World J Surg (2018) 42:2183–2189
https://doi.org/10.1007/s00268-017-4429-1

ORIGINAL SCIENTIFIC REPORT

Antireflux Surgery in the USA: Influence of Surgical Volume on Perioperative Outcomes and Costs—Time for Centralization?

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Published online: 30 December 2017

Abstract

Background Few studies have analyzed the relationship between surgical volume and outcomes after antireflux procedures. The aim of this study was to determine the effect of surgical volume on postoperative results and costs for patients undergoing surgery for gastroesophageal reflux disease.

Methods We analyzed the National Inpatient Sample (period 2000–2013). Adult patients (≥18 years old) with gastroesophageal reflux disease who underwent fundoplication were included. Hospital surgical volume was determined using the 30th and 60th percentile cut points using weighted discharges and categorized as low (<10 operations/year), intermediate (10–25 operations/year), or high (>25 operations/year). We performed multivariable logistic regression models to assess the effect of surgical volume on patient outcomes.

Results The studied cohort comprised 75,544 patients who had antireflux surgery. When operations performed at low-volume hospitals, postoperative bleeding, cardiac failure, renal failure, respiratory failure, and inpatient mortality were more common. In intermediate-volume hospitals, patients were more likely to have postoperative infection, esophageal perforation, bleeding, cardiac failure, renal failure, and respiratory failure. The length of hospital stay was longer at low- and intermediate-volume hospitals (1.08 and 0.55 days longer, respectively). There was an increase in charges of 5120 dollars per patient at low-volume centers, and 4010 dollars per patient at intermediate-volume centers.

Conclusions When antireflux surgery is performed at high-volume hospitals, morbidity is lower, length of hospital stay is shorter, and costs for the healthcare system are decreased.

Introduction

Gastroesophageal reflux disease (GERD) is the most common gastrointestinal disorder in the USA [1]. While most patients do well with lifestyle modifications and acid-reducing medications, others will need an antireflux operation because they have only partial control of symptoms, or experience complications related to the medications. The most commonly performed antireflux operation is the Nissen fundoplication (360°), which has long-term success in about 80–90% of patients [2–4].

Previous reports analyzed the benefit of centralizing high-risk surgical procedures, showing a decrease in postoperative

Oral presentation nominated for Grassi Prize during 47th World Congress of Surgery, Basel, Switzerland, August 13–17, 2017.

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complications and mortality in hospitals with a high volume [5–9]. The impact of surgical volume in less complex operations, such as fundoplication, however, remains elusive.

During the last decade, we have witnessed a decline in the number of antireflux procedures [10, 11]. This drop may be explained in part by the increased number of morbidly obese patients requiring bariatric surgery; however, poor outcomes of antireflux surgery in non-specialized centers may have contributed.

We used the National Inpatient Sample (NIS) to determine the effect of volume on outcome and cost for patients undergoing surgery for GERD. We hypothesize that antireflux surgery at low-volume hospitals is associated with poor postoperative outcomes and increased costs.

Methods

We performed a retrospective analysis of the NIS database during the period 2000–2013. The NIS is the largest publically available all-payer healthcare database in the USA and represents a 20% stratified sample of all hospitals in the USA. Using the International Classification of Diseases, ninth edition, Clinical Modification (ICD-9-CM) diagnostic and procedural codes, we included adult patients (≥18 years old) diagnosed with gastroesophageal reflux disease (530.11, 530.81, and 530.85) and who underwent fundoplication (44.66 and 44.67) during their inpatient hospitalization. Diagnostic codes for diaphragmatic hernia (551.3, 552.3, and 553.3) were not included in the analysis. Laparoscopic procedures were identified using codes 17.42, 44.67, 53.71, 53.83, and 54.21.

We included in our analysis the following surgical outcomes: postoperative complications, mortality, 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), bleeding (99.0–99.09, 998.11, and 998.12), esophageal perforation (42.82 and 530.4), cardiac failure (410–410.9, 428–428.9), renal failure (38.95, 39.95, 584–584.9, 586, and V45.11), respiratory failure (31.1–31.29, 96.04, 96.05, 96.7–96.72, and 799.1), and shock (998.0–998.09). A composite complication (i.e., at least one postoperative complication) was also analyzed.

Statistical analyses

Hospital surgical volume was determined using the 30th and 60th percentile cut points using weighted discharges. Yearly surgical volume was categorized as low (<10 operations/year), intermediate (10–25 operations/year), or high (>25 operations/year).

We compared patient demographics and outcomes across surgical volume using Chi-square and Wilcoxon–Mann–Whitney tests, where appropriate. Unadjusted, bivariate analyses of mortality, length of stay, hospital charges, and complication incidence across hospital volume were determined using Chi-square and Wilcoxon–Mann–Whitney tests.

Missing data for gender ($n = 228$, 0.3%), race/ethnicity ($n = 17{,}714$, 23.5%), primary insurance ($n = 321$, 0.4%), elective versus emergent admission status ($n = 17{,}177$, 22.7%), household income ($n = 1696$, 2.3%), hospital teaching status ($n = 330$, 0.4%), and bed size ($n = 330$, 0.4%) were estimated using Markov Chain Monte Carlo multiple imputation, $n = 40$.

We performed multivariable analyses on the potential effect of surgical volume on patient outcomes using logistic regression 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.

Finally, yearly trends in fundoplication usage in the USA were assessed using Poisson regression and tested using a likelihood ratio test. NIS discharge trend weights were used to get overall, national estimates.

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

A p value <0.05 was considered significant.

Results

The cohort comprised 75,544 patients. Between 2000 and 2013, 83.1% of patients underwent antireflux surgery in high-volume hospitals, 11.6% in intermediate-volume hospitals, and 5.3% in low-volume hospitals. Non-Hispanic White race, private primary insurance, and higher household income were more prevalent at high-volume hospitals. Table 1 shows patient and hospital characteristics stratified by hospital volume.

Among patients undergoing elective fundoplication, low- and intermediate-volume hospitals had a significantly higher incidence of esophageal perforation, bleeding, cardiac failure, and respiratory failure (Table 2). Among patients undergoing emergent fundoplication, low- and intermediate-volume hospitals had a significantly higher incidence of infection, bleeding, cardiac failure, and respiratory failure (Table 3). The median length of hospital

Table 1 Distribution of patient and hospital characteristics among adult patients undergoing fundoplication, 2000–2013, stratified by hospital volume, $n = 75{,}544$

	Low volume 3969 (5.3%)	Intermediate volume 8790 (11.6%)	High volume 62,785 (83.1%)
Gender, *n* (%)			
Male	1313 (33.1)	2875 (32.8)	22,714 (36.3)
Female	2651 (66.9)	5900 (67.2)	39,863 (63.7)
Age, median (IQR)	59 (47–70)	58 (46–69)	55 (43–67)
Race/Ethnicity, *n* (%)			
Non-Hispanic White	2731 (81.2)	6053 (83.0)	40,644 (86.2)
Non-Hispanic Black	223 (6.6)	386 (5.3)	2329 (4.9)
Hispanic	273 (8.1)	576 (7.9)	2597 (5.5)
Other	138 (4.1)	275 (3.8)	1605 (3.4)
Primary insurance, *n* (%)			
Private	1702 (43.2)	4105 (46.9)	35,458 (56.7)
Public	2010 (51.0)	4200 (48.0)	24,445 (39.1)
Other/self-pay	232 (5.9)	442 (5.1)	2629 (4.2)
Household income[a], *n* (%)			
Low	1061 (27.5)	1939 (22.7)	10,021 (16.3)
Medium	1115 (28.9)	2444 (28.6)	16,562 (27.0)
High	896 (23.2)	2191 (25.6)	16,898 (27.5)
Highest	792 (20.5)	1985 (23.2)	17,944 (29.2)
Comorbidities, *n* (%)			
Hypertension	1593 (40.1)	3342 (38.0)	21,489 (34.2)
Diabetes	390 (9.8)	753 (8.6)	4855 (7.7)
Obesity	403 (10.2)	1000 (11.4)	6437 (10.3)
Renal insufficiency	61 (1.5)	133 (1.5)	607 (1.0)
Coronary artery disease	317 (8.0)	660 (7.5)	3956 (6.3)
Peripheral vascular disease	31 (0.8)	79 (0.9)	450 (0.7)
COPD	84 (2.1)	147 (1.7)	978 (1.6)
Sleep apnea	125 (3.2)	252 (2.9)	1673 (2.7)
Elective admission, *n* (%)	1594 (74.3)	3714 (77.9)	43,627 (84.8)
Laparoscopic, *n* (%)	2404 (60.6)	5522 (62.8)	36,163 (57.6)
Hospital size, *n* (%)			
Small	1042 (26.3)	1769 (20.2)	5978 (9.6)
Medium	1293 (32.6)	2891 (33.0)	14,031 (22.5)
Large	1628 (41.1)	4112 (46.9)	42,470 (68.0)
Hospital type, *n* (%)			
Urban, teaching	897 (22.6)	1883 (21.5)	34,698 (55.5)
Urban, nonteaching	1889 (47.7)	4221 (48.1)	20,751 (33.2)
Rural, nonteaching	1177 (29.7)	2668 (30.4)	7030 (11.3)
Hospital region, *n* (%)			
Northeast	627 (15.8)	1320 (15.0)	9508 (15.1)
Midwest	920 (23.2)	2196 (25.0)	16,338 (26.0)
South	1658 (41.8)	3337 (38.0)	20,915 (33.3)
West	764 (19.3)	1937 (22.0)	16,024 (25.5)

IQR interquartile range, *COPD* chronic obstructive pulmonary disease

[a]Between 2000 and 2002, household income was characterized by the following quartiles: \$1–\$24,999 (low), \$25,000–\$34,999 (medium), \$35,000–\$44,999 (high), and \$45,000 and above (highest); from 2003 onward, income was characterized into quartiles within each ZIP code

Table 2 Incidence of postoperative complications, length of stay, and total hospital charges, among adults undergoing elective fundoplication, stratified by hospital surgical volume, $n = 48{,}935$

	Low volume 1594 (3.2%)	Intermediate volume 3714 (7.6%)	High volume 43,627 (89.2%)	p value[a]
Postoperative complications, *n* (%)				
Mortality	<11	<11	123 (0.3)	0.44
Venous thromboembolism	27 (1.7)	54 (1.5)	878 (2.0)	**0.05**
Wound complications	<11	12 (0.3)	138 (0.3)	0.99
Infection	16 (1.0)	36 (1.0)	353 (0.8)	0.43
Esophageal perforation	16 (1.0)	40 (1.1)	288 (0.7)	**0.005**
Bleeding	93 (5.8)	125 (3.4)	1032 (2.4)	**<0.0001**
Cardiac failure	51 (3.2)	77 (2.1)	735 (1.7)	**<0.0001**
Renal failure	11 (0.7)	18 (0.5)	302 (0.7)	0.33
Respiratory failure	39 (2.5)	53 (1.4)	600 (1.4)	**0.002**
Shock	<11	<11	34 (0.1)	0.69
Any complication[b], *n* (%)	203 (12.7)	342 (9.2)	3371 (7.7)	**<0.0001**
Length of stay, in days, median (IQR)	3 (1–5)	2 (2–4)	2 (1–3)	**<0.0001**
Charges, in thousands, median (IQR)	21.4 (14.9–32.4)	20.5 (13.9–31.1)	18.8 (13.0–29.1)	**<0.0001**

IQR interquartile range

[a]Chi-square and Wilcoxon–Mann–Whitney tests were used, where appropriate; p values <0.05 are denoted in bold

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

Table 3 Incidence of postoperative complications, length of stay, and total hospital charges, among adults undergoing emergent fundoplication, stratified by hospital surgical volume, $n = 9432$

	Low volume 551 (5.8%)	Intermediate volume 1052 (11.2%)	High volume 9432 (83.0%)	p value[a]
Postoperative complications, *n* (%)				
Mortality	<11	17 (1.6)	93 (1.2)	0.26
Venous thromboembolism	14 (2.5)	22 (2.1)	216 (2.8)	0.44
Wound complications	<11	<11	44 (0.6)	0.83
Infection	22 (4.0)	36 (3.4)	183 (2.3)	**0.01**
Esophageal perforation	12 (2.2)	26 (2.5)	143 (1.8)	0.32
Bleeding	63 (11.4)	116 (11.3)	522 (6.7)	**<0.0001**
Cardiac failure	39 (7.1)	50 (4.8)	372 (4.8)	**0.05**
Renal failure	24 (4.4)	46 (4.4)	249 (3.2)	0.06
Respiratory failure	41 (7.4)	82 (7.8)	336 (4.3)	**<0.0001**
Shock	<11	<11	14 (0.2)	**0.04**
Any complication[b], *n* (%)	144 (26.1)	249 (23.7)	1439 (18.4)	**<0.0001**
Length of stay, in days, median (IQR)	6 (3–11)	5 (2–10)	3 (2–8)	**<0.0001**
Charges, in thousands, median (IQR)	31.0 (17.7–58.1)	25.6 (16.1–50.5)	25.9 (15.2–49.1)	**0.0002**

IQR interquartile range

[a]Chi-square and Wilcoxon–Mann–Whitney tests were used, where appropriate; p values <0.05 are denoted in bold

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

stay was significantly shorter in high-volume hospitals in both elective and emergent procedures (Tables 2, 3).

After adjusting for patient and hospital characteristics, patients at low-volume (odds ratio [OR] 1.53, 95% confidence interval [CI] 1.38, 1.70) and intermediate-volume (OR 1.27, 95% CI 1.18, 1.38) hospitals were still significantly more likely to have postoperative complications, compared to patients at high-volume hospitals. When

Table 4 Adjusted odds ratios of low and intermediate surgical volumes, compared to high volume, on postoperative complications, length of stay, and hospital charges among adult patients undergoing fundoplication

	Low volume			Intermediate volume		
	Odds ratio	95% CI	*p* value	Odds ratio	95%CI	*p* value
Postoperative complications						
Venous thromboembolism	1.01	0.80, 1.27	0.94	0.89	0.75, 1.05	0.18
Wound complications	0.95	0.55, 1.67	0.87	1.18	0.81, 1.72	0.38
Infection	1.26	0.96, 1.65	0.10	1.23	1.00, 1.50	**0.05**
Esophageal perforation	1.36	0.98, 1.88	0.07	1.59	1.27, 1.99	**<0.0001**
Bleeding	1.67	1.43, 1.94	**<0.0001**	1.38	1.22, 1.55	**<0.0001**
Cardiac failure	1.57	1.30, 1.90	**<0.0001**	1.21	1.04, 1.41	**0.01**
Renal failure	1.60	1.25, 2.06	**0.0002**	1.33	1.09, 1.61	**0.004**
Respiratory failure	1.60	1.31, 1.96	**<0.0001**	1.43	1.23, 1.67	**<0.0001**
Shock	1.44	0.67, 3.10	0.35	1.32	0.74, 2.38	0.35
Mortality	1.52	1.02, 2.28	**0.04**	1.31	0.95, 1.81	0.10
Any complication[a]	1.53	1.38, 1.70	**<0.0001**	1.27	1.18, 1.38	**<0.0001**
	Change in estimate	95% CI	*p* value	Change in estimate	95% CI	*p* value
Length of stay, in days	1.08	0.90, 1.25	**<0.0001**	0.55	0.43, 0.67	**<0.0001**
Charges, in thousands	5.12	3.59, 6.78	**<0.0001**	4.01	2.90, 5.13	**<0.0001**

CI confidence interval

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

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

antireflux surgery was performed at low-volume hospitals, postoperative bleeding, cardiac failure, renal failure, respiratory failure, and inpatient mortality were more common. Patients at intermediate-volume hospitals were more likely to have postoperative infection, esophageal perforation, bleeding, cardiac failure, renal failure, and respiratory failure. On average, patients at low- and intermediate-volume hospitals stayed 1.08 and 0.55 days longer, respectively. There was an increase in charges of 5120 dollars and 4010 dollars per patient at low- and intermediate-volume centers, respectively (Table 4).

Overall, the number of procedures significantly decreased during the study period, from 33,795 procedures in 2000 to 24,540 procedures in 2013, $p < 0.0001$ (Fig. 1).

Discussion

The aim of this study was to determine the effect of surgical volume on postoperative outcomes and costs for patients undergoing antireflux surgery. We found that procedures performed at high-volume hospitals were associated with better postoperative outcomes, shorter length of hospital stay, and lower costs for the healthcare system.

The relationship between volume of operations and patient outcomes, in terms of morbidity and mortality, has been mostly studied in complex oncologic procedures [5, 9]. Evidence from these studies has been used to support initiatives to centralize high-risk operations into high-volume centers [12–14]. However, the impact of surgical volume on less complex procedures, such as surgery for benign esophageal disorders, remains elusive. For the surgical treatment of achalasia, Wang and colleagues [15] stated that high-volume centers were associated with shorter hospital stay and lower costs. Specifically for antireflux surgery, Colavita et al. [16] reported that there was an increase in postoperative morbidity because these procedures were more frequently performed at low-volume hospitals. On the other hand, Varban et al. [17] studied 1019 patients who underwent antireflux surgery in North Carolina between 2005 and 2008 and found no differences in mortality rates or median length of stay between low- and high-volume hospitals. Opposite to these findings, we found that patients at low- and intermediate-volume centers were more likely to have postoperative complications and had, on average, longer hospital stays. Enhancements in surgical technology and technique and significant improvements in perioperative care may explain the better outcomes found in high-volume hospitals. In addition to better postoperative outcomes, we found that antireflux surgery was more cost-effective when performed at high-volume hospitals. After adjusting for patient and hospital

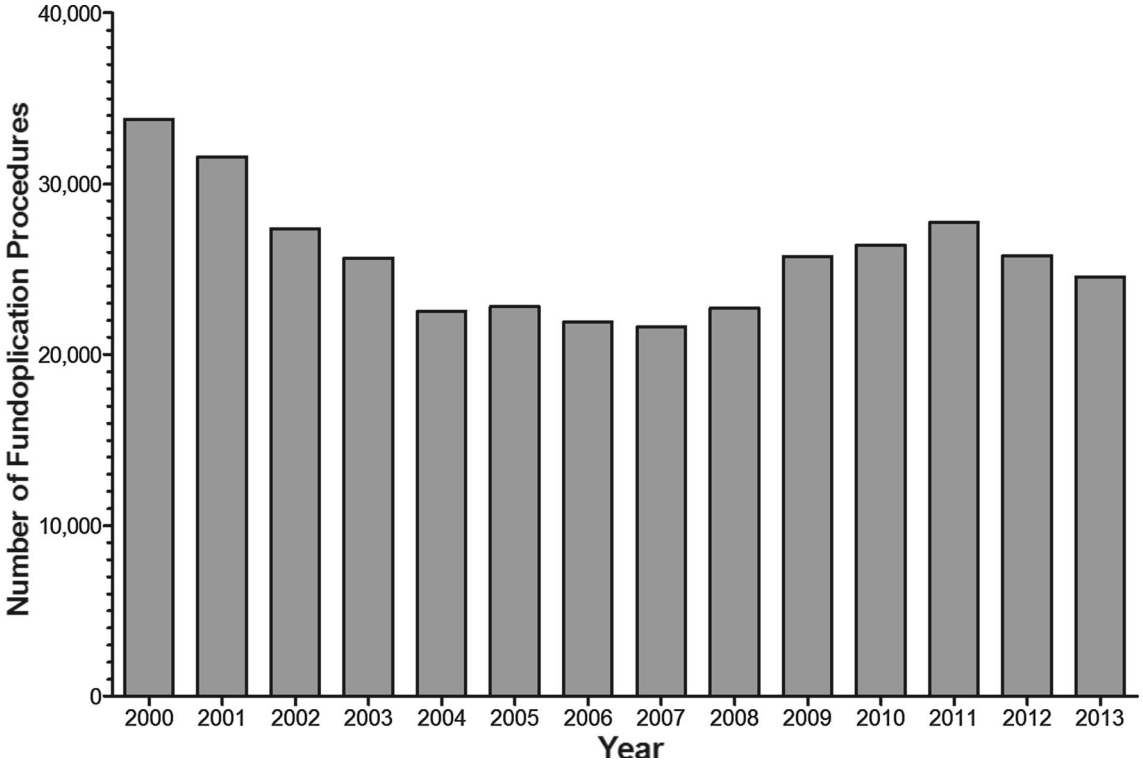

Fig. 1 Number of antireflux operations in the USA during the period 2000–2013

characteristics, there was an increase in charges of 5120 dollars and 4010 dollars per patient at low- and intermediate-volume centers, respectively.

Reasonably, the majority of high-volume centers in our analysis consisted in urban teaching hospitals. Thus, some patients would need to travel long distances to undergo surgery in these centers. This may be challenging due to patients' unwillingness or economic limitation to travel. Our analysis also showed that patient's access to high-volume hospitals was influenced by racial and socioeconomic factors. Non-Hispanic White race, private primary insurance, and higher household income were more prevalent at high-volume centers.

Remarkably, we noticed low rates of operations performed by minimally invasive techniques during the period 2000–2013, even at high-volume hospitals (57.6%). This is quite impressive considering that the first laparoscopic antireflux operation was reported by Bernard Dallemagne in Belgium in 1991 [18]. The high rates of open surgery may be due to older surgeons who never embraced laparoscopy, factors that might have led surgeons to perform a laparotomy rather than laparoscopy (redo-operation, high-risk patients, or patients with multiple prior abdominal operations), or simply coding errors in patient discharge records (denoting laparoscopic procedures is a separate, additional procedure code). Unfortunately, the NIS database does not provide this information. However, slow nationwide implementation of laparoscopy in USA has also occurred for other procedures, such as colorectal surgery [19]. Schlussel et al. showed that the percentage of open colectomies in the USA was 64.3% with NIS data (period 2006–2012) and 51% with NSQIP data (period 2006–2013) [19]. As laparoscopic antireflux surgery has shown significant advantages as compared to open surgery [3, 20, 21], we hope that laparoscopy will be fully embraced in the USA in the near future.

Our data also showed that between 2000 and 2013, fewer fundoplications were performed in the USA. Similar findings have been documented by others [10, 11, 22]. The increased number of bariatric operations for morbid obesity partially explains these findings. Poor outcomes of antireflux surgery may have caused an increased reluctance on the part of the gastroenterologists to refer patients for surgery.

This study has several limitations. First, with NIS data, we are unable to measure patients' outcomes that occur after the initial hospital discharge. Second, there are potential coding errors and differences in coding practices across centers in a large national database. Third, NIS does not provide details about the complexity of the cases (e.g., redo operations or surgical history of the patients), and we were not able to adjust for it.

In conclusion, antireflux surgery at high-volume hospitals was associated with a decreased number of complications, a shorter length of hospitalization, and decreased costs for the healthcare system.

These data suggest that implementation of volume standards would benefit patients undergoing fundoplication for the treatment of GERD.

Compliance with ethical standards

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

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