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The value of surgical experience: excess costs associated with the Roux-en-Y gastric bypass learning curve

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Abstract

Background Gastric bypass has a steep learning curve that is associated with increased adverse outcomes and these adverse outcomes are associated with increases in cost. This study sought to quantify the effect of cumulative procedure volume on inpatient cost and characterize the excess cost associated with a surgeon's learning curve.

Methods This was a retrospective study of 29 high-volume surgeons during the first 6 years of performing gastric bypass in a regionalized center of excellence system. Cumulative volume was determined using the procedure date and analyzed in blocks of 25 cases. The main outcomes of interest were inpatient cost for the initial hospital stay in 2014 Canadian dollars as well as prolonged length of stay (≥ 3 days).

Results Overall, 11,684 cases were identified from April 2009 to March 2015. After a surgeon's 50th case, the adjusted inpatient cost decreased by $2775 (95% CI $− 4352 to $− 1204 $p = 0.001$) compared to the first 25 cases. Cost savings were maintained through a surgeon's 400th case. The average cost savings after the 50th case was $2082 (95% CI $− 3194 to $− 962 $p < 0.001$) and the excess cost attributable to the first 50 cases was $104,077 (95% CI 48,104 to 159,682) per surgeon. Surgeon experience was also associated with a decrease odds of prolonged length of stay.

Conclusions This study demonstrated the influence of surgeon experience on improved cost efficiencies. We also characterized that the average excess cost per surgeon of implementing gastric bypass was approximately $104,000. This is relevant to future health system planning as well as providing an economic incentive for impactful training interventions.

Keywords Bariatric surgery · Learning curve · Costs

Bariatric surgery has been established as the best treatment for weight-loss and diabetes. There have been multiple randomized trials looking at outcomes related to weight-loss and diabetes and the results show the long-term superiority of bariatric surgery over medical therapy [1–5]. Beyond weight-loss and diabetes, multiple other outcomes including mortality, cardiovascular, obstetric, and oncologic have been studied and found to have very favorable results for bariatric surgery [6–12]. Despite the clinical benefits, bariatric surgery remains costly and, importantly, the largest contributor to the economic impact of bariatric surgery is the initial operation and hospital stay which accounts for between 2 and 5 times a patient's annual health expenditure [13, 14].

Of all bariatric operations, gastric bypass is arguably the best studied and one of the most common bariatric procedures. Despite its popularity, gastric bypass remains a complex procedure that is difficult to master. Previous research has suggested that the learning curve is approximately 100 cases but more recent data suggested that complication rates may not plateau until approximately 500 cases [15, 16]. Considering that complications can quintuple short-term

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hospital costs after major surgical operations, including bariatric surgery, [17, 18] the impact of this learning curve on costs may be substantial and has not been characterized. Characterizing these costs can provide health systems with an idea as to the expected excess costs a new surgeon will add in the short-term as well as provide economic incentive for interventions that shorten or mitigate any adverse effects of a surgeons learning curve.

Overall, the Roux-en-Y gastric bypass is a complex surgical procedure with major clinical benefits. Recent data have suggested that a long-term learning curve exists for this procedure with regard to complications but it is unknown how surgeon experience affects costs. Moreover, the cost of a surgeon's learning curve has never been characterized. Therefore, the purpose of this study is to evaluate the effect of cumulative volume on short-term hospital costs in a long-term cohort of bariatric surgeons.

Materials and methods

Design

This was a longitudinal analysis of administrative data in which the principle objective was to determine the effect of surgeon cumulative procedure volume on inpatient costs for the index admission. This study was approved by the Hamilton Integrated Research Ethics Board. No patients or the public were directly involved with this paper.

Population

All adult patients who underwent gastric bypass in Ontario, Canada from April 2009 until March 2015 meeting NIH criteria were included in the study [19].

Setting

The Ontario Bariatric Network (OBN) is a large-scale, regionalized surgical care system with accreditation standards. It was established in 2009 by the Ontario Ministry of Health and Long-Term Care and accordingly virtually all newly accredited centers of excellence began to deliver care simultaneously. Specific accreditation standards include having at least two fellowship-trained bariatric surgeons with a minimum of 50 cases per year and a total volume of 120 cases per year [20]. Due to this there were no low-volume surgeons included within the study. In addition, unlike many jurisdictions, gastric bypass is the standard procedure in Ontario accounting for approximately 90% of all procedures. Alternatively, sleeve gastrectomies are only used in special circumstances: as part of a two-stage duodenal switch procedure for patient BMI ≥ 60, when gastric bypass is not technically possible due to adhesions or when gastric bypass is specifically contraindicated [21]. Importantly, throughout the course of the study, financial incentives for bariatric surgery or length of stay were entirely unchanged within Ontario.

Sources of data

Patient demographics, comorbidity profiles, surgical procedures, costs, length of stay, 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 provided in the database. Patients were identified using morbid obesity as the most responsible diagnosis and this was clarified by the procedure code for gastric bypass. This database is highly accurate in documenting most responsible diagnoses and primary surgical procedures as well as morbidity causing a more than 24 hour increase in length of stay [22, 23].

Outcomes

The main outcome of interest for this study was inpatient cost during the index admission. Inpatient cost was quantified using a standard costing methodology developed by the CIHI and available within the dataset [24]. This methodology assigns a Resource Intensity Weight (RIW) for each hospitalized patient which measure the relative amount of resources need for a specific admission. Accordingly, to estimate the cost of an admission, the RIW for a patient is multiplied by the average cost per RIW in the same year as the admission occurred. Costs were adjusted for inflation as well as secular trends in costs and reported in 2014 Canadian dollars. Costs included all inhospital costs including operating and ward costs.

The secondary outcome, prolonged length of stay, was defined as a length of stay 3 days or greater. As the long-term surgeon complication rates have been described for this cohort previously, [16] this outcome was used to better characterize another important cause for increased costs.

Predictors and confounding variables

The main predictor of interest was surgeon cumulative volume measured from the beginning of the 2009 fiscal year. Cumulative volume was analyzed in blocks of 25 cases initially. After characterization of costs in these blocks for the first 500 procedures for each surgeon, volume status was classified in blocks of 50 after the first 100 and block of 100 after 200 procedures due to little cost variation at these levels. To ensure cumulative system cost efficiencies were not misattributed to surgeon cumulative volume, hospital cumulative volume, grouped by every 300 procedures, was also included in the study.

Confounding variables adjusted for in the analysis included demographics such as age, gender, and clinical variables including hypertension, coronary artery disease, mild diabetes, severe diabetes (diabetes with significant microvascular or macrovascular complications), chronic obstructive pulmonary disease (COPD), and obstructive sleep apnea. As previous studies have characterized annual volumes as an important factor in costs, annual hospital and surgeon volumes were included in the study. Both variables were classified as low, medium, and high-volume. Specifically, low-volume surgeons completed less than 75 procedures per year, medium volume surgeons completed 76–150 procedures and high-volume surgeons completed more than 150 procedures per year. Low-volume hospitals completed less than 300 per year, medium volume hospitals completed 301 two 450 procedures annually and high-volume centers completed more than 600 procedures per year. Lastly, fellowship teaching centers were also identified in the final analysis.

Statistical analysis

The χ^2 statistic was used to compare categorical variables and *t* tests were used for continuous variables. Univariable associations between cost and the study variables were analyzed using a simple linear regression with robust confidence intervals. Two multivariable hierarchical regression models were used to (1) determine predictors of inpatient costs and (2) determine predictors of prolonged length of stay. The main comparison was made from surgeons to themselves during the first 25 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 gender, age, comorbidities, annual hospital volume, annual surgeon volume (both categorized as low, medium or high volume), fellowship teaching center, hospital cumulative (in blocks of 300), and surgeon cumulative volume. Blocks of cumulative volume were determined through univariate analysis of data. Inpatient cost was modeled with a hierarchal linear mixed effects model and prolonged length of stay was modeled using a logistic hierarchal regression model. Based on the results of the initial costs model, an ad hoc model was utilized to determine the average savings from the 50th case onward by grouping all cases after the 50th case into one group and running the same model as above. As cost is not normally distributed, Monte Carlo Markov Chain estimation, which assumes no underlying distribution for the data, was used for the logistic and linear regression models with 100,000 iterations after a 5000 iteration burn-in. All chains were examined for convergence. Statistical significance was set at $p<0.05$. Data were analyzed using Stata (StataCorp version 12.1; College Station, TX) and MLwiN (Version 2.26; Centre for Multilevel Modelling, University of Bristol).

Results

We identified 11,684 procedures performed by 29 surgeons at nine centers of excellence from April 2009 until May 2015. Table 1 presents univariable associations between prolonged length of stay and patient demographics, clinical variables, surgeon volume variables and hospital variables. Figure 1 presents the univariable associations between surgeon cumulative volume and the two primary outcomes. Approximately 83% of the cohort was female and the average age was 44.6 years (SD ± 10.4). Obstructive sleep apnea, hypertension, and mild diabetes were the three most common comorbidities occurring in 32.0%, 27.1%, and 25.8% of the cohort, respectively. Most patients were treated by surgeons with 76–150 annual procedures and at centers with 300–450 procedures per year. Significant univariable associations occur between prolonged length of stay and all variables except gender ($p=0.792$) and annual surgeon volume ($p=0.422$).

Table 2 presents the univariable associations between inpatient costs and the study variables. Of the patient variables, only age was associated significantly with cost as for each 10 years increase in age, cost increase by $384 (95% CI 144–625 $p=0.002$). No level of surgeon cumulative volume or annual volume was associated with a significant decrease in costs in univariable analysis. Fellowship training centers were associated with an increase in cost of ($723 95% CI $232–$1213 $p=0.002$). Hospital annual volumes were not associated with cost differences though two levels of cumulative volume, 301–600 ($− 1257 95% CI $− 2404 to $− 110 $p=0.032$) and 1201–1500 ($− 1180 95% CI $− 2293 to $− 67 $p=0.002$) were associated with decreases.

Table 3 presents the results of the hierarchal logistic regression modeling the effect of the variables on prolonged length of stay. For this outcome, cumulative experience at the surgeon level was a significant predictor of a decreased odds of prolonged length of stay. Compared to the first 25 cases, the second 25 cases decreased the odds of prolonged length of stay by 26% (OR 0.74 95% CI 0.58–0.93 $p=0.012$). The odds continually decreased and were lowest for surgeons after their 400th case where the odds of prolonged length of stay were 70% less (OR 0.30 95% CI 0.19–0.44 $p<0.001$). Hospital cumulative volume had similar associations with prolonged length of stay as for hospitals that completed more than 1500 cases the odds of prolonged length of stay was 0.61 times lower (95% CI 0.41–0.88 $p=0.011$).

Table 1 Univariate associations between predictors of interest and prolonged length of stay (LOS, ≥3 days)

	None $N=8786$	Prolonged LOS $N=2898$	Total $N=11{,}684$	p Value
Female	7319 (83.3)	2408 (83.1)	9727 (83.3)	0.792
Age (mean ± SD)	44.1 (±10.4)	46.2 (±10.3)	44.6 (±10.4)	<0.001
Comorbidities				
Hypertension	2282 (26.0)	882 (30.4)	3164 (27.1)	<0.001
Mild diabetes	2171 (24.7)	845 (29.2)	3016 (25.8)	<0.001
Severe diabetes	207 (2.4)	121 (4.2)	328 (2.8)	<0.001
Coronary artery disease	54 (0.6)	43 (1.5)	97 (0.8)	<0.001
COPD	452 (5.1)	190 (6.6)	642 (5.5)	0.004
Obstructive sleep apnea	2682 (31.9)	1056 (36.4)	3738 (32.0)	<0.001
Surgeon factors				
Surgeon annual volume				
Low	1480 (16.8)	496 (17.1)	1976 (16.9)	0.422
Medium	5807 (66.1)	1938 (66.9)	7745 (66.3)	
High	1499 (17.1)	464 (16.0)	1963 (16.8)	
Surgeon cumulative volume				
<25	448 (5.1)	248 (8.5)	696 (6.0)	<0.001
26–50	487 (5.5)	214 (7.4)	701 (6.0)	
51–75	460 (5.2)	190 (6.6)	650 (5.6)	
76–100	432 (4.9)	218 (7.5)	650 (5.6)	
101–150	948 (10.8)	352 (12.2)	1300 (11.1)	
151–200	959 (10.9)	316 (10.9)	1275 (10.9)	
201–300	1734 (19.7)	524 (18.1)	2258 (19.3)	
301–400	1264 (14.4)	384 (13.2)	1648 (14.1)	
>400	2054 (23.4)	452 (15.6)	2506 (21.5)	
Hospital factors				
Fellowship training center	6612 (75.3)	2080 (71.8)	8692 (74.4)	<0.001
Hospital annual volume				
Low	2382 (27.1)	738 (25.5)	3120 (26.1)	<0.001
Medium	4046 (46.1)	1449 (50.0)	5495 (47.0)	
High	2358 (26.8)	711 (24.5)	3069 (26.2)	
Hospital cumulative volume				
0–300	1749 (19.9)	718 (24.8)	2467 (21.1)	0.001
301–600	1746 (19.9)	634 (21.9)	2380 (21.4)	
601–900	1261 (14.4)	470 (16.2)	1731 (14.8)	
901–1200	1124 (12.8)	376 (13.0)	1500 (12.9)	
1201–1500	1143 (13.0)	307 (10.6)	1450 (12.4)	
>1500	1763 (20.1)	393 (13.6)	2156 (18.5)	

Values represent *n*, (%) unless otherwise specified

SD standard deviation, *COPD* chronic obstructive pulmonary disease

The results of the hierarchal cost analysis are presented by Table 4. After multivariable adjustment, age ($389 95% CI $109–$655 $p=0.006$) and severe diabetes were associated with increased inpatient costs ($4765 95% CI $3052–$6475 $p<0.001$). Furthermore, surgeon cumulative volume had a substantial impact on costs. Compared to the first 25 cases, cases 51–75 conferred a decrease of $2775 (95% CI $−4352 to $−1204 $p=0.001$). After the 50th case, cost savings compared to the first 25 cases were relatively stable and maintained through a surgeons 400th case where the cost savings were $2402 less (95% CI $−4416 to $−413 $p=0.018$). Based on these findings, an ad hoc analysis was completed to determine the average savings after the 50th case compared to the first 25 cases. This demonstrated that the average cost savings after the 50th case were $2082 (95% CI $−3194 to $−962 $p<0.001$). Therefore, the excess surgeon costs associated with the first 50 cases are roughly $104, 077 (95% CI $−159,682 to $−48,104). With the

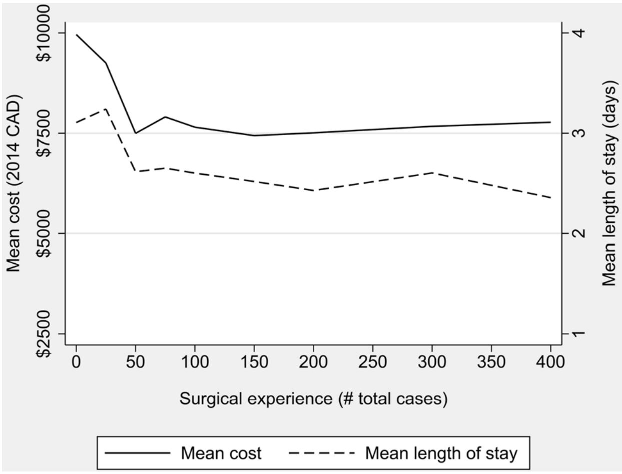

Fig. 1 Univariate association between surgeon cumulative volume and the primary outcomes (cost/length of stay)

adjustment for surgical cumulative volume, hospital cumulative volume did not have a significant effect on cost savings. Furthermore, neither surgeon annual volume or hospital annual volume had effects on case costs.

Discussion

This study examined the effect of surgeon experience on decreasing case costs for a complex surgical procedure. In this way, we were also able to examine the excess costs attributable to a surgeon's learning curve. With regard to our primary outcome, we found a substantial influence of surgeon cumulative volume on case costs. After the 50th case, cost savings compared to the first 25 cases were $2775 (95% CI $− 4352 to $− 1204 $p = 0.001$) and this was maintained through a surgeon's 400th case. Based on these findings, an ad hoc analysis found that the average savings after the first 50 cases was approximately $2082 (95% CI $− 3194 to $− 962 $p < 0.001$), and we contend that the cost of the learning curve for the Roux-en-Y gastric bypass is approximately $104,000 (95% CI $− 159,682 to $− 48,104) per surgeon. This gives a rough estimate of the excess costs attributable to the inexperienced surgeon compared to if those procedures were completed by a more experienced surgeon. Importantly, our findings are adjusted for annual surgeon and hospital volumes as well as hospital cumulative volume so as to not attribute hospital level efficiencies to individual surgeons. This also demonstrates that high annual volumes are probably a surrogate for surgeon experience rather than important variables by themselves.

There have been no previous studies which examine the effect of long-term surgeon experience on costs so as to determine when a plateau is reached. A meta-analysis reviewed previous learning curve studies of gastric bypass and found that these studies focused mostly on complication rates rather than cost and generally only follow-up patients for the first 100–150 cases [15]. Importantly, this meta-analysis found 14 papers that assessed the learning curve of 18 surgeons and only a single study reported costs though not in relation to surgeon experience. This demonstrates a paucity

Table 2 Excess inpatient cost due to predictors of interest for unadjusted univariable analyses

	Adjusted cost (95% CI)	*p* value
Unadjusted median cost (IQR)	$6669 ($6070 to $7522)	
Female	$317 ($− 82 to $716)	0.120
Age/per 10 years	$384 ($144 to $625)	0.002
Comorbidities		
Hypertension	$− 256 ($− 777 to $266)	0.337
Mild diabetes	$− 309 ($− 761 to $143)	0.180
Severe diabetes	$4651 ($− 452 to $9754)	0.074
Coronary artery disease	$− 356 ($− 953 to $241)	0.242
COPD	$832 ($− 1011 to $2675)	0.376
Obstructive sleep apnea	$− 280 ($− 784 to $224)	0.275
Surgeon factors		
Surgeon annual volume		
Low	Reference	
Medium	$− 400 ($− 1194 to $394)	0.323
High	$73 ($− 751 to $897)	0.862
Surgeon cumulative volume		
< 25	Reference	
26–50	$− 710 ($− 4277 to $2857)	0.696
51–75	$− 2465 ($− 5132 to $203)	0.070
76–100	$− 2055 ($− 4834 to $724)	0.147
101–150	$− 2312 ($− 5097 to $474)	0.104
151–200	$− 2521 ($− 5197 to $154)	0.065
201–300	$− 2453 ($− 5114 to $209)	0.071
301–400	$− 2290 ($− 4971 to $390)	0.094
> 400	$− 2188 ($− 4862 to $485)	0.109
Hospital factors		
Fellowship training center	$723 ($232–$1213)	0.004
Hospital annual volume		
Low	Reference	
Medium	$376 ($− 349 to $1102)	0.309
High	$− 617 ($− 1285 to $51)	0.070
Hospital cumulative volume		
0–300	Reference	
301–600	$− 1257 ($− 2404 to $− 110)	0.032
601–900	$− 671 ($− 1741 to $400)	0.220
901–1200	$− 932 ($− 1979 to $114)	0.081
1201–1500	$− 1180 ($− 2293 to $− 67)	0.038
> 1500	$− 955 ($− 2058 to $148)	0.090

SD standard deviation, *COPD* chronic obstructive pulmonary disease

Table 3 Odds of prolonged length of stay by predictors of interest after adjusted multivariable analysis (LOS, ≥ 3 days)

	Adjusted odds ratio (95% CI)	*p* value
Female	1.10 (0.97–1.24)	0.149
Age/10 years	1.22 (1.17–1.28)	< 0.001
Comorbidities		
Hypertension	1.03 (0.92–1.14)	0.671
Mild diabetes	1.11 (1.00–1.24)	0.048
Severe diabetes	1.60 (1.22–2.05)	0.001
Coronary artery disease	1.48 (0.93–2.27)	0.106
COPD	1.33 (1.09–1.59)	0.003
Obstructive sleep apnea	1.07 (0.97–1.19)	0.200
Surgeon factors		
Surgeon annual volume		
Low	Reference	
Medium	0.81 (0.69–0.96)	0.016
High	0.93 (0.70–1.23)	0.543
Surgeon cumulative volume		
< 25	Reference	
26–50	0.74 (0.58–0.93)	0.012
51–75	0.65 (0.50–0.83)	0.001
76–100	0.82 (0.62–1.06)	0.137
101–150	0.57 (0.43–0.74)	< 0.001
151–200	0.50 (0.36–0.67)	< 0.001
201–300	0.45 (0.32–0.61)	< 0.001
301–400	0.43 (0.28–0.60)	< 0.001
> 400	0.30 (0.19–0.44)	< 0.001
Hospital factors		
Fellowship training center	2.63 (1.14–6.48)	0.048
Hospital annual volume		
Low	Reference	
Medium	1.32 (1.05–1.62)	0.014
High	2.00 (1.37–2.79)	< 0.001
Hospital cumulative volume		
0–300	Reference	
301–600	1.03 (0.85–1.27)	0.777
601–900	0.90 (0.69–1.16)	0.398
901–1200	0.79 (0.57–1.06)	0.120
1201–1500	0.69 (0.48–0.95)	0.029
> 1500	0.61 (0.41–0.88)	0.011

CI confidence interval, *COPD* chronic obstructive pulmonary disease, *LOS* length of stay

of generalizable data on a surgeon long-term learning curve for gastric bypass and essentially no data on the effect of surgeon experience on costs. The largest study on the learning curve of gastric bypass to date demonstrated continually decreasing trend in morbidity rates until approximately the 500th procedure which agreed with a previous Brazilian study that suggested a plateau at approximately 500 cases [16, 25]. These findings suggested that the cost learning

Table 4 Excess inpatient cost due to predictors of interest after adjusted multivariable analysis

	Cost (95% CI)	*p* value
Adjusted median cost (IQR)#	$8803 ($7015–$10,547)	
Female	$577 ($− 154 to $1302)	0.119
Age/10 years	$386 ($109–$655)	0.006
Comorbidities		
Hypertension	$− 197 ($− 856 to $476)	0.563
Mild diabetes	$− 176 ($− 825 to $467)	0.596
Severe diabetes	$4765 ($3052–$6475)	< 0.001
Coronary artery disease	$− 2464 ($− 5537 to $584)	0.111
COPD	$892 ($− 284 to $2074)	0.138
Obstructive sleep apnea	$− 16 ($− 658 to $618)	0.961
Surgeon factors		
Surgeon annual volume		
Low	Reference	
Medium	$350 ($− 616 to $1312)	0.475
High	$489 ($− 941 to $1916)	0.501
Surgeon cumulative volume		
< 25	Reference	
26–50	$− 958 ($− 2478 to $548)	0.215
51–75	$− 2775 ($− 4352 to $− 1204)	0.001
76–100	$− 2358 ($− 4036 to $− 691)	0.006
101–150	$− 2576 ($− 4164 to $− 978)	0.001
151–200	$− 2653 ($− 4397 to $− 944)	0.003
201–300	$− 2454 ($− 4167 to $− 716)	0.005
301–400	$− 2317 ($− 4184 to $− 469)	0.015
> 400	$− 2402 ($− 4416 to $− 413)	0.018
Cumulative volume > 50 (compared to first 50)	$− 2082 ($− 3194 to $− 962)	< 0.001
Hospital factors		
Fellowship training center	$705 ($− 1031 to $2711)	0.436
Hospital annual volume		
Low	Reference	
Medium	$898 ($− 303 to $2191)	0.161
High	$752 ($− 1371 to $2900)	0.493
Hospital cumulative volume		
0–300	Reference	
301–600	$− 815 ($− 1977 to $346)	0.170
601–900	$− 553 ($− 2030 to $911)	0.461
901–1200	$− 957 ($− 2722 to $808)	0.287
1201–1500	$− 1255 ($− 3047 to $565)	0.175
> 1500	$− 648 ($− 2683 to $1405)	0.533

Values represent *n*, (%) unless otherwise specified

SD standard deviation, *COPD* chronic obstructive pulmonary disease

#Represents cost of a gastric bypass for a 44-year-old male with all reference values (no comorbidities, non-fellowship training center and lowest volume predictors) curve could decrease until 500 cases and that a long-term study was needed to assess the question of plateaued costs. Studies in other realms of surgery that do examine the relationship between surgeon experience and cost generally suffer from the same issues of small sample size and short follow-up and generally do not show consensus on the relationship. A study of 85 robotic-assisted rectal dissections demonstrated a decrease in cost of approximately $4000 from case 43–85 to the first 42 cases [26]. Conversely, a study of the learning curve of laparoscopic colectomy did not show a difference in cost from the first 40 procedures to the next 40 [27].

This is one of the first studies to quantify the excess system costs of a surgeon's learning curve while implementing a complex procedure within a healthcare system. The long-term timeline of this study allowed us to ascertain when cost savings due to surgeon experience plateaued and accordingly we found that this was after the 50th case for gastric bypass. Overall, the individual surgeon learning curve cost was approximately $104,000. The cost savings described in this study likely derive mostly from a shorter length of stay as after the 50th case there was at least a 35% lower odds of prolonged length of stay. This shorter length of stay is likely in part due to a decrease in the rate of complications as well as shorter operating times [16]. The specific cost found in this study however should be interpreted with caution and not applied to any other major procedure. Gastric bypass has a relatively low complication rate and length of stay and surgeon experience may have a more substantial impact on procedures with a more variation in their outcomes, such as a Whipple procedure. However, we feel that this is a phenomenon that does occur with every complex surgical procedure the exact figure would be different for all. Regardless of the exact figure for each surgical procedure, the study shows that it is substantial, especially for public healthcare systems. Of note, the learning curve presented by this study is likely the most optimal as it models procedures performed in a centralized care system using only fellowship-trained, high-volume surgeons. Costs may be higher for low-volume surgeons without fellowship training. Furthermore, based on the fact that there were 29 surgeons in our study means that the cost of the certain learning curve to Ontario, a province of 13.5 million people, was approximately $3 million. Overall then, the purpose of this study was not to dissuade surgeons from learning new techniques but rather to ensure that there is an understanding that the learning curve comes with real economic costs and that implementation of new procedures should be done with care in a deliberate and meaningful manner. In addition, any interventions that speed the learning curve should be seen in a very favorable economic light, especially when the implementation of a procedure is even more widespread than in this case. An intervention that decreases the costs associated with the learning curve by 50% would have been worth $1.5 million to the province Ontario. Therefore, interventions such as surgical coaching or further fellowship training may actually be cost-effective.

This study has several limitations. The specific number of procedures completed in fellowship and residency could not be ascertained from due to the de-identified nature of the surgeon data within the administrative database. However, stapled case loads in fellowship are approximately 50–100 and very few gastric bypass were done in Ontario previous to 2009. Additionally, using random effects for each surgeon accounted for the unmeasured variation at the surgeon level and it demonstrated no substantial variation across surgeons. Moreover, the exact way that the surgeons gain cost efficiencies could not be ascertained. No causal connections could be made between the cost efficiencies and complications. However, based on the effect of experience on complications and prolonged length of stay [16], we feel that cost-savings was largely due to a shortened length of stay and likely a decrease in major complications but other intraoperative cost efficiencies could not be entirely ruled out. However, based on the fact that hospital cumulative volume did not have a significant effect, we do not feel that a system solution caused the efficiency but was rather something at the surgeon level. This study also did not include low-volume surgeons (< 50 annual volume) or non-fellowship-trained surgeons and thus the cost efficiencies described may not be applicable to these groups. Furthermore, this study was completed in a universal health care system within the Canadian province of Ontario and therefore the costs may not be generalizable to other jurisdictions. Lastly, this study included only inpatient costs rather than 30-day costs. A previous economic analysis within the Ontario context confirmed that the 30-day readmission rate was low (6.1%) and costs for readmission were approximately $2000 per visit which translates to only 3 readmission within the first 50 cases and likely not a large impact on the final results [18, 28].

Conclusion

This study demonstrated the influence of surgeon cumulative volume on improved cost efficiencies. This also showed that introducing a new procedure costs approximately $104,000 per surgeon in total excess costs compared to if the procedures were completed by an experienced surgeon. The study will inform future cost planning and surgeon training within healthcare systems.

Compliance with ethical standards

Disclosures Drs. Doumouras, Saleh, Gmora, Anvari, and Hong have no conflicts of interest or financial ties to disclose.

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