Mastery in Bariatric Surgery: The Long-term Surgeon Learning Curve of Roux-en-Y Gastric Bypass

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Objective: To determine the effect of cumulative volume on all-cause morbidity and operative time.

Background: Gastric bypass is an important public health procedure, but it is difficult to master with little data about how surgeon cumulative volume affects outcomes longitudinally.

Methods: This was a longitudinal study of 29 surgeons during the first 6 years of performing bariatric surgery in a high-volume, regionalized center of excellence system. Cumulative volume was determined using date and time of the procedure. Cumulative volume was analyzed in blocks of 75 cases. The main outcome of interest was all-cause morbidity during the index admission and the secondary outcome was operative time.

Results: Overall, 11,684 gastric bypasses were performed by 29 surgeons at 9 centers of excellence. The overall morbidity rate was 10.1% and short-term outcomes were related significantly to cumulative volume. Perioperative risk plateaued after approximately 500 cases and was lowest for surgeons who had completed more than 600 cases (odds ratio 0.53 95% confidence interval 0.26–0.96 $P = 0.04$) compared to the first 75 cases. Operative time also stabilized after approximately 500 cases, with an operative time 44.7 minutes faster than surgeons in their first 75 cases (95% confidence interval 37.0–52.4 min $P < 0.001$).

Conclusions: The present study demonstrated the clear, substantial influence of surgeon cumulative volume on improved perioperative outcomes and operative time. This finding emphasizes role of the individual surgeon in perioperative outcomes and that the true learning curve needed to master a complex surgical procedure such as gastric bypass is longer than previously thought, in this case requiring approximately 500 cases to plateau.

Keywords: gastric bypass, learning curve, morbidity, operative time

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Gastric bypass is a common operation with significant application to public health accounting for approximately 60,000 procedures annually in the United States.[1,2] It is, however, a technically demanding procedure with a significant learning curve.[3] Previous research has established the association between annual surgical case volume and better patient outcome.[4–12] In addition, it has been demonstrated that median operative time has been associated with better patient outcomes in bariatric surgery.[13] This is not surprising as objective skill in the operating room has been previously linked to better patient outcomes[14] and those who are able to minimize operative times are likely highly skilled considering the demanding nature of the procedure. Despite the fact we, however, know that both highly skilled surgeons and those with higher annual volumes have better outcomes, the effect of cumulative volume has been poorly characterized and little is known as to whether a long-term learning curve exists.

The current fellowship training requirements by the American Society for Metabolic and Bariatric Surgery requires fellows to participate in at least 100 weight-loss operations, of which at least 50 should be intestinal bypass operations.[15] Previous research has suggested that the learning curve for the gastric bypass is approximately 100 cases and that fellowship training in bariatric surgery can further reduce this learning curve.[3] In a meta-analysis of 18 studies, most studies, however, only followed surgeons for 100 cases and the purpose of these studies was to measure time taken until competence is achieved, rather than mastery.[3] Competence refers to having outcomes not significantly different than average while mastery would be having outcomes significantly better than the average surgeon. One Brazilian study suggested that the learning curve may be up to 500 cases in a longer-term follow-up of a single center.[16] Therefore, a more comprehensive study of the long-term learning curve is required to determine whether outcomes plateau at a higher number of cases than previously thought.

Roux-en-Y gastric bypass is a complex procedure with major public health implications. In addition, it is known that highly skilled surgeons with significantly better perioperative outcomes exist but little is known as to whether a long-term learning curve exists and how important it is to patient outcomes. Therefore, the purpose of this study is to evaluate the outcomes in a long-term cohort of bariatric surgeons and determine how outcomes change as cumulative volume increases.

METHODS

Design and Setting

This was a longitudinal analysis of administrative data in which the principle objective was to determine the effect of surgeon cumulative volume on all-cause morbidity and operative time. The present study was approved by the Hamilton Integrated Research Ethics Board.

Population

All patients, 18 years of age or older, who underwent gastric bypass in the Ontario Bariatric Network (OBN) from April 2009 until March 2015 for the purpose of weight loss were included in the study. Patients were identified using morbid obesity as the most responsible diagnosis and this was clarified by the procedure code for gastric bypass.

Setting

The OBN was established by the Ontario Ministry of Health and Long-Term Care in the 2009 fiscal year. It is a large-scale regionalized surgical care system with accreditation standards, allowing for the standardized and systematic delivery of bariatric

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care. The minimum criteria for a hospital to receive bariatric centre of excellence status in Ontario include being a full acute care/inpatient facility with a 24-hour intensive care unit, emergency, and surgical coverage; at least 2 fellowship-trained bariatric surgeons with a minimum of 50 cases per year and a total volume of 120 cases per year; and multidisciplinary medical, psychiatric and respiratory support for perioperative care.[17] Before this, bariatric care was offered at only 1 hospital in Ontario with no specific formal accreditation; as such, virtually all newly accredited centers of excellence began to deliver care simultaneously. In addition, Ontario is a jurisdiction where the gastric bypass is the standard procedure accounting for approximately 90% of all procedures with the sleeve gastrectomy only being used in special circumstances: as part of a 2-stage duodenal switch procedure for patient body mass index (BMI) of 60 or higher, when gastric bypass is not technically possible due to adhesions or when gastric bypass is specifically contraindicated.[18]

Sources of Data

Patient demographics, comorbidity profiles, surgical procedures, all-cause morbidity, and volumes were derived from the Canadian Institute for Health Information (CIHI) Discharge Abstract Database. Dates, start times, and end times for each procedure were also given. Operative times were derived from the procedure start and end times. This database is highly accurate in documenting most responsible diagnoses and primary surgical procedures and morbidity causing a more than 24-hour increase in length of stay.[19,20] Specific demographics included sex and age, whereas the comorbidities of interest included hypertension, mild diabetes, severe diabetes (diabetes with complications), coronary artery disease, chronic obstructive pulmonary disease, and obstructive sleep apnea.

Outcomes and Predictors

The main outcomes of interest for the present study were all-cause morbidity during the index admission and operative time. All-cause morbidity included any documented complication that occurred during the index admission, which extended length of stay by 24 hours or required a separate, unplanned procedure. This was a composite outcome that was determined by CIHI during the initial data collection process and therefore is the most comprehensive outcome afforded by the dataset. Similar composite outcomes have been shown to be more valid in explaining hospital- and surgeon-level variation in serious complication rates.[21] In addition, bariatric outcomes such as leak and hemorrhage have a lower statistical reliability. To better determine whether any change in outcome is related to technical skill increases, operative time was used as a secondary outcome. Operative time has been previously demonstrated to be independently associated with complication rates and has been related to surgeon technical skill.[13,14] Operative time was measured as the time from patient entry to patient exit from the room and includes induction time.

The main predictor of interest, individual surgeon cumulative volume was measured from the beginning of the 2009 fiscal year with each procedure numbered from earliest to most recent and grouped by every 75 procedures. To ensure cumulative system efficiencies were not attributed to surgeon cumulative volume, hospital cumulative volume, grouped by every 300 procedures, was also included in the study. Other predictors included in the analysis were patient demographics, comorbidities, annual surgeon volumes, annual hospital volumes, and fellowship teaching center status. Lastly, gastric bypass technique in Ontario was relatively homogenous, although 5.8% of cases, all at a single center, used a circular stapled gastrojejunostomy technique before changing to a linear stapled technique. Because many skills are transferable between linear stapled and circular stapled techniques (eg, jejunojejunostomy, closing of the mesenteric defects, and creation of gastric pouch), we kept these cases within the main analysis but performed a sensitivity analysis that excluded the circular stapled cases.

Statistical Analysis

The χ^2 statistic was used to compare categorical variables and *t* tests were used for continuous variables. Normal and binomial 95% confidence intervals (CIs) were presented for univariate statistics where appropriate. Two multivariable hierarchical regression models were used to (1) determine predictors of operative time and (2) determine predictors of all-cause morbidity. The main comparison was made from surgeons to themselves during the first 75 procedures. To account for unmeasured confounding at the hospital and provider level and account for correlation, surgeon and hospital identifiers were used as independent random effects for both models. Fixed effects included sex, age, comorbidities, annual hospital volume, annual surgeon volume (both as continuous variables due to the homogeneity of surgeon volumes and lack of low volume surgeons), fellowship teaching center, hospital cumulative (in blocks of 300), and surgeon cumulative volume (in blocks of 75). Surgical time was modeled with a linear mixed effects model using restricted maximum likelihood estimation. All-cause morbidity was modeled using a logistic hierarchal regression model. Monte Carlo Markov Chain estimation was used for the logistic model with 100,000 iterations after a 5000 iteration burn-in. All chains were examined for convergence. Statistical significance was set at *P* less than 0.05. Data were analyzed using Stata (StataCorp version 12.1; College Station, TX) and MLwiN (Version 2.26; Centre for Multilevel Modelling, University of Bristol, Bristol, UK).

RESULTS

Table 1 presents the demographics, comorbidities, hospital volume, surgeon volume, and fellowship teaching status by all-cause morbidity rates. Overall, 11,684 gastric bypasses were performed by 29 surgeons in 9 hospitals in Ontario from April 2009 until May 2015. More than 83% of the cohort were women, whereas the average age was 44.6 ($\pm$10.4) years. Obstructive sleep apnea, hypertension, and mild diabetes were present in 32.0%, 27.1%, and 25.8% of the cohort, respectively. The median annual hospital volume was 377 (interquartile range 285–481) patients, whereas the median annual surgeon volume was 102 patients (interquartile range 85–133). Seventy-four percent of patients (N = 8692) were treated at centers with a fellowship training program.

Table 2 presents the univariate associations between the main predictor of interest, surgeon cumulative volume, and hospital cumulative volume and the outcomes of interest, operative time, and all-cause morbidity. For the 2047 patients undergoing surgery within the surgeons' first 75 cases, the all-cause morbidity rate was 11.6% (95% CI 10.3%–13.1%) and the average operative time was 183.8 (95% CI 181.4–186.2) minutes. For patients undergoing gastric bypass after the surgeon had performed at least 600 cases within the OBN, the all-cause morbidity rate was 6.4% (95% CI 4.3%–9.1%) and the average operative time was 131.5 minutes (95% CI 127.5–135.4). Significant differences were observed globally for the trends for both main outcomes in univariate analyses. Hospital cumulative volume demonstrated a significant association with operative time ($P < 0.001$), although hospital cumulative volume was note associated with all-cause morbidity.

Table 3 and Figure 1 present the results of the mixed effects regression modeling adjusted operative time. After adjustment for patient factors, surgeon volume and hospital volume were both statistically significant. For each additional 25 cases in annual surgeon volume, the mean operative time decreased by 3.6 minutes

TABLE 1. Patient Factors and Univariate Associations With All-cause Morbidity

	None	Complication	Total	
	N = 10,499	N = 1185	N = 11,684	P
Female	8750 (83.3)	977 (82.5)	9727 (83.3)	0.44
Age (mean ± SD)	44.5 (±10.4)	46.0 (±10.1)	44.6 (±10.4)	<0.001
Comorbidities				
Hypertension	2795 (27.3)	420 (31.4)	3674 (27.7)	0.001
Mild diabetes	2683 (25.6)	333 (28.1)	3016 (25.8)	0.59
Severe diabetes	275 (2.6)	53 (4.5)	328 (2.8)	0.001
Coronary artery disease	76 (0.7)	21 (1.8)	25 (0.8)	0.001
COPD	586 (5.6)	56 (4.7)	642 (5.5)	0.25
Obstructive sleep apnea	3347 (31.9)	391 (33.0)	3738 (32.0)	0.43
System factors*				
Surgeon annual volume	103 (86–133)	100 (81–129)	102 (85–133)	0.003
Hospital annual volume	377 (285–481)	419 (324–481)	377 (285–481)	<0.001
Fellowship training center	7719 (73.5)	973 (82.1)	8692 (74.4)	<0.001

COPD indicates chronic obstructive pulmonary disease; SD, standard deviation.
Values represent n, (%) unless otherwise specified.
*Median value [interquartile range (IQR)].

(95% CI 2.5–4.7, $P < 0.001$). Alternatively, after adjustment, annual hospital volume actually increased operative time by 2.2 minutes for each additional 50 cases a hospital performs each year (95% CI 1.2–3.1, $P < 0.001$). For individual surgeon cumulative volume, when compared to the first 75 cases, operative time decreased significantly for every cumulative volume category. A similar but less substantial relationship was seen between hospital cumulative volume and operative time. Figure 1 plots the clear relationship between faster operative times and cumulative volume at the surgeon and hospital levels. The relationship between cumulative surgeon volume and operative time plateaus at approximately 525 to 600 cases in which the operative time is 44.7 minutes faster (95% CI 37.0–52.4, $P < 0.001$) than during the first 75 cases.

Table 4 and Figure 2 present the adjusted relationship between cumulative surgical volume and all-cause morbidity. After adjustment, annual surgical volume, annual hospital volume, and fellowship training center status were not significantly associated with all-cause morbidity. Compared to the first 75 cases, all-cause morbidity for the next 75 cases was not significantly different but the odds of morbidity was 0.69 times lower after the 150th case (95% CI 0.49–0.92, $P = 0.02$). Odds of all-cause morbidity did plateau after 150 cases but did not consistently show significantly lower odds of morbidity until the 500th case approximately. From 450 to 525 cases the odds of all-cause morbidity was 0.54 (95% CI 0.31–0.83, $P = 0.01$). The lowest all-cause morbidity was for patients undergoing surgery by surgeons who had logged more than 600 cases as the odds of all-cause morbidity was 0.53 (95% CI 0.26–0.96, $P = 0.04$) compared to the first 75 cases. Hospital cumulative volume, compared to the first 300 cases had no significant effect independent of surgeon cumulative volume. Results of the sensitivity analysis that excluded the circular stapled cases demonstrated the same effect on cumulative volume.

DISCUSSION

This is the first multicenter study to quantify the long-term learning curve of a complex surgical procedure for fellowship trained surgeons. The present study followed the same high-volume, fellowship trained surgeons, in the same centers over time and compared their later outcomes to earlier outcomes. The major finding is that

TABLE 2. Complication Rate and Operative Time by Cumulative Volume

	N	Operative Time, min (95% CI)	P	Complication rate (95% CI)	P
Surgeon volume					
0–75	2047	183.8 (181.4–186.2)	<0.001	11.6% (10.3–13.1)	<0.001
76–150	1950	170.6 (168.8–172.5)		11.3% (9.9–12.8)	
151–225	1893	160.8 (158.9–162.7)		9.6% (8.3–11.0)	
226–300	1640	150.2 (148.2–152.2)		9.9% (8.5–11.5)	
301–375	1299	142.5 (140.3–144.6)		10.2% (8.6–11.9)	
376–450	999	133.6 (130.8–136.4)		10.8% (9.0–12.9)	
451–525	846	125.3 (123.2–127.5)		8.3% (6.5–10.3)	
526–600	570	125.9 (123.6–128.2)		7.7% (5.7–10.2)	
>600	440	131.5 (127.5–135.4)		6.4% (4.3–9.1)	
Hospital volume					
0–300	2467	181.4 (179.2–183.5)	<0.001	10.2% (9.1–11.5)	0.14
301–600	2378	164.9 (163.1–166.7)		9.0% (7.9–10.2)	
601–900	1730	157.8 (155.8–159.8)		11.0% (9.5–12.6)	
901–1200	1500	149.3 (147.0–151.6)		11.4% (9.8–13.1)	
1201–1500	1450	138.8 (137.2–140.4)		9.5% (8.0–11.1)	
>1500	2154	127.8 (126.3–129.3)		10.0% (8.7–11.4)	

SD indicates standard deviation.

TABLE 3. Adjusted Mean Operative Time Difference*

	Adjusted Time Difference, min (95% CIs)	*P*
Female	−6.7 (−8.5 to −4.8)	<0.001
Age (mean ± SD)	2.3 (1.6 to 3.0)	<0.001
Comorbidities		
Hypertension	0.9 (−0.8 to 2.6)	0.28
Mild diabetes	0.2 (−1.4 to 1.9)	0.77
Severe diabetes	3.9 (−0.4 to 8.2)	0.08
Coronary artery disease	−0.5 (−8.2 to 7.2)	0.90
COPD	0.4 (−2.6 to 3.4)	0.80
Obstructive sleep apnea	3.3 (1.7 to 4.9)	<0.001
Annual surgeon volume (per 25 cases)	−3.6 (−4.7 to −2.5)	<0.001
Annual hospital volume (per 50 cases)	2.2 (1.2 to 3.1)	<0.001
Teaching status	−5.8 (−40.9 to 29.4)	0.75
Cumulative surgeon volume		
0–75	Ref	
76–150	−11.0 (−8.0 to −14.0)	<0.001
151–225	−18.6 (−14.6 to −22.6)	<0.001
226–300	−24.4 (−19.6 to −29.3)	<0.001
301–375	−32.5 (−26.8 to −38.2)	<0.001
376–450	−36.6 (−30.2 to −42.9)	<0.001
451–525	−43.5 (−36.6 to −50.5)	<0.001
526–600	−44.7 (−37.0 to −52.4)	<0.001
>600	−40.2 (−31.1 to −49.2)	<0.001
Cumulative hospital volume		
0–300	Ref	
301–600	−7.2 (−4.0 to −10.4)	<0.001
601–900	−8.0 (−3.6 to −12.4)	<0.001
901–1200	−12.6 (−7.2 to −18.0)	<0.001
1201–1500	−16.3 (−10.2 to −22.5)	<0.001
>1500	−11.6 (−4.4 to −18.8)	0.001

Negative values denote decrease in operative time.
*Adjusted for surgeon and hospital random effects.
COPD indicates chronic obstructive pulmonary disease.

procedural mastery and short-term outcomes in gastric bypass is related significantly to cumulative surgeon volume and that it takes approximately 500 cases to plateau. At this level, the odds of an all-cause morbidity was approximately half compared to the same surgeons during the first 75 cases (odds ratio 0.54 95% CI 0.31–0.83 $P = 0.01$) and perioperative risk was lowest for surgeons who had completed more than 600 cases (odds ratio 0.53 95% CI 0.26–0.96, $P = 0.04$). Of note, this finding is adjusted for annual case volumes, which had a less substantial effect on preoperative outcomes than surgeon cumulative volume. Furthermore, it is adjusted for hospital cumulative volume so that system efficiencies are not incorrectly attributed to surgeons. In addition, operative time also plateaued after approximately 500 cases with a decrease in operative time of 44.7 minutes compared to surgeons in their first 75 cases (95% CI 37.0–52.4, $P < 0.001$). The latter reinforces that the drop in outcomes is likely related in part to an increase in surgeon technical skill and procedural mastery. The importance of this finding is that it emphasizes the role of individual surgeon cumulative volume on all-cause morbidity and that the true learning curve needed to master a complex surgical procedure such as gastric bypass is likely much longer than previously thought. In addition, it demonstrates that substantial differences in outcomes exist between even fellowship trained surgeons at different levels of cumulative volume.

A meta-analysis that analyzed the learning curve of gastric bypass suggested that the learning curve was 105 cases for non-fellowship trained surgeons and 95 for those with specific bariatric training.[3] Specifically, the 4 studies in fellowship trained surgeons only followed surgeons for a maximum of 109 cases found a post-operative complication rate of approximately 8%.[22–25] Another review by Zevin et al,[26] which reviewed ex vivo simulation-based technical skills training programs, also reported a learning curve of 50 to 100 procedures but states that most studies were of poor quality. This underscores 2 major issues with the previous literature: the follow-up is too short to determine where outcomes truly plateau and the purpose of the studies was to determine learning curve to competence rather than mastery. Competency, in this case, refers to performing procedure with a safety level comparative to national averages, whereas mastery refers to outcomes that would be significantly better than national averages. Despite this, our study did find a general plateau of decreased outcomes between 150 and 450 cases, which may correlate to the phenomenon described in previous learning curve studies. In the only other previous long-term follow-up study of the gastric bypass learning curve, a previous single-center study from Brazil did suggest that there was a procedural learning curve, which plateaued at approximately 500 cases

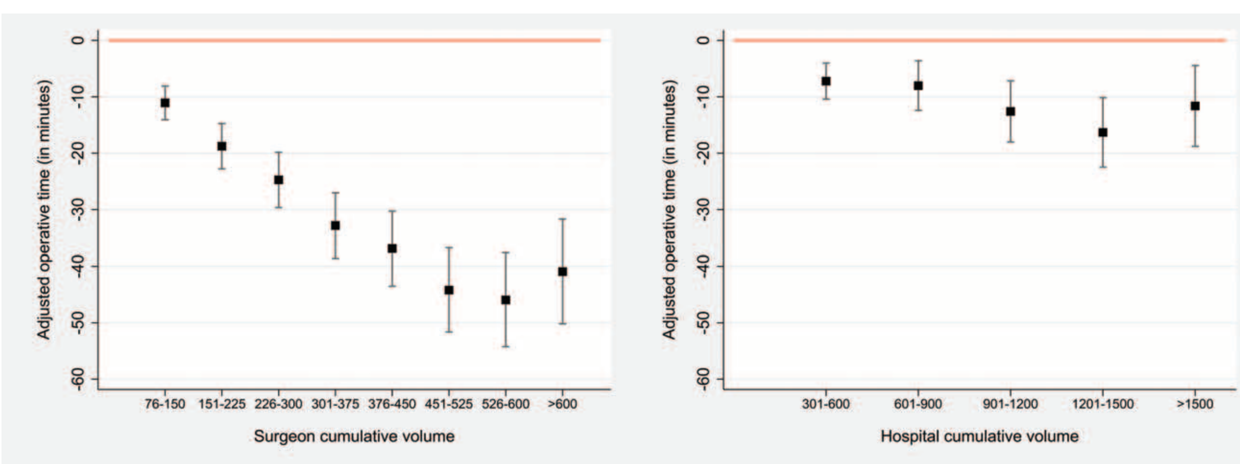

FIGURE 1. Adjusted operative time by surgeon cumulative volume (left) and hospital cumulative volume (right). Red line is reference group (0–75 cases for surgeons/0–300 cases for hospitals). Squares represent effect sizes with 95% confidence intervals.

TABLE 4. Adjusted Odds of All-cause Morbidity*

	Adjusted Odds Ratio (95% CIs)	*P*
Female	1.04 (0.87–1.23)	0.69
Age/10 yr	1.13 (1.06–1.21)	<0.001
Comorbidities		
Hypertension	1.20 (1.03–1.40)	0.02
Mild diabetes	1.04 (0.90–1.21)	0.63
Severe diabetes	1.46 (1.02–2.03)	0.04
Coronary artery disease	1.75 (0.95–2.86)	0.06
COPD	0.88 (0.64–1.16)	0.34
Obstructive sleep apnea	1.05 (0.90–1.20)	0.55
Annual surgeon volume (per 25)	0.94 (0.86–1.02)	0.18
Annual hospital volume (per 50)	1.03 (0.94–1.11)	0.47
Teaching status	1.53 (0.93–2.54)	0.13
Cumulative surgeon volume		
0–75	Ref	
76–150	0.93 (0.71–1.19)	0.51
151–225	0.69 (0.49–0.92)	0.02
226–300	0.69 (0.46–0.97)	0.04
301–375	0.70 (0.45–1.01)	0.06
376–450	0.70 (0.43–1.04)	0.09
451–525	0.54 (0.31–0.83)	0.01
526–600	0.54 (0.30–0.89)	0.02
>600	0.53 (0.26–0.96)	0.04
Cumulative hospital volume		
0–300	Ref	
301–600	1.02 (0.76–1.33)	0.95
601–900	1.27 (0.89–1.78)	0.22
901–1200	1.45 (0.97–2.22)	0.12
1201–1500	1.18 (0.71–1.88)	0.57
>1500	1.05 (0.61–1.76)	0.95

*Adjusted for surgeon and hospital random effects.
COPD indicates chronic obstructive pulmonary disease.

and this is in agreement with our findings.[16] With regards to operative time, a previous study by Reames et al[13] demonstrated that median operative time is independently associated with all-cause morbidity, venous thromboembolism and extended length of stay for gastric bypass patients in Michigan. Another study by Birkmeyer et al[14] demonstrated the link between operative time and surgeon skill. Both of these studies provide the basis for the likely relationship found in our study relating increasing technical mastery, using operative time as a proxy, to better operative outcomes. It should be noted, however, gains in operative time can also come from system-level factors. Specifically, Maruthappu et al[27] have previously demonstrated that decreases in operative times in orthopedic surgery can be attributed to repeated team collaborations with the most substantial effect occurring for cases done by teams with more than 40 collaborations (the highest grouping), which decreased operative time by 21 minutes. In the same study, however, the most significant contributor to decreased operative time was surgeon experience, peaking for surgeons with 25 years of experience.[27] In addition, a study by Mannaerts et al[28] demonstrated that gains from anesthesia times after the implementation of an enhanced recovery program accounted for very little in overall improvement and that most gains were due to gains in operative time. This corroborates our findings that system effects had a significant effect on operative time but its effect was not as substantial as surgeon cumulative experience.

The importance of surgical skill in patient outcomes has been emphasized in recent years but little has been quantified as to the development of highly skilled surgeons. We know that they exist and that they have better outcomes but few studies have attempted to follow the outcomes of individual surgeons over a long period of time. To this point, we feel that the present study clearly demonstrates the importance of surgeon cumulative volume on all-cause morbidity after gastric bypass. Importantly, we feel that these findings are largely related to surgeon technical mastery as the secondary outcome, operative time also plateaued at a similar volume. Furthermore, these outcomes are also likely not related to system efficiencies as hospital cumulative volume demonstrated no such relationship. In addition to determining the trend, this study also found that outcomes likely do not completely plateau until approximately 500 gastric bypass cases and this likely represents the number of cases required for mastery. These findings were independent of individual surgeon volume and are applicable to fellowship trained surgeons who perform at least 50 cases per year. Moreover, because all of the surgeons have specialty training in minimally invasive/bariatric surgery the number of cases may be more for surgeons without such subspecialty training, although this distinction is becoming of less relevance within the current North American context. These findings have direct implications for organizations

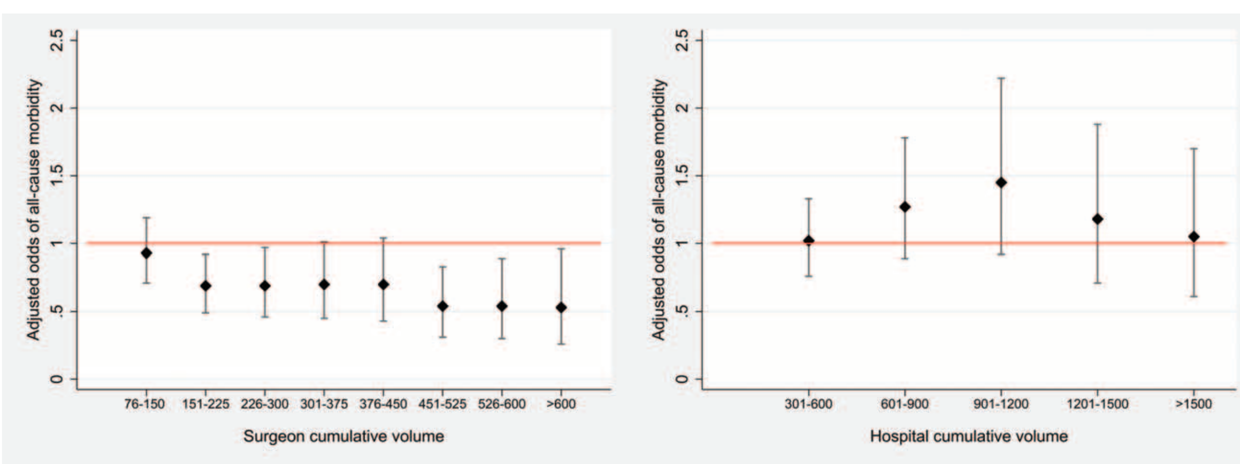

FIGURE 2. Adjusted odds of all-cause morbidity by surgeon cumulative volume (left) and hospital cumulative volume (right). Red line is reference group (0–75 cases for surgeons/0–300 cases for hospitals). Diamonds represent effect sizes with 95% confidence intervals.

that ensure the quality of surgical care and oversee the credentialing of bariatric surgeons. This study clearly demonstrates the importance of individual surgeons in perioperative outcomes and helps to identify surgeons to target with ancillary development strategies, such as coaching, to ensure optimal effect of interventions. This is a major question identified by Greenberg et al[29] in their exploration of the current role of coaching in surgery. Similarly, the results of the study suggest that surgeons early in their careers or those beginning to provide a novel procedure could benefit from increased feedback and oversight from more experienced surgeons. For organizations tasked with ensuring surgical quality, the cumulative number of cases, in addition to annual volumes, could be tracked and considered another potential quality metric. Tracking such volumes in other procedures would also allow a better understanding of whether this phenomenon extends to other complex surgical procedures.

The study has several limitations. The specific number of bypasses completed in fellowship, residency and before beginning practice in the OBN could not be ascertained due to the deidentified nature of the surgeon data within the administrative database. The random effects model, however, does create a unique random effect for each surgeon which accounts for the unmeasured variation of each surgeon and these effects were not significantly different from average. The present study also did not include either nonfellowship trained surgeons or low-volume surgeons (<50 annual volume) and thus whether the same long-term learning curve applies to these 2 groups is not clear from this analysis. BMI was not used in the risk-adjustment for the present study as CIHI uses only a morbid obesity code (BMI > 35) within their database. In Ontario, patients with BMI greater than 60, however, tend to receive a sleeve gastrectomy and thus the highest BMI patients would likely have been excluded from the present study. In addition, previous research within the OBN has demonstrated that BMI does not vary significantly by site or across the years.[17] Although system effects were accounted for in the present study, operative time could also be reduced by omitting unnecessary steps rather than an increase in surgical skill and this could not be discerned from the database. In addition, differences in techniques could not be accounted for in this dataset. Overall, the results should be applied to a gastric bypass technique that uses a linear stapler. Because of the statistical reliability of specific complications and the ambiguity with coding them, we elected to use all-cause morbidity for the present study. Although the specific measure may be difficult to replicate, its prevalence does corroborate appropriately with other major studies on complications after gastric bypass.[6] Lastly, we did not have readmission data for the present study and therefore could not use 30-day complication rates but rather all-cause morbidity during the index admission. Although we cannot generalize our results to readmissions, we do not feel that delayed complications would differ significantly than in-hospital morbidity.

CONCLUSIONS

This study evaluated the long-term learning curve of gastric bypass for fellowship trained surgeons in a center of excellence system. It found that risk-adjusted all-cause morbidity and operative time did not plateau until approximately 500 cases. This finding was likely caused by an increase in technical skill as surgeon cumulative volume was also significantly correlated with decreased operative times. This is the first multicenter study to suggest that the learning curve of gastric bypass is longer than the 100 procedures previously thought. In addition, it emphasizes the role of the surgeon in perioperative outcomes and will likely inform future research on training and coaching of in-practice surgeons and provide another measure of surgical quality.

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