and helped with literature search and writing of the manuscript.

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Introduction

Paraesophageal hernias (PEH) account for 5% of all hiatal hernias[1], and they are associated with potentially lethal complications such as volvulus, strangulation, incarceration, and perforation[2]. Surgical treatment is considered mainly for symptomatic PEH, and given the progressive aging of the US population, the number of PEH repairs is expected to increase in the future[3].

The relationship between surgical volume and postoperative morbidity and mortality has been examined in many previous studies[4–7]. However, most of them focused on the most demanding oncologic surgical procedures such as pancreatectomy or esophagectomy, showing significantly lower rates of postoperative morbidity and mortality in high-volume centers[8–10]. Despite this, the impact of surgical volume on postoperative results after surgery for benign esophageal disorders remains elusive. Colavita and colleagues[11] reported that the percentage of anti-reflux operations has increased in low-volume centers with a consequent increase in postoperative complications. For esophageal myotomy, Wang et al.[12] showed that a larger volume of procedures in a hospital was associated with shorter length of stay and lower total charges.

To our knowledge, the impact of surgical volume on perioperative results after a PEH repair has not yet been analyzed. Therefore, the aims of this study were as follows: (a) to characterize the trend of utilization of PEH repair stratified by surgical volume in the USA and (b) to analyze the impact of surgical volume on perioperative outcomes.

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 healthcare database in the USA and includes over 7 million hospitalizations from 1000 hospitals each year, representing a 20% stratified sample of all hospitals in the USA. 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, ninth revision, Clinical Modification (ICD-9-CM) diagnostic and procedural codes. This study was approved by the University of North Carolina School of Medicine Institutional Review Board.

Adult patients (≥18 years old) diagnosed with a paraesophageal hernia (ICD-9-CM 551.3, 552.3, and 553.3) or gastroesophageal reflux disease (530.11, 530.81, and 530.85), and who underwent paraesophageal hernia repair (53.7–53.75, 53.80, and 53.83) during their inpatient hospitalization, were eligible for inclusion. Hernia repair was further classified as either abdominal (53.7–53.75) or thoracic (53.8, 53.80, and 53.83), as well as either open (53.72, 53.75, and 53.80), laparoscopic (53.71), or thoracoscopic (53.83). Laparoscopic procedures were also identified using non-specific laparoscopic and robot-assisted procedural codes (17.42 and 54.21).

Relevant comorbidities 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 (491–492.8), and sleep apnea (327.23).

Surgical outcomes of interest were mortality, postoperative complications, length of stay, and total charges. Postoperative complications 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). A composite complication (i.e., at least one postoperative complication) was also analyzed.

Statistical Analyses

Patient demographics, hospital characteristics, and procedure type were compared across hospital surgical volume using chi-square and Wilcoxon-Mann-Whitney tests, where appropriate. Overall hospital surgical volume was determined using the 30th and 60th percentile cut points using weighted discharges. Surgical volume was categorized as small (<6 operations/year), intermediate (6–20 operations/year), or high (>20 operations/year). Unadjusted, bivariate analyses of mortality, length of stay, hospital charges, and complication incidence across low, intermediate, and high surgical volume was also assessed using chi-square and Wilcoxon-Mann-Whitney tests. A p value <0.05 was considered significant.

The yearly incidence of paraesophageal hernia repair stratified across hospital volume, was calculated using Poisson regression and expressed as the number of procedures per 100 patients. Weighted discharge records were also used. Due to changes in NIS sampling strategy, discharge records from 2012 and 2013 were excluded in the trend analysis.

Missing data for gender (n = 51, 0.1%), race/ethnicity (n = 9047, 14.2%), primary insurance (n = 378, 0.6%), household income (n = 1338, 2.1%), admission type (n = 25,326, 39.7%), hospital teaching status (n = 347, 0.5%), and bed size (n = 347, 0.5%) were estimated using Markov Chain Monte Carlo (MCMC) multiple imputation, n = 40. A non-informative prior, 200 burn-in iterations and 100 iterations between imputations was specified. MCMC models included the variables with missing data plus benign esophageal diagnosis, the outcomes of interest (i.e., each postoperative complication, length of stay, and hospital charges), admit year, age, comorbidities, and hospital region. Variables estimates were not rounded or bounded.

Main effect multivariable analyses on the potential effect of surgical volume on patient outcomes were performed using linear and logistic regression, where appropriate, on the imputed datasets. Models were adjusted for admit year, age, gender, race/ethnicity, comorbidities, primary insurance, household income, admit type, laparoscopic procedure, hospital region, teaching status, and size. Patient age was modeled as linear variable as determined by functional form assessment and centered at 50 years old.

All analyses were performed using SAS software version 9.4 (SAS Inc., Cary, NC).

Results

A total of 63,812 patients were included. During the study period, 84.0% of patients underwent PEH repair in high-volume hospitals, 11.9% in intermediate-volume hospitals, and 4.1% in low-volume hospitals. The use of the laparoscopic approach was significantly different among the groups (small volume 38.4%; intermediate volume 41.8%; high volume 67.4%; $p < 0.0001$). Demographic and patient characteristics, stratified by hospital volume, are described in Table 1.

Between 2000 and 2011, the rate of procedures across hospital volume has significantly changed ($p < 0.0001$). Specifically, the number of procedures, per 100 patients, occurring at high-volume hospitals, significantly increased from 65.8 procedures/100 patients to 94.4 procedures/100 patients between 2000 and 2011, while the number of procedures at low- and intermediate-volume hospitals has decreased from 9.0 and 25.2 procedures/100 patients to 1.2 and 4.4 procedures/100 patients, respectively (Fig. 1).

As compared to high-volume hospitals, low and intermediate-volume hospitals had a significantly higher incidence of complications (26.4 and 24.1%, respectively, vs. 12.7%; $p < 0.0001$). Specifically, patients at low- and intermediate-volume hospitals had higher rates of postoperative wound complications, infection, esophageal perforation, bleeding, cardiac failure, renal failure, respiratory failure, and inpatient mortality. The median length of hospital stay was 5 days (interquartile range [IQR] 2–9) for low-volume hospitals, 4 days (IQR 2–8) for intermediate-volume hospitals, and 2 days (IQR 1–4) for high-volume hospitals ($p < 0.0001$). No significant differences were seen in hospital charges, $p = 0.10$ (Table 2).

After adjusting for patient and hospital characteristics, patients receiving care at a low-volume (OR 1.23, 95% CI 1.11, 1.38, $p = 0.0002$) and intermediate-volume (OR 1.18, 95% CI 1.10, 1.26) hospitals were still more likely to have postoperative complications, compared to patients at high-volume hospitals (Table 3). Specifically, patients at low-volume hospitals were more likely to have postoperative bleeding (OR 1.20, 95% CI 1.03, 1.40), cardiac failure (OR 1.28, 95% CI 1.08, 1.52), and respiratory failure (OR 1.45, 95% CI 1.22, 1.72). Patients at intermediate-volume hospitals were more likely to have postoperative bleeding (OR 1.23 95% CI 1.11, 1.36), respiratory failure (OR 1.35, 95% CI 1.20. 1.52), and shock (OR 1.77, 95% CI 1.13, 2.78). On average, patients at low-volume hospitals stayed 0.8 days longer (95% CI 0.52, 1.04) and patients at intermediate-volume hospitals stayed 0.6 days longer (95% CI 0.45, 0.77). No significant differences in average hospital charges were seen across hospital volumes (Table 3).

Discussion

The aims of this study were to characterize the trend of utilization of PEH repair stratified by surgical volume in the USA, and analyze its impact on perioperative outcomes. We found that the percentage of procedures performed at high-volume hospitals has significantly increased in the last decade. In addition, we found that patients undergoing PEH repair at high-volume hospitals had lower rates of postoperative complications and shorter length of hospital stay.

Several studies have shown the potential advantages of centralizing esophageal and other high-risk procedures into specialized centers[13–15]. Other procedures such as anti-reflux surgery or PEH repair are considered a component of the general surgeon's armamentarium, and therefore more difficult to be regionalized. A recent study showed that the percentage of anti-reflux operations has increased in low-volume hospitals (33.3% in 1999 and 40.4% in 2009)[11]. Surprisingly, we noticed a spontaneous centralization for PEH repair in the last decade in the USA. The percentage of procedures occurring at high-volume hospitals increased from 65.8 to 94.4% in the period 2000–2011. We can speculate that the increase in referral to specialized centers was a consequence of the complexity of this operation, which may be associated with serious complications and high incidence of recurrence.

Our intergroup comparisons of perioperative outcomes by hospital volume indicated that a higher volume (>20 PEH repair/year) was associated with fewer postoperative complications and shorter length of hospital stay. Advancements in surgical technology and technique and significant improvements in perioperative care may explain the better outcomes obtained in high-volume centers. In fact, several studies have demonstrated a consistent improvement in postoperative outcomes associated with increased hospital volumes for different surgical procedures[8–12]. In contrast to evaluating highly complex procedures, we found that volume is important also for PEH repair. Patients at high-volume hospitals were less likely to experience postoperative morbidity, and had shorter length of hospital stay. Unfortunately, with the NIS dataset we were not able to determine the surgical complexity of the cases (size of hernia or redo operations). However, if more of these complex PEH repairs are being done in high-volume centers, the outcome differences we noticed may be even more dramatic and favor these specialized centers. In fact, the proportion of patients with hypertension, diabetes, and obesity was higher in high-volume centers. This is not an uncommon referral pattern as complex patients benefit from the variety of services offered at large teaching hospitals.

Table 1 Distribution of patient and hospital characteristics among adult patients undergoing paraesophageal hernia repair between 2000 and 2013, stratified by hospital volume, $n = 63{,}812$

	Low volume 2630 (4.1%)	Intermediate volume 7562 (11.9%)	High volume 53,620 (84.0%)
Gender, *n* (%)			
Male	851 (32.4)	2329 (30.8)	12,845 (24.0)
Female	1777 (67.6)	5229 (69.2)	40,730 (76.0)
Age, median (IQR)	66 (53–77)	65 (52–76)	54 (43–66)
Race/ethnicity, *n* (%)			
Non-Hispanic white	1799 (82.0)	5158 (83.0)	35,762 (77.2)
Non-Hispanic black	130 (5.9)	353 (5.7)	4807 (10.4)
Hispanic	176 (8.0)	520 (8.4)	3756 (8.1)
Other	89 (4.1)	186 (3.0)	2029 (4.4)
Primary insurance, *n* (%)			
Private	884 (33.8)	2697 (35.9)	30,315 (56.9)
Public	1538 (58.7)	4374 (58.2)	19,807 (37.2)
Other/self-pay	197 (7.5)	448 (6.0)	3174 (6.0)
Comorbidities, *n* (%)			
Hypertension	1177 (44.8)	3530 (46.7)	26,407 (49.3)
Diabetes	299 (11.4)	848 (11.2)	9535 (17.8)
Obesity	380 (14.5)	1447 (19.1)	30,026 (56.0)
Renal insufficiency	72 (2.7)	187 (2.5)	993 (1.9)
Coronary artery disease	243 (9.2)	726 (9.6)	3819 (7.1)
Peripheral vascular disease	27 (1.0)	68 (0.9)	442 (0.8)
COPD	68 (2.6)	156 (2.1)	576 (1.1)
Sleep apnea	86 (3.3)	384 (5.1)	8901 (16.6)
Elective admission, *n* (%)	876 (57.5)	2558 (56.7)	25,562 (78.4)
Approach, *n* (%)			
Abdominal, laparoscopic	1010 (38.4)	3157 (41.8)	36,154 (67.4)
Abdominal, open	1422 (54.1)	3775 (49.9)	14,569 (27.2)
Thoracic, laparoscopic	26 (1.0)	96 (1.3)	791 (1.5)
Thoracic, open	172 (6.5)	534 (7.1)	2106 (3.9)
Hospital size, *n* (%)			
Small	690 (26.3)	1434 (19.0)	7890 (14.8)
Medium	831 (31.7)	2377 (31.5)	13,214 (24.8)
Large	1104 (42.1)	3730 (49.5)	32,195 (60.4)
Hospital type, *n* (%)			
Urban, teaching	458 (17.5)	2372 (31.5)	31,379 (58.9)
Urban, non-teaching	1385 (52.8)	4003 (53.1)	19,666 (36.9)
Rural, non-teaching	782 (29.8)	1,166,915.5)	2254 (4.2)
Hospital region, *n* (%)			
Northeast	392 (14.9)	1269 (16.8)	11,715 (21.9)
Midwest	667 (25.4)	1887 (25.0)	10,431 (19.5)
South	1036 (39.4)	2761 (36.5)	20,172 (37.6)
West	535 (20.3)	1645 (21.8)	11,302 (21.1)

IQR interquartile range, *COPD* chronic obstructive pulmonary disease

Surprisingly, the median age of patients at low- and intermediate-volume centers was 66 and 65 years, respectively, and 54 years at high-volume centers. In addition, other patient's characteristics were different across hospital volume. High-volume hospitals were more likely to have patients covered by private insurance, which younger individuals are more likely to have (patients who are ≥65 years old qualify for Medicare, which is considered public insurance). Additionally, hospital characteristics (e.g., type, region) were different across hospital volume, which could also impact the

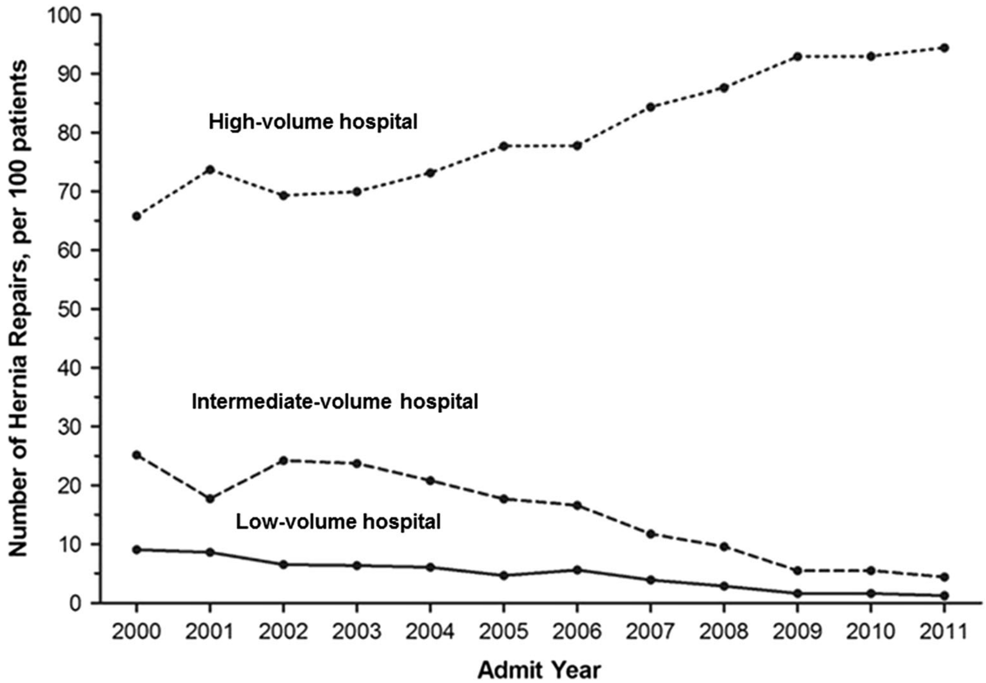

Fig. 1 Yearly rate of paraesophageal hernia repair procedures, per 100 patients, stratified by low (*solid line*), intermediate (*long-dashed line*), and high (*short-dashed line*) surgical volume

distribution of age in patient population. We believe that the difference in age was most likely due to differences in case mix across hospitals. There is no reason to suspect that coding practices (i.e., patient selection) were the cause of the difference in age, although this assumption cannot be tested in the data. For example, for age to be associated with selection, high-volume hospitals would have to systematically code patient procedures differently between their older and younger patients. This is unlikely, especially considering that these procedure codes are used for billing purposes.

Interestingly, we found that the use of the laparoscopic approach was significantly different among the different volume hospitals (small volume 38.4%; intermediate volume 41.8%; high volume 67.4%). Previous studies have shown that laparoscopic PEH repair, as compared to open, was associated with significantly better postoperative outcomes in

Table 2 Incidence of postoperative complications, length of stay, and total hospital charges, among adults undergoing paraesophageal hernia repair, stratified by hospital surgical volume, $n = 63{,}812$

	Low volume 2630 (4.1%)	Intermediate volume 7562 (11.9%)	High volume 53,620 (84.0%)	*p* value[a]
Postoperative complications, *n* (%)				
Venous thromboembolism	74 (2.8)	239 (3.2)	1541 (2.9)	0.37
Wound complications	21 (0.8)	77 (1.0)	241 (0.5)	*<0.0001*
Infection	124 (4.7)	312 (4.1)	999 (1.9)	*<0.0001*
Esophageal perforation	31 (1.2)	108 (1.4)	292 (0.5)	*<0.0001*
Bleeding	274 (10.4)	733 (9.7)	2286 (4.3)	*<0.0001*
Cardiac failure	215 (8.2)	503 (6.7)	1785 (3.3)	*<0.0001*
Renal failure	137 (5.2)	357 (4.7)	1211 (2.3)	*<0.0001*
Respiratory failure	231 (8.8)	593 (7.8)	1540 (2.9)	*<0.0001*
Shock	<11	36 (0.5)	78 (0.2)	*<0.0001*
Mortality	77 (2.9)	178 (2.4)	405 (0.8)	*<0.0001*
Any complication,[b] *n* (%)	693 (26.4)	1822 (24.1)	6825 (12.7)	*<0.0001*
Length of stay, in days, median (IQR)	5 (2–9)	4 (2–8)	2 (1–4)	*<0.0001*
Charges, in thousands, median (IQR)	35 (21–63)	37 (22–64)	37 (24–57)	0.10

p values <0.05 are denoted in italics

IQR interquartile range

[a] Chi-square and Wilcoxon-Mann-Whitney tests were used, where appropriate

[b] At least one postoperative complication (compared to no complications)

Table 3 Adjusted odds ratios of low and intermediate surgical volume hospitals, compared to high volume, on postoperative complications, length of stay, and hospital charges among adult patients undergoing paraesophageal hernia repair

	Low volume			Intermediate volume		
	Odds ratio	95% CI	*p* value	Odds ratio	95%CI	*p* value
Postoperative complications						
Venous thromboembolism	0.92	0.71, 1.17	0.49	0.99	0.85, 1.16	0.93
Wound complications	0.84	0.51, 1.36	0.47	1.23	0.92, 1.64	0.17
Infection	1.16	0.93, 1.45	0.19	1.14	0.98, 1.33	0.08
Esophageal perforation	0.95	0.63, 1.44	0.82	1.24	0.96, 1.59	0.10
Bleeding	1.20	1.03, 1.40	*0.01*	1.23	1.11, 1.36	*<0.0001*
Cardiac failure	1.28	1.08, 1.52	*0.006*	1.07	0.95, 1.21	0.29
Renal failure	1.11	0.89, 1.39	0.34	1.14	0.99, 1.33	0.07
Respiratory failure	1.45	1.22, 1.72	*<0.0001*	1.35	1.20, 1.52	*<0.0001*
Shock	1.29	0.62, 2.68	0.49	1.77	1.13, 2.78	*0.01*
Mortality	1.24	0.93, 1.66	0.14	1.13	0.92, 1.39	0.24
Any complication[a]	1.23	1.11, 1.38	*0.0002*	1.18	1.10, 1.26	*<0.0001*
	Change in estimate	95% CI	*p* value	Change in estimate	95% CI	*p* value
Length of stay, in days	0.80	0.52, 1.04	*<0.0001*	0.63	0.45, 0.77	*<0.0001*
Charges, in thousands	−0.40	−3.01, 2.33	0.80	−0.19	−1.87, 1.49	0.82

Models were adjusted for admit year, age, gender, race/ethnicity, insurance type, income, comorbidities, admit type, laparoscopic procedure, hospital size, location/teaching status, and region; missing data was imputed using Markov Chain Monte Carlo multiple imputation. *p* values <0.05 are denoted in italics

CI confidence interval

[a] At least one postoperative complication (compared to no complications)

terms of morbidity, mortality, length of hospital stay, and costs[16–19]. The percentage of laparoscopic PEH repair at high-volume centers (67.4%) could still be considered low. In fact, the rates of laparoscopic surgery in the US are somehow surprising. A recent study compared the perioperative outcomes and costs between laparoscopic and open anti-reflux surgery using the NIS database[20]. Regardless of the well-known advantages of laparoscopic surgery, in the period 2000–2013, 41.6% of the anti-reflux operations in the USA were still performed either through a laparotomy or a thoracotomy[20]. Colorectal surgery is another important example. A recent study showed that the percentage of open colectomies in the USA is still 64.3% with NIS data (period 2006–2012), and 51% with the American College of Surgeons National Surgical Quality Improvement Program (NSQIP) data (period 2006–2013)[21]. Although in our analysis high-volume centers had better outcomes even after adjusting for surgical approach, we believe that the early adoption of laparoscopic surgery in specialized centers will also contribute to even better postoperative results in those patients.

We also found higher percentage of patients admitted electively at high-volume hospitals (78.4 vs. 57.5% and 56.7% at low- and intermediate-volume hospitals, respectively). Emergent PEH repair has shown to be associated with markedly higher mortality and morbidity than elective repair[22,23]. Augustin et al.[24] reported that the increased mortality among patients undergoing emergent PEH was related to patient's comorbidities, preoperative sepsis, and open surgical approach. This is not surprising as emergent cases usually involve sick and elderly patients, very often with sepsis. The higher percentage of elective cases may have contributed to the higher number of laparoscopic operations at high-volume centers. It is worth to mention, however, that the better outcomes achieved in these centers were independent from the type of admission, as the models were adjusted for that variable.

Limitations of our study include that NIS does not link hospital records, meaning that patients' outcomes, including complications, readmission, and mortality, occurring after the initial hospital discharge, are unable to be measured. There is also potential for coding errors and differences in coding practices across hospitals in a large administrative database. In addition, details about the complexity of the cases are not provided by NIS (previous surgical history of the patients, type or size of the hernias, redo operations), and we were not able to adjust for it.

Despite these limitations, this is the first study that shows the importance of surgical volume to obtain better postoperative results after PEH repair. This study warrants serious consideration by healthcare professionals, insurance companies, and patients. Based on our results, we believe that volume standards should be implemented. Designating centers of excellence for PEH repair based on local expertise will improve postoperative outcomes.

Conclusions

A spontaneous centralization towards high-volume centers for PEH repair has occurred in the last decade in the USA. High-volume hospitals are associated with higher rates of laparoscopic operations, decreased surgical morbidity, and shorter length of hospital stay. Volume standards should be implemented in order to obtain better postoperative outcomes.

Compliance with Ethical Standards This study was approved by the University of North Carolina School of Medicine Institutional Review Board.

Conflict of Interest The authors declare that they have no conflict of interest.

References

1. Andujar JJ, Papasavas PK, Birdas T, Robke J, Raftopoulos Y, Gagné DJ, Caushaj PF, Landreneau RJ, Keenan RJ. Laparoscopic repair of large paraesophageal hernia is associated with a low incidence of recurrence and reoperation. Surg Endosc 2004; 18(3):444–7.
2. Hill LD. Incarcerated paraesophageal hernia. A surgical emergency. Am J Surg 1973; 126(2):286–91.
3. Davis SS Jr Current controversies in paraesophageal hernia repair. Surg Clin North Am 2008; 88(5):959–78.
4. Begg CB, Cramer LD, Hoskins WJ, Brennan MF. Impact of hospital volume on operative mortality for major cancer surgery. JAMA 1998; 280(20):1747–1751.
5. Finlayson EV, Goodney PP, Birkmeyer JD. Hospital volume and operative mortality in cancer surgery: a national study. Arch Surg 2003; 138(7):721–725.
6. Birkmeyer JD, Siewers AE, Finlayson EV, Stukel TA, Lucas FL, Batista I, Welch HG, Wennberg DE. Hospital volume and surgical mortality in the United States. N Engl J Med 2002; 346(15):1128–1137.
7. Finks JF, Osborne NH, Birkmeyer JD. Trends in hospital volume and operative mortality for high-risk surgery. N Engl J Med 2011; 364(22):2128–2137.
8. Alsfasser G, Leicht H, Günster C, Rau BM, Schillinger G, Klar E. Volume-outcome relationship in pancreatic surgery. Br J Surg 2016; 103(1):136–143.
9. Munasinghe A, Markar SR, Mamidanna R, Darzi AW, Faiz OD, Hanna GB, Low DE. Is it time to centralize high-risk cancer care in the United States? Comparison of outcomes of esophagectomy between England and the United States. Ann Surg 2015; 262(1):79–85.
10. Markar SR, Karthikesalingam A, Thrumurthy S, Low DE. Volume-outcome relationship in surgery for esophageal malignancy: systematic review and meta-analysis 2000-2011. J Gastrointest Surg 2012; 16(5):1055–1063.
11. Colavita PD, Belyansky I, Walters AL, Tsirline VB, Zemlyak AY, Lincourt AE, Heniford BT. Nationwide inpatient sample: have antireflux procedures undergone regionalization? J Gastrointest Surg 2013; 17(1):6–13.
12. Wang YR, Dempsey DT, Friedenberg FK, Richter JE. Trends of Heller myotomy hospitalizations for achalasia in the United States, 1993-2005: effect of surgery volume on perioperative outcomes. Am J Gastroenterol 2008; 103(10):2454–2464.
13. Henneman D, Dikken JL, Putter H, Lemmens VE, Van der Geest LG, van Hillegersberg R, Verheij M, van de Velde CJ, Wouters MW. Centralization of esophagectomy: how far should we go? Ann Surg Oncol 2014; 21(13):4068–4074.
14. Aquina CT, Probst CP, Becerra AZ, Iannuzzi JC, Kelly KN, Hensley BJ, Rickles AS, Noyes K, Fleming FJ, Monson JR. High volume improves outcomes: The argument for centralization of rectal cancer surgery. Surgery 2016; 159(3):736–748.
15. Ryan CE, Wood TW, Ross SB, Smart AE, Sukharamwala PB, Rosemurgy AS. Pancreaticoduodenectomy in Florida: do 20-year trends document the salutary benefits of centralization of care? HPB (Oxford) 2015; 17(9):832–838.
16. Kubasiak J, Hood KC, Daly S, Deziel DJ, Myers JA, Millikan KW, Janssen I, Luu MB. Improved patient outcomes in paraesophageal hernia repair using a laparoscopic approach: a study of the national surgical quality improvement program data. Am Surg 2014; 80(9):884–9.
17. Mungo B, Molena D, Stem M, Feinberg RL, Lidor AO. Thirty-day outcomes of paraesophageal hernia repair using the NSQIP database: should laparoscopy be the standard of care? J Am Coll Surg 2014; 219(2):229–36.
18. Nguyen NT, Christie C, Masoomi H, Matin T, Laugenour K, Hohmann S. Utilization and outcomes of laparoscopic versus open paraesophageal hernia repair. Am Surg 2011; 77(10):1353–7.
19. Schlottmann F, Strassle PD, Farrell TM, Patti MG. Minimally invasive surgery should be the standard of care for paraesophageal hernia repair. J Gastrointest Surg 2017; 21(5):778–784.
20. Schlottmann F, Strassle PD, Patti MG. Comparative Analysis of Perioperative Outcomes and Costs Between Laparoscopic and Open Antireflux Surgery. J Am Coll Surg 2017; 224(3):327–333.
21. Schlussel AT, Delaney CP, Maykel JA, Lustik MB, Nishtala M, Steele SR. A National Database Analysis Comparing the Nationwide Inpatient Sample and American College of Surgeons National Surgical Quality Improvement Program in Laparoscopic vs Open Colectomies: Inherent Variance May Impact Outcomes. Dis Colon Rectum 2016; 59(9):843–854.
22. Polomsky M, Jones CE, Sepesi B, O'Connor M, Matousek A, Hu R, Raymond DP, Litle VR, Watson TJ, Peters JH. Should elective repair of intrathoracic stomach be encouraged? J Gastrointest Surg 2010; 14(2):203–210.
23. Jassim H, Seligman JT, Frelich M, Goldblatt M, Kastenmeier A, Wallace J, Zhao HS, Szabo A, Gould JC. A population-based analysis of emergent versus elective paraesophageal hernia repair using the Nationwide Inpatient Sample. Surg Endosc 2014; 28(12):3473–3478.
24. Augustin T, Schneider E, Alaedeen D, Kroh M, Aminian A, Reznick D, Walsh M, Brethauer S. Emergent Surgery Does Not Independently Predict 30-Day Mortality After Paraesophageal Hernia Repair: Results from the ACS NSQIP Database. J Gastrointest Surg 2015; 19(12):2097–2104.