Published in final edited form as:

Surg Obes Relat Dis. 2010 March 4; 6(2): 118–125. doi:10.1016/j.soard.2009.09.009.

The Relationship between Surgeon Volume and Adverse Outcomes after RYGB in the Longitudinal Assessment of Bariatric Surgery (LABS) Study

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Abstract

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Presented at the plenary session of the American Society of Metabolic and Bariatric Surgery meeting in Grapevine, Texas, 2009

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Background—Bariatric surgery is technically demanding surgery performed on high-risk patients. Previous studies using administrative databases have shown a relationship between surgeon volume and patient outcome following Roux-en-Y gastric bypass (RYGB).

Objective—To examine the relationship between surgeons' annual RYGB volumes and 30-day patient outcomes.

Setting—Ten centers within the United States.

Methods—LABS-1 is a prospective study examining 30-day adverse outcomes following bariatric surgery. Outcome following RYGB was adjusted for procedure type (open vs. laparoscopic), functional status, BMI, past history of deep vein thrombosis (DVT), pulmonary embolism (PE) and obstructive sleep apnea (OSA). The data were examined to determine the nature and strength of association between surgeon's volume and patients' short-term (30-day) adverse outcome following RYGB surgery.

Results—The analysis included 3410 initial RYGB operations performed by 31 surgeons, 15 of whom averaged fewer than 50 cases/year. The crude composite adverse outcome (death, DVT, PE, re-intervention or non-discharge at day 30) incidence was 5.2%. After risk adjustment, higher surgeon RYGB volume was associated with lower CE rates with a continuous relationship (i.e., various cutpoints differentiated rates of CE) such that for each 10 cases/year increase in volume the risk of CE is decreased by 10%.

Conclusions—In LABS, patient's risk of an adverse outcome following RYGB operation decreased significantly with the increase in surgeon's RYGB volume (cases per year).

Keywords

LABS; RYGB; volume-outcome; complications

Introduction

Obesity is a major public health issue in the United States and worldwide. According to the Centers for Disease Control and Prevention, in 2007 26.3% of the United States population was considered obese (body mass index [BMI] greater than 30 kg/m²)¹. This figure has been steadily rising, up from 20.1% in 2000 and 15.9% in 1995. Worldwide, obesity is an increasing problem for developed and developing nations. The World Health Organization predicts by 2015 more than 700 million adults will be obese². The increasing prevalence of obesity is associated with an increasing incidence of type 2 diabetes, cardiovascular disease and some cancers.

For obese patients the low levels of weight loss achieved through non-surgical means, combined with the high levels of recidivism, led to the National Institutes of Health (NIH) convening a Consensus Development Conference leading to a consensus statement in 1991³. This now 18 year old document advocates considering bariatric surgery in severely obese patients who are unsuccessful at non-surgical weight loss. In 2003 over 100,000 bariatric surgical procedures were performed in the United States, and over 80% of these were roux-en-Y gastric bypass surgeries⁴. Laparoscopic roux-en-Y gastric bypass remains the most frequently performed bariatric procedure in the United States although there is growing interest in laparoscopic adjustable gastric banding⁵, and more recently sleeve gastrectomy⁶.

Roux-en-Y gastric bypass is a technically demanding operation, and patients undergoing bariatric surgery are frequently at high surgical risk. Reported mortality rates vary from 0.2 to 2% for this operation^{7,8}. Furthermore serious complications such as anastomotic leak and pulmonary embolism are reported in 0.6 to 4.4% of patients⁹.

Previous authors have examined the relationship between hospital or surgeon volume and complication rates following Roux-en-Y gastric bypass^{10–15}. All were conducted using administrative databases with limited information on patient co-morbidities and outcomes. These studies have reported mixed findings on whether surgeon volume influences patient outcome.

In an attempt to improve outcomes for patients undergoing bariatric surgery two ‘center of excellence’ accreditation programs have been developed in the United States. One is overseen by the Surgical Review Corporation¹⁶ (SRC) and the other by the American College of Surgeons¹⁷ (ACS). Both of these programs require that accredited bariatric centers have at least two surgeons who perform an average of 50 or more bariatric procedures annually. Prospective testing of this volume threshold has not been published in the peer reviewed literature.

The Longitudinal Assessment of Bariatric Surgery (LABS) is a multi-center observational cohort study conducted by the National Institute of Diabetes, Digestive and Kidney Diseases (NIDDK) in the National Institute of Health (NIH). It involves prospective, standardized and comprehensive collection of clinical data, and includes several related studies. LABS-1 comprised 30-day outcome data on consecutive patients, 18 years or older, undergoing an initial bariatric procedure.

The aim of the present study is to determine the relationship between surgeon volume of gastric bypass procedures and patient outcome in LABS-1 patients undergoing roux-en-Y gastric bypass, and to investigate the volume threshold of 50 cases per year for the 30 day outcome.

Methods

LABS-1 procedures were conducted by 33 LABS certified surgeons at: University of Pittsburgh Medical Center (Pennsylvania), New York-Presbyterian Hospital [Columbia and Weill-Cornell Medical Centers] (New York), East Carolina Medical Center (North Carolina), the MeritCare Health Systems through the Neuropsychiatric Research Institute (North Dakota), Sacramento Bariatric (California), University of Washington Medical Center or Virginia Mason Medical Center (Washington), and Oregon Health and Sciences University or Legacy Good Samaritan Hospital (Oregon). The LABS-1 protocol and consent form were approved by the Institutional Review Board at each institution.

The LABS-1 inclusion criteria and data collection has previously been described in detail¹⁸. Data were collected prospectively on consecutive patients aged 18 years and above between March 2005 and December 2007 and sent to the Data Coordinating Center at the University of Pittsburgh, Graduate School of Public Health.

Participating surgeons completed a questionnaire on their previous experience in bariatric surgery prior to participating in LABS (lifetime number of cases performed, number of years performing bariatric surgery and recent volume over the preceding 12 months). The lifetime cases were collected in categories of 0–24, 25–99, 100–499, 500–999, 1000–1499, 1500–1999, 2000–2999, and 3000+ separately for each procedure type. For the purposes of analysis, a surgeon’s lifetime experience is represented by the mid-point of the lifetime experience category. A surgeon’s volume in LABS is calculated as the ratio of total number of RYGB surgeries performed by that surgeon in LABS and the number of years between first and last RYGB surgery included in LABS for that surgeon.

In addition to post-operative mortality, data were collected on the composite event (CE) created for the LABS-1 main paper¹⁹. The CE is defined as occurrence of any one of the following

events: death, venous thrombosis, pulmonary embolism, re-operation, non-discharge at 30-days, or re-hospitalization within 30 days following initial discharge.

Patient and surgeon characteristics are described using summary statistics such as frequencies, percentages, means, confidence intervals, medians and quartiles. Characteristics across categories were compared using Pearson's chi-square test for categorical variables and the Kruskal-Wallis test for continuous variables. To summarize the 30-day adverse outcomes across different categories of surgeon and patient characteristics, we used crude incidence rates and 95% confidence intervals. Multilevel univariable and multivariable generalized linear Poisson regression models were used to evaluate the relative risk of the 30-day CE. Level 1 variables included patient demographic and health status characteristics and level 2 included the surgeon experience and volume variables. Clustering among patients undergoing surgery at the same site and by the same surgeon was accounted for using different random intercepts for sites and for surgeons within site. Since the focus of this analysis was on surgeon volume, the multivariable model included the surgeon characteristics along with other patient-level characteristics that were previously shown to be associated with 30-day outcome in LABS-1¹⁹. Results are presented using relative risks and 95% confidence intervals. Since the unadjusted relationship between 30-day adverse outcome and the BMI showed a quadratic pattern, both linear and quadratic terms of BMI were considered as predictors in the model. For all tests a p-value of <0.05 was considered to be statistically significant. Predicted event rates for a surgeon were calculated by averaging the predicted rates of CE for individual patients within that surgeon. For all statistical analyses, SAS 9.1.3 (SAS Institute Inc., Cary, NC) was used.

Results

The LABS-1 data set included 3412 first-time Roux-en-Y gastric bypass (RYGB) operations out of a total of 5069 bariatric operations performed by 33 surgeons. Two surgeons performed only one RYGB operation each and were excluded from the analysis, leaving a total of 3410 RYGB operations (31 surgeons). Fifteen surgeons performed an average of 49 or fewer RYGB operations per year in LABS. Of surgeons averaging at least 50 RYGB operations per year, 9 averaged 50 to 99, and 7 averaged 100 or more. For the 30 surgeons for whom self-reported surgeon experience data were available, half performed bariatric surgery for at least 5 years prior to participating in LABS with 7 surgeons having at least 10 years of bariatric surgery experience. The number of cases performed in the 12 months prior to LABS participation ranged from 20 to 450, with a median of 117.5 cases. The median estimated number of lifetime cases prior to LABS was 649, with a quarter of surgeons having performed more than 1000 cases.

Of the 3410 people who underwent RYGB surgeries, 437(12.8%) had open RYGB procedure. The median age was 44.0 years, the median BMI was 47.2 kg/m², 19.8% were men and 89.1% were white. More than half (56.2%) of the participants had at least two of the recorded co-morbidities, hypertension being the most common (55.7%) followed by obstructive sleep apnea [OSA](50.5%), diabetes(35.9%), and asthma (23.8%). These characteristics were similar to those in the full LABS-1 cohort¹⁹, and are described in Table 1 and Table 2.

There were 15 (0.4%) deaths and 177 patients (5.2%) had at least one of the adverse outcomes comprising the composite endpoint. The distribution of adverse outcomes according to surgeon annual case volume is shown in Table 3. No significant difference was observed between the mortality rates of low and high volume surgeons although this study had little power to detect any but extreme differences. As surgeon annual RYGB case volume increased, however, the percentage of participants with a CE decreased significantly. In univariable analysis, surgeon's LABS RYGB volume was inversely associated with the CE (RR = 0.89 per 10 cases/year, 95%

CI 0.84–0.95). Patient BMI, functional status, history of DVT and history of OSA that were shown to be significantly associated with adverse outcomes in the full cohort¹⁹ were also significantly associated in this sub-cohort of RYGB patients (Table 4). After adjusting for procedure type (open vs. laparoscopic) and the aforementioned patient characteristics (patient BMI, functional status, history of DVT, and history of OSA), higher surgeon RYGB volume was associated with lower CE rates (RR = 0.90, 95% CI: 0.82–0.98) such that for each 10 cases/year increase in volume, the rate of CE decreased by 10%. The independent and continuous effect of surgeon annual RYGB case volume on predicted CE rate is shown for four hypothetical patients in Figure 1. The self-reported surgeon experience data (case volume prior to LABS, lifetime bariatric experience, and number of years practicing bariatric surgery) were not significantly associated with the CE in either the univariable model or multivariable model (Table 4).

There were two low-volume surgeons with high CE rates. Analysis excluding these two surgeons produced a similar result (RR of CE = 0.92, 95% CI 0.85–0.99 per 10 cases/year volume). Surgeons' annual adjustable gastric band volume within LABS was not significantly associated with the CE rate following RYGB surgeries (RR=0.97 95% CI 0.88–1.07 per 10 LAGB cases/year). Furthermore inclusion of band volume as a separate adjusting variable in the multivariable model did not affect the association between RYGB volume and RYGB CE rates (RR=0.90 95% CI 0.84–0.97 per 10 RYGB cases/year).

Discussion

The findings of this study support the hypothesis that surgeon annual case volume of RYGB is inversely associated with the risk of adverse post-operative outcomes. This relationship appears continuous, with risk continuing to decrease as annual case volume is increased. Annual laparoscopic adjustable gastric band volume was not significantly associated with CE rate after RYGB. There were no significant associations between self reported surgeon experience prior to LABS participation and patient short-term adverse outcomes. In this cohort, mortality was too uncommon to draw any conclusions about surgeon annual case volume and 30-day post-operative mortality risk.

Although this is the first study on the volume outcome relationship following RYGB using a prospectively collected clinical database, similar findings have been seen in other studies. In 2003 Courcoulas et al¹¹ reviewed outcomes after RYGB in Pennsylvania using an administrative database. They found that surgeons performing fewer than 50 RYGBs per year had a significantly increased rate of post-operative complications compared to those with higher volume. Furthermore this effect was magnified when low volume surgeons operated in low volume hospitals. Another study from New York State in 2006 found that both surgeon volume of fewer than 25 cases per year and low hospital volume was associated with increased risk of complications¹⁵. This study also used an administrative database and looked at patients undergoing gastropasty as well as RYGB for treating morbid obesity. Two other studies using administrative data looking at hospital volume alone also found an association between low volume and increased post-operative complications^{12,14}. Another study on complications following RYGB found that hospital size, in number of beds, rather than annual hospital case volume, influenced complication rates¹⁰.

The concept of a relationship between low surgeon volume and increased post-operative complications has also been proposed in other surgical disciplines. Most of these studies address volume at a hospital level rather than surgeon volume. Relationships between hospital annual case volume and post-operative outcomes have been described for pancreaticoduodenectomy²⁰, abdominal aortic aneurysm repair²¹, Heller myotomy for achalasia²², and laparoscopic colorectal surgery²³. Conversely, a volume outcome study of laparoscopic

colorectal surgery, in the setting of a randomized trial, did not find a significant relationship between volume and outcome²⁴.

There are several possible explanations for the relationship between surgeon annual case volume and short-term patient safety outcome. High volume surgeons may be more likely to operate at high volume hospitals, which may provide better multi-disciplinary care²⁵. High volume surgeons may also systematically differ in their technique from low volume surgeons, or vary their technique when operating on high risk patients.

Another possibility is that case-mix may be different with high volume surgeons operating on proportionally fewer high risk patients. Extremes of BMI, obstructive sleep apnea, history of venous thromboembolism and inability to walk 200ft have been found to be independent risk factors for poor outcome in LABS¹⁹. This study found that high volume surgeons operated on proportionally fewer patients who could not walk 200 feet than lower volume surgeons; however the higher volume surgeons operated on a higher percentage of patients with obstructive OSA than did lower volume surgeons. The prevalence of other risk factors was similar between low and high volume surgeons. The relationship between surgeon volume and the composite endpoint persisted even after adjusting for these risk factors.

This study did not find a statistically significant difference between surgeon experience data prior to participation in LABS and short-term patient safety outcome. It is possible that a real effect has been missed due to the self-reported and categorical nature of these data. The surgeon experience (i.e., at least 25 cases with gastric bypass, adjustable gastric band, vertical banded gastroplasty or biliopancreatic diversion plus “minimal” experience with each procedure being performed on a LABS participant) and credentialing requirements for LABS (medical degree, general surgery residence training, board certification or F.A.C.S. or F.R.C.S.C.) may have negated the learning curve effect of pre-LABS experience in the study surgeons. It is also possible that current volume is more important than previous or lifetime experience in RYGB when it comes to post-operative complication rates.

The LABS-1 study involved only a small proportion of bariatric centers and surgeons within the United States. All hospitals were accredited centers of excellence by the end of the LABS study. The minimum standards for surgeon experience and hospital facilities that must be met for such accreditation have led to a highly standardized study environment, however, it may limit the generalizability of these findings to other bariatric surgeons and centers.

It is noteworthy that a relationship between volume and outcome was demonstrated within the tightly controlled environment of this study. Even when minimum standards are set for surgeon experience and hospital facilities, increased surgeon annual RYGB case volume is still associated with decreased post-operative CE rates. The observed relationship between annual RYGB volume and CE rate was continuous, and did not suggest any specific annual volume threshold for surgeon credentialing requirements. The impact of specific surgeon and hospital processes on outcome will be addressed in future studies.

Acknowledgments

This clinical study was a cooperative agreement funded by the National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK). Grant numbers: DCC -U01 DK066557; Columbia-Presbyterian - U01-DK66667; University of Washington - U01-DK66568 (in collaboration with GCRC, Grant M01RR-00037); Neuropsychiatric Research Institute - U01-DK66471; East Carolina University – U01-DK66526; University of Pittsburgh Medical Center – U01-DK66585; Oregon Health & Science University – U01-DK66555.

References

1. National Center for Chronic Disease Prevention & Health Promotion. Prevalence and Trends Data. Overweight and Obesity (BMI).
2. World Health Organisation. Fact sheet No 311. Obesity and overweight.
3. Gastrointestinal Surgery for Severe Obesity; NIH Consensus Statement Online. 1991. p. 1-20.
4. Santry HP, Gillen DL, Lauderdale DS. Trends in bariatric surgical procedures. *JAMA* 2005;294:1909–1917. [PubMed: 16234497]
5. Hinojosa MW, Varela JE, Parikh D, Smith BR, Nguyen XM, Nguyen NT. National trends in use and outcome of laparoscopic adjustable gastric banding. *Surg Obes Relat Dis* 2009;5:150–155. [PubMed: 18849200]
6. Iannelli A, Dainese R, Piche T, Facchiano E, Gugenheim J. Laparoscopic sleeve gastrectomy for morbid obesity. *World J Gastroenterol* 2008;14:821–827. [PubMed: 18240338]
7. Flum DR, Salem L, Elrod JA, Dellinger EP, Cheadle A, Chan L. Early mortality among Medicare beneficiaries undergoing bariatric surgical procedures. *JAMA* 2005;294:1903–1908. [PubMed: 16234496]
8. Maggard MA, Shugarman LR, Suttrop M, et al. Meta-analysis: surgical treatment of obesity. *Ann Intern Med* 2005;142:547–559. [PubMed: 15809466]
9. Nguyen NT, Wilson SE. Complications of antiobesity surgery. *Nat Clin Pract Gastroenterol Hepatol* 2007;4:138–147. [PubMed: 17339851]
10. Carbonell AM, Lincourt AE, Matthews BD, Kercher KW, Sing RF, Heniford BT. National study of the effect of patient and hospital characteristics on bariatric surgery outcomes. *Am Surg* 2005;71:308–314. [PubMed: 15943404]
11. Courcoulas A, Schuchert M, Gatti G, Luketich J. The relationship of surgeon and hospital volume to outcome after gastric bypass surgery in Pennsylvania: a 3-year summary. *Surgery* 2003;134:613–621. discussion 621-3. [PubMed: 14605622]
12. Liu JH, Zingmond D, Etzioni DA, et al. Characterizing the performance and outcomes of obesity surgery in California. *Am Surg* 2003;69:823–828. [PubMed: 14570356]
13. Morino M, Toppino M, Forestieri P, Angrisani L, Allaix ME, Scopinaro N. Mortality after bariatric surgery: analysis of 13,871 morbidly obese patients from a national registry. *Ann Surg* 2007;246:1002–1007. discussion 1007-9. [PubMed: 18043102]
14. Nguyen NT, Paya M, Stevens CM, Mavandadi S, Zainabadi K, Wilson SE. The relationship between hospital volume and outcome in bariatric surgery at academic medical centers. *Ann Surg* 2004;240:586–593. discussion 593-4. [PubMed: 15383786]
15. Weller WE, Rosati C, Hannan EL. Relationship between surgeon and hospital volume and readmission after bariatric operation. *J Am Coll Surg* 2007;204:383–391. [PubMed: 17324771]
16. Surgical Review Corporation. BSCOE Requirements: Provisional Status.
17. American College of Surgeons Bariatric Surgery Center Network Accreditation Program. Bariatric Accreditation Program Manual.
18. Belle SH, Berk PD, Courcoulas AP, et al. Safety and efficacy of bariatric surgery: Longitudinal Assessment of Bariatric Surgery. *Surg Obes Relat Dis* 2007;3:116–126. [PubMed: 17386392]
19. Flum D, Belle SH, Berk PD, et al. Peri-operative safety in the longitudinal assessment of bariatric surgery. *New Eng. J of Med*. Accepted.
20. Eppsteiner RW, Csiksz NG, McPhee JT, Tseng JF, Shah SA. Surgeon volume impacts hospital mortality for pancreatic resection. *Ann Surg* 2009;249:635–640. [PubMed: 19300225]
21. Eckstein HH, Bruckner T, Heider P, et al. The relationship between volume and outcome following elective open repair of abdominal aortic aneurysms (AAA) in 131 German hospitals. *Eur J Vasc Endovasc Surgery* 2007;34:260–266.
22. Wang YR, Dempsey DT, Friedenberg FK, Richter JE. Trends of heller myotomy hospitalizations for achalasia in the United States, 1993–2005 Effect of. *Am J Gastroenterol*. 2008
23. Kuhry E, Bonjer HJ, Haglind E, et al. Impact of hospital case volume on short-term outcome after laparoscopic operation for colonic cancer. *Surg Endosc* 2005;19:687–692. [PubMed: 15798899]

24. Larson DW, Marcello PW, Larach SW, et al. Surgeon volume does not predict outcomes in the setting of technical credentialing: results from a randomized trial in colon cancer. *Ann Surg* 2008;248:746–750. [PubMed: 18948801]
25. Joseph B, Morton JM, Hernandez-Boussard T, Rubinfeld I, Faraj C, Velanovich V. Relationship between hospital volume, system clinical resources, and mortality in pancreatic resection. *J Am Coll Surg* 2009;208:520–527. [PubMed: 19476785]
26. Livingston EH, Elliott AC, Hynan LS, Engel E. When policy meets statistics: the very real effect that questionable statistical analysis has on limiting health care access for bariatric surgery. *Arch Surg* 2007;142:979–987. [PubMed: 17938312]

Figure 1.

Predicted CE rate by Surgeon Annual RYGB Volume

Risk of 30-day adverse outcome by surgeon's RYGB LABS volume for selected patients having RYGB surgery with a BMI of 48.8 kg/m² (mean BMI of the analysis cohort):

Patient A. Can walk 200ft, no OSA, no DVT

Patient B. Can walk 200ft, with OSA, no DVT

Patient C. Can't walk 200ft, with OSA, no DVT

Patient D. Can't walk 200ft, with OSA and DVT

Table 1
Demographics of LABS-1 Participants with RYGB surgeries by Low/High Surgeon Volume

Characteristic	Surgeon LABS RYGB Volume (cases/year)						p_value*
	Total (N=3409)	n	%	0-49 (N=812)	n	%	
Patient age (years), mean, median	43.9, 44.0			43.5, 44.0			
Patient age (years)							
<30	358	10.5	101	12.4	257	9.9	
30-39	917	26.9	206	25.4	711	27.4	
40-49	1001	29.4	247	30.4	754	29.0	
50-59	856	25.1	190	23.4	666	25.6	
60-64	208	6.1	57	7.0	151	5.8	
65+	69	2.0	11	1.4	58	2.2	
BMI (kg/m ²), mean, median	48.8, 47.2			49.3, 47.4			0.13
BMI (kg/m ²)							0.40
<35	21	0.6	5	0.6	16	0.6	
35-<40	340	10.0	83	10.2	257	9.9	
40-<50	1787	52.4	407	50.1	1380	53.1	
50-<60	933	27.4	226	27.8	707	27.2	
60+	328	9.6	91	11.2	237	9.1	
Male	674	19.8	185	22.8	489	18.8	0.014
Patient race white	3009	89.1	658	83.2	2351	90.9	<.0001
Missing, n	32		21		11		
Hispanic	211	6.2	113	13.9	98	3.8	<.0001
Missing, n	1		0		1		
Smoker within last year	537	15.8	141	17.4	396	15.2	0.14
Missing, n	1		1				

* Chi-square test for categorical variables (with continuity correction for categorical data), Kruskal-Wallis test for continuous variables

Table 2

Baseline Health Status of LABS-1 Participants with RYGB surgeries by high/low surgeon volume

Characteristic	Surgeon LABS RYGB Volume (cases/year)						p_value*
	Total (N=3409)		0-49 (N=812)		50+ (N=2597)		
	n	%	n	%	n	%	
Hypertension	1897	55.6	415	51.1	1482	57.1	0.003
Medication:							0.08
No medication	217	11.6	59	14.5	158	10.8	
Single medication	815	43.6	164	40.3	651	44.6	
Multiple medication	836	44.8	184	45.2	652	44.6	
Diabetes	1225	35.9	296	36.5	929	35.8	0.72
Medication:							0.08
No diabetes medication	188	15.4	34	11.5	154	16.6	
Single oral medication	363	29.7	89	30.2	274	29.5	
Multiple oral medication	305	24.9	70	23.7	235	25.3	
Insulin (with or without oral meds)	367	30.0	102	34.6	265	28.6	
Congestive heart failure	68	2.0	14	1.7	54	2.1	0.53
Asthma	813	23.8	210	25.9	603	23.2	0.12
Can't walk 200 ft	57	1.7	26	3.2	31	1.2	<.0001
Missing, n	1		1				
History of DVT or PE	124	3.6	29	3.6	95	3.7	0.91
Sleep apnea	1721	50.5	340	41.9	1381	53.2	<.0001
CPAP	1407	81.8	265	77.9	1142	82.7	0.04
Supplemental oxygen dependent	61	3.6	10	2.9	51	3.7	0.50
Ischemic heart disease	130	3.8	31	3.8	99	3.8	0.99
Pulmonary hypertension	34	1.0	11	1.4	23	0.9	0.24

Characteristic	Surgeon LABS RYGB Volume (cases/year)						p_value*
	Total (N=3409)		0-49 (N=812)		50+ (N=2597)		
	n	%	n	%	n	%	
Venous edema w/ulcerations	144	4.6	48	6.5	96	4.0	0.004
Missing, n	267		77		190		
Number of comorbidities, mean, median		1.8, 2.0		1.7, 2.0		1.8, 2.0	0.008
Number of comorbidities, n (%)							0.001
1 or more comorbidities	2856	83.8	650	80.1	2206	84.9	
2 or more comorbidities	1915	56.2	421	51.9	1494	57.5	
3 or more comorbidities	954	28.0	209	25.8	745	28.7	
4 or more comorbidities	356	10.4	96	11.8	260	10.0	
Missing, n	1		1				
Beta-blocker	611	18.2	163	20.5	448	17.5	0.062
Missing, n	60		16		44		
Statin/lipid-lowering agent	908	26.6	226	27.8	682	26.3	0.38
Therapeutic anticoagulation	155	4.5	34	4.2	121	4.7	0.57
Narcotic	579	17.0	138	17.0	441	17.0	0.99
Anti-depressant	1388	41.4	288	36.2	1100	43.1	0.001
Missing, n	60		16		44		

* Chi-square test for categorical variables (with continuity correction for categorical data), Kruskal-Wallis test for continuous variables

Table 3

Events and event rates by surgeon volume

	# of Surgeons	Number of Surgeries Total Median (25 th %ile, 75 th %ile)	Death #, rate (%), and 95% CI	Composite event ± #, rate (%), and 95% CI	Crude Risk ratio of composited event 95% CI	Adjusted Risk ratio [^] of composited event 95% CI
Overall	31	3410 95 (50, 165)	15 0.4 (0.0, 0.9)	177 5.2 (3.6, 6.8)	N/A	N/A
Surgeon volume in LABS of 0-24 cases per year	9	352 47 (27, 54)	7 2.0 (0.8, 4.1)	46 13.1 (9.7, 17.0)	Ref	Ref
Surgeon volume in LABS of 25-49 cases per year	6	461 84 (50, 95)	3 0.7 (0.0, 1.6)	28 6.1 (3.3, 8.9)	0.52 (0.28, 0.99) P = 0.045	0.61 (0.30, 1.25) P = 0.17
Surgeon volume in LABS of 50-99 cases per year	9	1219 115 (110, 166)	4 0.3 (0.0, 0.6)	55 4.5 (3.2, 5.9)	0.36 (0.21, 0.64) P = 0.001	0.41 (0.22, 0.79) P = 0.007
Surgeon volume in LABS of 100+ cases per year	7	1378 177 (115, 293)	1 0.1 (0.0, 0.2)	48 3.5 (1.5, 5.5)	0.29 (0.16, 0.55) P < 0.001	0.35 (0.16, 0.76) P = 0.008

[±] Composite event = Death/DVT/PE/no discharge within 30 days//post-bariatric surgery operation/post-bariatric surgery re-admission.[^] Adjusted for clustering due to surgeon and site, and for covariates procedure, patient BMI, history of DVT, and surgeon experiences prior to LABS

Table 4

Composite event by patient/surgeon characteristics (n=3410). (Variables appearing in multivariable model are presented here. Details of association with other patient characteristics are reported in the main paper for all surgeries).

Patient/surgeon Characteristics	Univariable model*		Multivariable model (n=3383) ^a	
	RR (95% CI)	P	RR (95% CI)	P
Patient BMI (kg/m ²)		0.040	NA **	linear (0.28) quadratic (0.01)
<40	1.54 (0.96, 2.47)	0.07		
40–<50	Ref	Ref		
50–<60	1.18 (0.82, 1.70)	0.37		
60+	1.77 (1.13, 2.75)	0.01		
Procedure open vs. lap	1.51 (0.92, 2.45)	0.10	0.99 (0.55, 1.77)	0.97
Cannot walk 200 ft	2.79 (1.52, 5.15)	0.001	1.38 (2.06, 1.08)	0.029
History of DVT	2.21 (1.28, 3.81)	0.005	2.08 (1.19, 3.63)	0.010
History of OSA	1.45 (1.05, 2.00)	0.024	1.45 (1.04, 2.01)	0.027
Surgeon LABS volume (per year)***				
Continuous (per 10)	0.89 (0.84, 0.95)	0.001	0.90 (0.82, 0.98)	0.011
50+ vs 0–49	0.46 (0.29, 0.74)	0.001		
25+ vs 0–24	0.38 (0.23, 0.63)	<0.001		
Bariatric case volume prior to LABS (per 100 cases)	0.75 (0.54, 1.04)	0.08	0.98 (0.93, 1.04)	0.60
Lifetime cases prior to LABS (per 100 cases)	1.00 (0.98, 1.03)	0.86	1.16 (0.66, 2.05)	0.60
Years performing bariatric surgery	1.02 (1.00, 1.05)	0.046	1.02 (0.98, 1.05)	0.34

* Only accounting for site and surgeon.

** We have both linear and quadratic BMI terms in the model; therefore the risk ratio is not constant (depends on the level of BMI).

*** Surgeon volume is included as a continuous variable in the multivariable model.

^a The surgeon experience form was missing for 1 surgeon (26 surgeries) and functional status was missing for one patient.