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ORIGINAL CONTRIBUTIONS

A Longitudinal Analysis of Short-Term Costs and Outcomes in a Regionalized Center of Excellence Bariatric Care System

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Abstract
Background Evaluating how morbidity and costs evolve for new bariatric centers is vital to understanding the expected length of time required to reach optimal outcomes and cost efficiencies. Accordingly, the objective of this study was to evaluate how morbidity and costs changed longitudinally during the first 5 years of a regionalized center of excellence system.
Methods This was a longitudinal analysis of the first 5 years of a bariatric center of excellence system. The main outcomes of interest were all-cause morbidity and cost for the index admission. Predictors of interest included patient demographics, comorbidities, annual hospital and surgeon volume, fellowship teaching center status, and year of procedure. Hierarchical regression models were used to determine predictors of morbidity and costs.
Results Procedures done in 2012 (OR 0.65, 95%CI 0.52–0.79; $p < 0.001$), 2013 (OR 0.63, 95%CI 0.51–0.78; $p < 0.001$), and 2014 (OR 0.53, 95%CI 0.43–0.65; $p < 0.001$) all conferred a significantly lower odds of morbidity when compared to the initial 2009/2010 years. Surgeon volume was associated with a decreased odds of morbidity as for each increase in 25 bariatric cases per year the odds of all-cause morbidity was 0.94 lower (95%CI 0.88–1.00; $p = 0.04$). There was no significant variation at the hospital or surgeon level in perioperative outcomes.
Conclusion This study determined that volume was important even for high resource, fellowship-trained surgeons. It also found a decrease in morbidity over time for new centers. Lastly, there was little variation in outcomes across hospitals and surgeons suggesting that strict accreditation standards can help to ensure high quality across hospital sites.

Keywords Bariatric surgery · Outcomes · Costs

This data has not been presented previously.

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Introduction

Bariatric surgery has been increasingly utilized as a long-term treatment for severe obesity and type II diabetes [1]. Not only are major clinical outcomes, such as mortality, improved, but there is also an economic benefit due to decreased patient healthcare utilization [2, 3]. For the treatment of diabetes, bariatric surgery is also associated with a decrease in diabetic complications and remission in up to 70% of patients [4]. In addition, there has been increasing data on improved outcomes related to surgeon factors, such as procedure volume and experience, and hospital volumes in bariatric surgery [5–7]. Considering the growing importance of bariatric surgery in treating obesity and obesity-related comorbidities as well as the evidence demonstrating the importance of surgeon and hospital factors, a large-scale center of excellence system was recently established in Ontario in 2009.

The Ontario Bariatric Network (OBN) was created by the Ontario Ministry of Health and Long-Term Care in the late 2009. Overall, the OBN consists of 9 hospitals and 29 surgeons spread across 5 cities which service over 12 million people. Only bariatric Centers of Excellence (COE) are authorized to perform bariatric surgeries in Ontario. Specific standards for accreditation by the OBN include appropriate facilities, such as 24 h emergency and ICU care, and the presence of at least two high-volume, fellowship-trained surgeons [8]. Prior to this, bariatric care was offered at only one hospital in Ontario. As such, virtually, all newly accredited COEs began to deliver care simultaneously, and the OBN can be used to follow the evolution of newly regionalized hospitals over time. Previous work looking at initial outcomes in the OBN identified that there was significant variation in outcomes among centers [9]. Additionally, short-term drivers of costs have already been established [10]. Overall, few studies exist documenting the longitudinal evolution in costs and outcomes in addition to the variation between hospitals and surgeons in a newly regionalized healthcare system.

Determining how hospital outcomes evolve over time is vital to ensuring that patients receive the highest quality of care. Currently, research tends to focus on 1-year outcomes, but longitudinal analyses are needed to better qualify how hospitals are expected to change and if an initial period of worse outcomes is expected. This study aims to report costs and outcomes from the Ontario Bariatric Network in an effort to better delineate the evolution of a regionalized surgical care system.

Methods

Design and Setting

This was a longitudinal analysis in which the principle objective was to evaluate the evolution and variation of short-term outcomes and costs within the OBN over its first 5 years.

Population

All patients 18 years of age or older who underwent bariatric surgery in the Ontario Bariatric Network from April 2009 to March 2015 for the purpose of weight loss were included in the study. Patients were identified using morbid obesity as the most responsible diagnosis. This was then clarified using the procedure codes for gastric bypass and sleeve gastrectomy.

Setting

The OBN was established by the Ontario Ministry of Health and Long-Term Care in the middle of the 2009 fiscal year with full operation beginning in 2010. The minimum criteria for a hospital to receive bariatric center of excellence status in Ontario included being a full acute care/inpatient facility with 24-h intensive care, emergency room, and surgical coverage; at least 2 fellowship-trained bariatric surgeons with a minimum of 50 cases per year and a total hospital volume of 120 cases per year; and multidisciplinary medical, psychiatric, and respiratory support for preoperative, postoperative, and clinic care [8]. As part of accreditation, all hospitals must submit outcomes to a registry which provides surgeons with reports on unadjusted outcomes on a quarterly basis. All gastric bypasses and sleeve gastrectomies in Ontario must be performed within the OBN and are not sanctioned at outside hospitals.

Sources of Data

Patient demographics, comorbidity profiles, surgical procedures, complications, and costs were derived from the Canadian Institute for Health Information (CIHI) Discharge Abstract Database. Patients from the fiscal years 2009 and 2010 were combined due to the small number of patients in the 2009 fiscal year. This database is highly accurate in documenting the most responsible diagnosis and primary surgical procedures as well as morbidity causing a more than 24 h increase in length of stay [11, 12]. Specific demographics included gender and age while 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 were all-cause morbidity and cost during the index admission. All-cause morbidity included any documented complication that occurred during the index admission which extended length of stay by 24 h 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 due to having better statistical reliability than more specific outcomes such as leak or hemorrhage [13].

Costs were quantified using a standardized costing methodology [14] where a resource intensity weight is assigned to each hospitalized patient based on their utilization. This weight is multiplied by the average cost per weight for each health region for the year that the admission occurred. Costs represent the cost of the index admission and were adjusted for inflation. All costs are represented as 2010 Canadian dollars. Inflation statistics were taken from Statistics Canada [15].

The predictors of interest included in the analysis were patient demographics, comorbidities, annual hospital volume, annual surgeon volume, whether the center actively trained new bariatric/minimally invasive surgery fellows, and year of procedure. For the volume predictors, volume represented the surgeon and hospital volume for the year that each surgery occurred. To avoid collinearity, hospital volume was treated as a categorical variable and surgeon volume remained continuous.

Statistical Analysis

Descriptive statistics were used to characterize the patient population. The χ^2 statistic was used to compare categorical variables, and analyses of variance (ANOVA) were used for continuous variables. Hierarchical regression models were used to determine predictors of all-cause morbidity and costs. To account for unmeasured confounding at the hospital and provider level and obtain unbiased effect estimates, surgeon and hospital identifies were used as cross-classified random effects. These random effects represent the risk and reliability adjusted outcomes for each surgeon and hospital. Fixed effects included gender, age, comorbidities, annual hospital volume, annual surgeon volume, procedure, fellowship teaching center status, and year of procedure. Morbidity was modeled using a logistic hierarchal regression model. Surgical cost was modeled using a linear mixed effects model. In both models, Markov Chain Monte Carlo estimation was used 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

Table 1 presents the univariate associations between patient factors and all-cause morbidity. Overall, there were 13,256 patients identified since 2009 and the all-cause morbidity rate was 10.1%. During the course of the study, there were 29 individual surgeons identified at 9 sites. The mean patient age was 45 years and approximately 82% of the cohort were female. More than 29% of the cohort had hypertension while approximately 26 and 33% had uncomplicated diabetes and obstructive sleep apnea, respectively. Gastric bypass accounted for nearly 88% of the procedures. The median annual surgeon volume was 103 cases (IQR 86–138). Ten thousand cases were done at centers that were actively training minimally invasive fellows as part of the procedures. Univariate associations with all-cause morbidity were noted for age, hypertension, coronary artery disease, renal disease, severe diabetes, surgeon volume, and fellowship training center status but not for procedure type.

The all-cause morbidity and average costs by year of surgery are displayed in Table 2. Morbidity peaked in 2010 with a rate of 12.6% and continuously decreased until 2014 when the rate reached 7.8%. This trend reached statistical significance ($p < 0.001$). Costs ranged from \$7046 (±5189) in 2013 to \$7839 (±21,793) in 2009/2010, but there was no relationship found between operative cost and year of surgery in univariate statistics.

Table 3 presents the effect of the predictors on the odds of all-cause morbidity. Age was significantly associated with all-cause morbidity; as for each 10-year increase in age, the odds of morbidity increased by 1.14 times (95%CI 1.08–1.221; $p = <0.001$). Severe diabetes was the most substantial comorbidity in predicting all-cause morbidity as it increased the odds of morbidity by 1.51 times (95%CI 1.11–2.01; $p = 0.01$). Surgeon volume was associated with decreased odds of morbidity; as for each increase in 25 bariatric cases per year, the odds of all-cause morbidity was 0.94 lower (95%CI 0.88–1.00; $p = 0.04$). Conversely, hospital volume was associated with an increase in all-cause morbidity as compared to the years where hospital volumes were lower than 200; years with hospital volumes greater than 400 cases had a risk of morbidity 1.70 times greater (95%CI 1.20–2.33; $p = <0.001$). The year of surgery had a substantial impact on the odds of morbidity. Compared to the initial year, surgeries done in 2012 (OR 0.65, 95%CI 0.52–0.79; $p < 0.001$), 2013 (OR 0.63, 95%CI 0.51–0.78; $p < 0.001$), and 2014 (OR 0.53, 95%CI 0.43–0.65; $p < 0.001$) all conferred a significantly lower odds of morbidity. Gender, fellowship training site status, and procedure (gastric bypass vs sleeve) were not associated with differences in all-cause morbidity.

Table 4 presents the adjusted cost effects of the predictors of interest. The most substantial predictor was the presence of a complication which increased the average hospital costs by \$8340 (95%CI \$7625–\$9053; $p < 0.001$). Severe diabetes was independently associated with an increased cost of \$3160 (95%CI \$1886–\$4434; $p < 0.001$). The gastric bypass procedure predicted a decrease in costs compared to the sleeve gastrectomy, as patients undergoing this procedure had a average hospital cost \$754 less than those undergoing sleeve gastrectomy (95%CI \$1454–\$53; $p = 0.02$). Importantly, adjusted average costs did not decrease over the course of the study, and gender, volume, and fellowship training site status also were not significantly associated with cost differences.

Figures 1 and 2 depict the risk and reliability adjusted random effects for each surgeon and hospital. The important insight is that in this regionalized center of excellence system, using high-volume, fellowship trained surgeons, and accreditation standards, the odds of all cause morbidity did not differ significantly between hospitals or surgeons after risk adjustment. Similarly, costs among hospitals identified only a single outlying hospital with costs that were significantly greater than the average. Conversely, adjusted individual surgeon costs demonstrated very little variation, and even more importantly, the absolute value of the differences between surgeons was very little.

Table 1 Patient factors and univariate associations with all-cause morbidity

	None $N = 11{,}917$	Morbidity $N = 1339$	Total $N = 13{,}256$	p value
Female	9813 (82.3)	1093 (81.6)	10,906	0.52
Age	44.9 (10.5)	46.5 (10.2)	45.0 (10.5)	<0.001
Comorbidities				
Hypertension	3254 (27.3)	420 (31.4)	3674 (27.7)	0.002
Coronary artery disease	122 (1.0)	26 (1.9)	148 (1.1)	0.005
Severe diabetes	372 (3.1)	71 (5.3)	443 (3.3)	0.001
Mild diabetes	3087 (25.9)	368 (27.5)	3455 (26.1)	0.21
COPD	685 (5.8)	60 (4.5)	745 (5.6)	0.06
Obstructive sleep apnea	3913 (32.8)	456 (34.1)	4369 (33.0)	0.37
Procedures				
Gastric bypass	10,499 (88.1)	1185 (88.5)	11,684 (88.1)	0.69
Sleeve gastrectomy	1418 (11.9)	154 (11.5)	1572 (11.9)	
Annual hospital volume				<0.001
<200	2161 (18.1)	203 (15.2)	2364 (17.8)	
200–400	4318 (36.2)	380 (28.4)	4698 (35.4)	
>400	5438 (45.6)	756 (56.5)	6194 (46.7)	
Annual surgeon volume (IQR)	100 (85–135)	103 (86–138)	103 (86–138)	0.017
Fellowship teaching center	8899 (74.7)	1101 (82.2)	10,000 (75.4)	<0.001

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

SD standard deviation, *COPD* chronic obstructive pulmonary disease

Discussion

This study evaluated outcomes and costs over time in a center of excellence system and identified several important insights for newly formed regionalized care systems. Overall, there was an overall improvement in outcomes during the course of the study while costs seemed to reach efficiency in the first year. For all-cause morbidity, the year of surgery had a substantial impact on the odds of occurrence. Surgeries done in 2012 (OR 0.65, 95%CI 0.52–0.79; $p < 0.001$), 2013 (OR 0.63, 95%CI 0.51–0.78; $p < 0.001$), and 2014 (OR 0.53, 95%CI 0.43–0.65; $p < 0.001$) all conferred a significantly lower odds of morbidity when compared to the initial 2009/2010 years. With regard to costs, the most substantial predictor was the presence of a complication which increased its average hospital costs by $8340 (95%CI $7625–$9053; $p < 0.001$). This means that costs reached efficiency quickly and excess costs are likely due to excess complications rather than inefficiencies within the system. Additionally, after risk and reliability adjustment, there was little variation between the centers of excellence with regard to costs and outcomes. Lastly, even for fellowship trained surgeons in high resource settings, surgeon volume was the most important modifiable factor associated with decreased odds of morbidity; as for each increase in 25 bariatric cases per year, the odds of all-cause morbidity was 0.94 lower (95%CI 0.88–1.00; $p = 0.04$).

Recently, Aird et al. examined whether the OBN's standardization of bariatric care had appreciable effects on both short and long-term clinical outcomes [8]. Consistent with our results, they found a significant decrease in postoperative complication

Table 2 All-cause morbidity and cost (in 2010 CAD) by year

		All-cause morbidity			Cost	
	None	Morbidity	Rate (%)	p value	Cost ($ ± SD)	p value
2009/2010	2232 (18.7)	321 (24.0)	12.6	<0.001	7839 (21,793)	0.61
2011	2122 (17.8)	292 (21.8)	12.1		7310 (11,942)	
2012	2493 (20.9)	255 (19.0)	9.3		7472 (10,125)	
2013	2471 (20.7)	250 (18.7)	9.2		7046 (5819)	
2014	2599 (21.8)	221 (16.5)	7.8		7341 (9300)	

Costs expressed in 2010 Canadian dollars

SD standard deviation

Table 3 Adjusted odds of all-cause morbidity during the index admission

	Odds ratio (95%CI)	*p* value
Female	1.05 (0.90–1.22)	0.52
Age (per 10 years)	1.14 (1.08–1.22)	<0.001
Comorbidities		
Hypertension	1.20 (1.04–1.37)	0.01
Coronary artery disease	1.34 (0.80–2.08)	0.28
Severe diabetes	1.51 (1.11–2.01)	0.01
Mild diabetes	1.00 (0.87–1.14)	0.93
COPD	0.84 (0.60–1.04)	0.18
Obstructive sleep apnea	1.06 (0.93–1.22)	0.38
Annual surgeon volume (per 25)	0.94 (0.88–1.00)	0.04
Annual hospital volume (compared to <200)		
200–400	0.95 (0.73–1.20)	0.62
>400	1.70 (1.20–2.33)	<0.001
Fellowship teaching center	1.25 (0.86–1.81)	0.26
Gastric bypass	0.98 (0.81–1.19)	0.83
Year (compared to 2009/2010)		
2011	0.84 (0.69–1.03)	0.08
2012	0.65 (0.52–0.79)	<0.001
2013	0.63 (0.51–0.78)	<0.001
2014	0.53 (0.43–0.65)	<0.001

CI confidence interval, *COPD* chronic obstructive pulmonary disease

Table 4 Adjusted cost differences of the index admission

	Adjusted cost (95%CI)	*p* value
Female	$336 ($241–$911)	0.13
Age (per 10 years)	$226 ($7–$446)	0.02
Comorbidities		
Hypertension	$- 251 ($786–$285)	0.18
Coronary artery disease	$- 2253 ($4402–$116)	0.02
Severe diabetes	$3160 ($1886–$4434)	<0.001
Mild diabetes	$- 226 ($748–$293)	0.20
COPD	$857 ($98–$1811)	0.04
Obstructive sleep apnea	$- 21 ($526–$482)	0.47
Complication	$8340 ($7625–$9053)	<0.001
Annual surgeon volume (per 25)	$110 ($119–$340)	0.17
Annual hospital volume (compared to <200)		
200–400	$85 ($899–$1077)	0.43
>400	$- 1034 ($2489–$398)	0.08
Fellowship teaching center	$938 ($669–$2679)	0.12
Gastric bypass	$- 754 ($1454–$53)	0.02
Year (compared to 2009/2010)		
2011	$- 370 ($1232–$494)	0.20
2012	$- 9 ($861–$851)	0.49
2013	$- 482 ($1329–$374)	0.13
2014	$- 69 ($909–$784)	0.44

Costs expressed in 2010 Canadian dollars

CI confidence interval, *COPD* chronic obstructive pulmonary disease

rates between 2010/2011 and 2014/2015, with outcomes continuing to improve over the course of the study. Interestingly, we found significant associations between surgeon and hospital volume and outcomes but in opposite directions. Several studies have shown surgeon volume to be independently associated with improved patient outcome. Padwal et al., in a systematic review, showed that high-volume surgeons had significantly decreased odds of morbidity and rates of serious complications compared to low-volume surgeons [16]. Weller et al. also showed that surgeon volume, independent of hospital volume, significantly affected patient outcome [17]. The association between hospital case volume has also been demonstrated by various studies [6, 7, 18, 19], although Zevin et al. noted a weaker association between hospital volume and outcome compared to the effect of surgeon volume [20]. While many studies support the use of hospital volume as a predictor of better surgical outcomes, comparatively fewer studies adjusted for both surgeon volume and hospital volume and previous studies may have attributed the surgeon volume effect as a hospital volume effect. There have been several studies suggesting designated COEs do not produce better surgical outcomes [19, 21–23]. However, Jafari et al. found that accreditation had a significant impact in determining outcome while Telem et al. showed accreditation to be independently associated with fewer major complications [24, 25]. Pradarelli et al. found that of 40 hospitals analyzed in Michigan, only 4 were identified as outliers. This demonstrates that outcomes can be relatively stable across high volume centers [23]. We also recently investigated the cost of bariatric surgery within the OBN and found the importance of several complications on surgical costs [10].

This study examined outcomes and costs in a regionalized, high-volume center of excellence system and discovered several important insights. From this study, a clear trend toward improved outcomes over time was found in this study. In the fifth year from inception, the risk of morbidity was approximately half as compared to the first year. This finding is important as it shows that even for high-volume center of excellence surgeons with fellowship training, improvements in outcomes over time can be seen. This suggests that interventions to improve surgeon outcomes may be of use to even for the most highly trained surgeons and high resource settings. It also suggests that new sites added to a high volume center of excellence system could also have a similar learning curve, and therefore, several years should elapse before outcomes are expected to stabilize. Reasons for this improvement could be related to surgeons gaining cumulative experience [5], but it is unknown if the effect would be as profound without the periodic feedback on outcomes and accreditation standards for volume afforded by the regionalized center of excellence model. We feel that the latter two are vital to ensuring an optimal learning curve. In addition, the importance of annual surgeon volume is

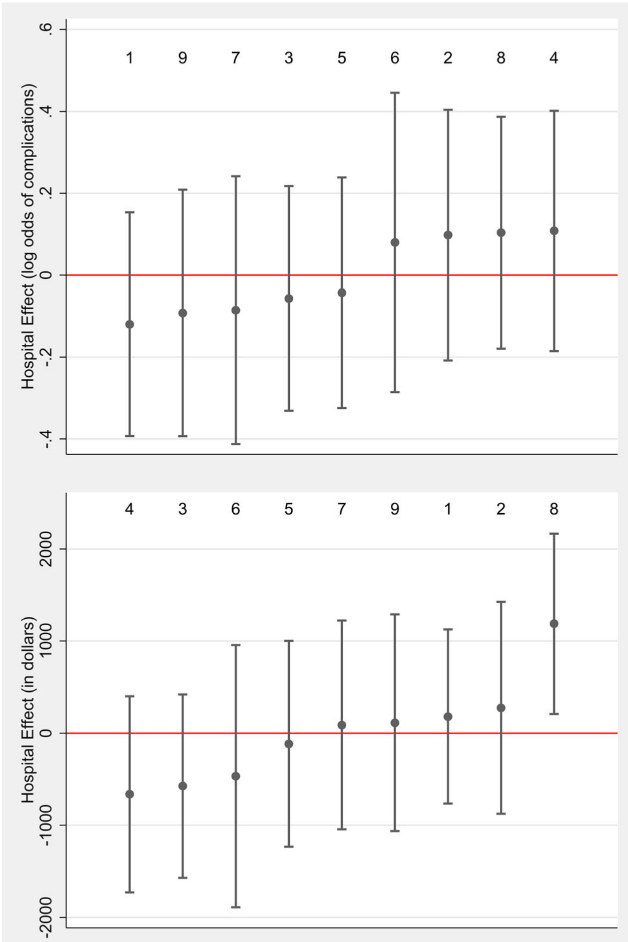

Fig. 1 Hospital level variation in risk and reliability adjusted costs and outcomes

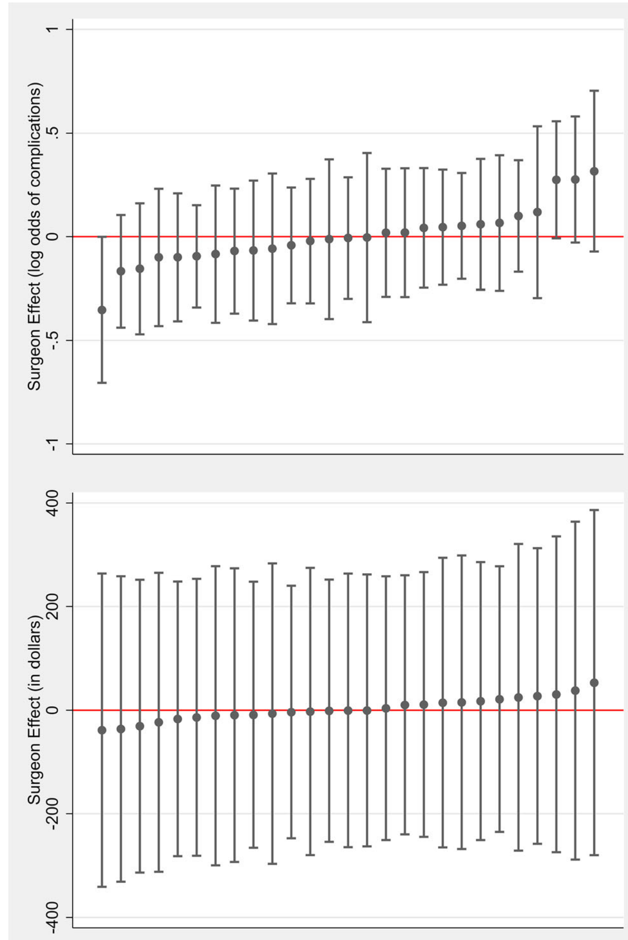

Fig. 2 Surgeon level variation in risk and reliability adjusted costs and outcomes

underscored by this analysis as it is one of the more important modifiable aspects in the improvement of patient care. From the analysis of surgeon and hospital level outcomes, we found that there was no significant variation between the hospitals and surgeons in morbidity after adjustment for important predictors suggesting that the implementation of a high-volume center of excellence system, such as that in Ontario, can likely lead to decreased variability in outcomes across sites. This is likely due in part to the strict accreditation standards required by each site and periodic feedback on outcomes. The importance of complications on costs was also underscored by the study and was demonstrated by our previous work [10]. Lastly, this work also shows that surgeon variation in costs is relatively small after important risk adjustments. Accordingly, tracking individual surgeon costs may not be the most important aspect when attempting to improve costs at a system level.

This study has several limitations. We were also unable to adjust for all potential confounders including BMI due to limitations on the dataset; the previous work of ours suggests that BMI distributions are similar among centers of excellence in Ontario [8, 9]. In addition, as the main outcome of interest, all-cause morbidity is relatively ill-defined and may be hard to replicate in other studies. However, the morbidity rates found in this study to mimic other large cohorts and previous studies have shown good validity for CIHI data in recording complications [11, 21, 26]. This study was not able to capture morbidity from readmissions. The readmission rate in Ontario is 6.1% based on previous work with approximately 10% of these patients already having a complication [27]. However, it is unlikely that these patients would be different than the group with inpatient complications. Importantly, with regard to costs, this study did not include full 30-day costs for each procedure. Previous work, which also included the cost of readmissions, demonstrated higher costs for gastric bypass procedure [10]. Because the current work was designed to evaluate longitudinal costs, inference about costs between procedures is limited.

Conclusions

We evaluated short-term outcomes and costs after bariatric surgery in a newly formed center of excellence system. This study underscored the importance of surgeon volume in outcomes even in high resource settings for fellowship trained surgeons. It also demonstrated that there was improvement in outcomes over time for high-volume fellowship-trained surgeons in the center of excellence system suggesting a cumulative volume effect. In addition, after adjustment, there is little variation in outcomes across hospitals and surgeons suggesting that accreditation standards can lead to little variation across sites for risk-adjusted outcomes. With regard to cost, complications were the most substantial predictor and there was little variation in the surgeon level.

Compliance with Ethical Standards This study was approved by the Hamilton Integrated Research Ethics Board.

Ethical Approval Statement This article does not contain any studies with human participants or animals performed by any of the authors. For this type of study, formal consent is not required.

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

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Informed Consent Statement Does not apply.

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