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ORIGINAL CONTRIBUTIONS

Bariatric Surgery Performed at a Tertiary Care Hospital and an Ambulatory Hospital: A 5 Year Comparison of Outcomes, OR Efficiencies and Costs

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Abstract

Purpose To explore change in 30-day post-operative complications, operative times, operating room (OR) efficiencies for bariatric surgery performed at a tertiary care hospital (TH) and an ambulatory hospital with overnight stay (AH) within one hospital network over 5 years; and to compare perioperative costs at the TH and AH.

Materials and Methods We performed a retrospective analysis of existing data from a cohort of consecutive adult patients who underwent primary laparoscopic Roux-en-Y gastric bypass (LRYGB) and sleeve gastrectomy (LSG) between September 2016 and August 2021 at TH and AH.

Results A total of 805 patients (762 LRYGB, 43 LSG) had surgery at AH, while 109 (92 LRYGB, 17 LSG) at TH. OR times for LRYGB and LSG performed at AH were significantly shorter versus TH (150 ± 24 vs 178 ± 51 min; $p < 0.01$) and (123 ± 24 vs 147 ± 34 min; $p = 0.01$). OR turnovers (19.2 ± 6.0 min vs 28.1 ± 6.1 min; $p < 0.01$) and Post Anesthetic Care Unit (PACU) times (2.4 ± 0.6 h vs 3.1 ± 1.5 h; $p < 0.01$) were significantly faster at AH versus TH. Proportion of patients requiring transfer for a complication from AH to TH remained constant over time (range 1.5–6.2%/year; $p = 0.14$). 30-day complication rates were similar between AH and TH (5.5–11% vs 0–15%; $p = 0.12$). LRYGB and LSG costs were similar between AH and TH (8,855 ± 1,328CAD vs 8,799 ± 2,729CAD; $p = 0.91$ and 8,763 ± 1,449CAD vs 7,857 ± 1,825CAD; $p = 0.41$).

Conclusion There was no difference in 30-day post-operative complications for LRYGB and LSG performed at AH and TH. Performing bariatric surgery at AH has the benefit of improved OR efficiency without a significant difference in total perioperative costs.

Keywords Bariatric surgery · Ambulatory surgery · Roux-en-Y gastric bypass · Sleeve gastrectomy · Costs · Efficiencies

Key Points

- There is no difference in 30-day complications of primary bariatric surgery performed at an ambulatory hospital with an overnight stay versus a tertiary care hospital.
- It is more efficient to perform primary bariatric surgery at an ambulatory hospital with an overnight stay versus a tertiary care hospital.
- One to 6 percent of patients per year require transfer from the ambulatory hospital to the tertiary care hospital for a post-operative complication, and this transfer rate remains constant over time.
- There is no difference in perioperative costs for surgery performed at an ambulatory hospital versus a tertiary care hospital with the current structure of nursing care.

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Introduction

Obesity is a chronic progressive disease that affects the life of as many as 1 in 4 Canadians [1, 2]. Laparoscopic Roux-en-Y gastric bypass (LRYGB), laparoscopic sleeve gastrectomy (LSG), and biliopancreatic diversion (BPD) with duodenal switch (DS) are publicly funded procedures in Canada; however, access to these procedures remains limited and is not uniform [2]. There were 4297 operations performed in the province of Ontario in 2017–2018, with 10,364 total bariatric operations performed in Canada for the same year [2].

It has been hypothesized that access to publicly funded bariatric surgery can be improved by performing these operations in ambulatory hospitals affiliated with a tertiary care hospital without increased rates of post-operative complications [3, 4]. We previously analyzed the outcomes of

2 years of our bariatric surgery program and demonstrated that LRYGB and LSG can be safely performed in low- to moderate-risk patients at an ambulatory hospital with an overnight stay (AH) with a 4.1% transfer rate to a tertiary care hospital (TH) for a postoperative complication [5].

Our objectives for this study were to: (1) explore the change in 30-day post-operative complications, operative times, operating room (OR) efficiencies for bariatric surgery performed at the tertiary care hospital (TH) and the ambulatory hospital with overnight stay (AH) located within one hospital network over 5 years; and (2) to compared perioperative costs at the AH and the TH.

Methods

Study Design

We performed a retrospective analysis of existing data from a cohort of consecutive adult patients who underwent LRYGB or LSG surgery at AH and TH of our hospital system. Data for surgeries performed at AH was collected from September 1, 2016 and August 31, 2021. Data for surgeries performed at TH was collected from September 1, 2018 to August 31, 2021.

Inclusion/Exclusion Criteria

We included all patients over 18 years of age who underwent a primary LRYGB or LSG. We included patients who had concurrent procedures such as hiatus hernia repair, cholecystectomy, ventral / incisional / umbilical hernia repair. We excluded all patients who underwent a revision, conversion, or reversal bariatric procedure. Patients with untreated obstructive sleep apnea and with an Obesity Surgery Mortality Risk Score of 4 or higher were not eligible to undergo surgery at the AH and had their surgery at the TH.

Description of Ambulatory and Tertiary Care Hospital Sites

The bariatric surgery program in our hospital network (Kingston Health Sciences Centre) was accredited in 2016 to perform bariatric surgery at both TH and AH. In Ontario (Canada), accreditation of hospitals to perform publicly funded bariatric surgery is done by the Ontario Bariatric Network. At a minimum, accreditation requires: (1) a full acute care and inpatient facility; (2) ICU availability; (3) 24 h emergency department and surgical coverage; (4) oximetry beds for postop care with respiratory technician availability; (5) at least 2 laparoscopic bariatric surgeons with each surgeon performing a minimum of 50 cases per year; (6) a minimum volume of 120 bariatric cases per year, (7) a multi-disciplinary clinic for preoperative and postoperative care, (8) medical bariatric support for clinic and inpatient care, and (8) psychiatry support for preoperative and postoperative assessment if necessary. The TH and AH are 1.4 km apart. AH is open from Monday to Friday, and patients undergoing bariatric surgery can be admitted post-operatively for up to 48 h. There is no after-hours access to imaging, operating rooms, resident physician coverage, intensive care unit or medical consultation services. Surgery residents, bariatric surgery fellow and anesthesia residents participate in the LRYGB and LSG cases performed at the AH.

TH has 24-h imaging availability, in-house resident physician coverage, access to ICU, and medical consultation services. A strict protocol is in place to facilitate urgent transfers from AH to TH for postoperative complications.

Operative Technique and Perioperative Care

Our operative technique and perioperative care for LRYGB and LSG was previously described [5]. Patients were assessed by the surgical team daily to make decisions relevant to patient discharge or transfer from AH to TH if patients were deviating from expected post-operative course. In January 2020, we changed our technique for the LRYGB gastrojejunal anastomosis from a circular-stapled to a linear-stapled technique with stapled closure of common enterotomy over a 40F dilator.

Transfer Criteria

As per preprinted orders, surgeons are alerted by nursing staff if patients' vital signs fall outside of normal parameters or if patients experience an unusual postoperative course (e.g., increased abdominal pain, nausea or vomiting, melena or hematemesis). A surgeon assesses the patient and decides whether the patient should be transferred to the TH. Examples of indications for transfer include sustained sinus tachycardia, ongoing nausea and vomiting, gastrointestinal bleeding, hypoxemia requiring supplemental oxygen on the day of planned discharge, severe abdominal pain and postoperative bleeding.

Demographic Data

We collected the following demographic data: age, sex, height (cm), weight on the day of surgery (kg), American

Society of Anesthesiologists (ASA) score, Edmonton Obesity Staging System (EOSS) score, and obesity-related comorbidities. Body Mass Index (BMI) was calculated used height and weight on the day of surgery.

Outcomes

We collected 30-day post-operative complications (anastomotic leak/perforation, small bowel obstruction (SBO), DVT/PE, incisional hernia, wound infection, anastomotic erosion/ulcer, anastomotic stricture, acute kidney injury (AKI), and bleeding), number of transfers from AH to TH, total duration of surgery defined as combined anesthesia and surgery time (OR time; min), duration of turnover between cases (OR turnover; min), duration of stay in the post anesthetic care unit (PACU; hrs), and length of hospital stay (days).

Perioperative Costs

Patients who underwent concurrent procedures such as hiatal hernia repair, cholecystectomy, ventral/umbilical hernia repair were excluded for the purposes of cost comparison. We collected both direct and indirect costs for the index hospital admission including labour, supply, and equipment costs. As the case mix at the AH and TH was different, we created a matched cohort of patients who underwent LRYGB and LSG from the AH and TH with the following characteristics: sex (female), ASA (1–3), and EOSS (1–2).

Statistical Analysis

We examined the change in outcomes over 5-years using ANOVA for continuous variables, and Wilcoxon rank test for discrete variables. We compared outcomes between AH and TH using student's t-test for continuous variables, and Chi-square test for categorical variables. Statistical analysis was performed in the R statistical environment (v4.0.2).

Results

A total of 805 patients (762 LRYGB, 43 LSG) had surgery at AH, while 109 (92 LRYGB, 17 LSG) at TH. Patient demographics and change in demographics over time at AH and TH are summarized in Appendix Table 1.

Patients who had surgery at AH were younger (43.1 ± 10.0 years vs 50.5 ± 11.4 years; $p < 0.01$), had a lower mean BMI (46.3 ± 6.0 kg/m^2 vs 51.0 ± 10.8 kg/m^2, $p < 0.01$) and had a lower comorbidity burden as reflected by their median ASA (3(2–3) vs 3(3–3), $p < 0.01$) and median EOSS (2(1–2) vs 2(2–3), $p < 0.01$) scores. As the program evolved over 5 years, there was a significant increase in the mean BMI and median ASA scores for patients at the AH (Appendix Table 1).

Patients' obesity-related comorbidities are summarized in Appendix Table 2. The most common obesity-related comorbidity was obstructive sleep apnea (78.8%). Patients who had surgery at TH had significantly higher rates of obesity-related comorbidities (Appendix Table 2).

Comparisons of Case Volumes

A significantly higher proportion of cases performed at AH were LRYGB as compared to TH (95% vs 84%; $p < 0.01$). Concurrent procedures were significantly more common at TH versus AH (25 out of 109 (22.9%) vs 78 out of 805 (9.7%); $p < 0.01$) (Appendix Table 3). Hiatus hernia repair was the most common concurrent procedure at both AH and TH.

Comparisons of Efficiencies Between AH and TH

The operative times were significantly shorter for LRYGB (150.0 ± 25.4 min vs 178.0 ± 51.4 min; $p < 0.01$) and LSG (122.9 ± 23.9 min vs 147.1 ± 34.3 min; $p = 0.01$) at AH versus the TH (Appendix Table 4). OR turnover times (19.2 ± 6.0 min vs 28.1 ± 6.1 min; $p < 0.01$) and PACU recovery times (2.4 ± 0.6 h vs 3.1 ± 1.5 h; $p < 0.01$) were also significantly shorter at AH versus TH. Length of hospital stay was similar between both sites for LRYGB (2.0 (0.7) vs 2.1 (3.5) days; $p > 0.05$) and LSG (2.0 (0.3) vs 2.1 (1.0) days; $p > 0.05$).

As our bariatric surgery program evolved over 5 years, we observed several trends over time (Appendix Table 4). The duration of time to perform a LRYGB at AH decreased significantly from 161.2 ± 24.4 min in year 1 to 140.8 ± 20.5 min in year 5 ($p < 0.01$). The duration of time to perform LRYGB at TH, and the duration of time to perform LGS at both sites did not change over time. OR turnover times and PACU times at AH did not change over time; however, OR turnover times at TH increased significantly over time (26.3 ± 5.3 min to 31.5 ± 6.4 min; $p < 0.01$). Mean LOS after LRYGB at AH decreased significantly over time from 2.1 ± 0.5 days in year 1 to 1.7 ± 0.7 days in year 5 ($p < 0.01$). Mean LOS for LRYGB at TH, and for LGS at both sites did not change over time.

Post-op Complications and Transfers from AH to TH

The overall proportion of patients requiring transfer from AH to TH for a post-operative complication was 3.6% (29 out of 805 patients). This proportion remained constant over 5 years and ranged from 1.5% to 6.2% per year ($p = 0.14$) (Appendix Table 5). The most common reason for transfer was post-operative bleeding. Proportion of patients with post-operative bleeding did not change over 5 years at AH (0.8–5.6% per year; $p > 0.05$) and TH (0–3.8% per year; $p > 0.05$). Similarly, proportion of patients with an anastomotic leak/perforation remained low and constant over time at AH (0–1.6% per year; $p > 0.05$) and TH (0%). Proportion of patients with at least 1 complication within 30 days of surgery was similar between the two sites (5.5–11% vs 0–15%; $p = 0.12$) with no significant change over 5 years at AH and a significant decrease from 15% to 3.2% at TH ($p = 0.03$).

Comparison of Perioperative Costs

Two matched cohorts of patients were created for analysis of perioperative costs for LRYGB (289 patients at AH and 35 at TH) and two matched cohorts were created for LSG (17 patients at AH and 4 at TH) (Appendix Table 6). Demographic characteristics were similar between two LRYGB cohorts for age (42.5 ± 10.3 years vs 42.2 ± 11.7 years; $p > 0.05$), and for severity of their disease of obesity (EOSS scores 2(1–2) vs 2(2–2); $p > 0.05$). Despite matching, TH cohort had a significantly higher BMI (46.8 ± 6.7 kg/m^2 vs 51.4 ± 9.3 kg/m^2; $p < 0.01$) and higher ASA score (3(2–3) vs 3(3–3); $p = 0.01$). Demographic characteristics were similar between two LSG groups for BMI (47.0 ± 5.8 kg/m^2 vs 49.0 ± 11.1 kg/m^2; $p = 0.60$), ASA (3(2–3) vs (3(3–3); $p = 0.18$) and EOSS (2(2–2) vs 2(2–2); $p = 0.30$). However, patients in AH group were younger despite the matching (44.9 ± 8.3 years vs 55.8 ± 4.6 years; $p = 0.02$).

Overall, there was no significant difference in average cost per LRYGB case ($8,855 ± $1,328 CAD vs $8,799 ± $2,729 CAD; $p = 0.91$) and LSG ($8,763 ± 1,449CAD vs $7,857 ± 1,825CAD; $p = 0.41$) performed at AH versus TH. However, direct labour costs were significantly higher at the AH compared to the TH, while supply and equipment costs were significantly lower at the AH compared to the TH (Appendix Table 7).

Discussion

We described the 5-year evolution of our publicly funded bariatric surgery program at a tertiary care hospital and its ambulatory site by examining the outcomes of 916 patients who underwent primary LRYGB and LSG. As our program evolved, we were able to perform primary LRYGB and LSG at the AH on patients with higher BMIs, higher ASAs and higher stages of obesity with unchanged low risk of 30-day complications. We demonstrated that primary LRYGB and LSG can be performed more efficiently at the AH with shorter operative times, OR turnover times, and PACU stay. Our transfer rate from AH to TH, however, remained unchanged despite overcoming the initial learning curve for both the surgeons and the program. The total cost of performing a primary LRYGB and LSG for matched cohorts of female patients at AH and TH were similar; however, direct labour costs were significantly higher, while supply and equipment costs were significantly lower at the AH compared to the TH.

We showed a significant improvement over 5 years in operative times for a LRYGB performed at the AH (161.2 ± 24.4 min in year 1 to 140.8 ± 20.5 min in year 5; $p < 0.01$). The improvement in operative times is likely a result of the surgeons and the bariatric program overcoming the learning curve for LRYGB, which has been shown to be around 500 cases [6]. Doumouras et al. (2018) reported a decrease in the operative times (procedure start to end time) for LRYGB from 183.8 min for surgeons who performed fewer than 75 cases to 125.9 min for surgeons who performed greater than 500 cases [6]. In contrast, we did not see a significant decrease in operative times for LSG procedures. This may be explained by decreased complexity and shorter learning curve for the LSG, reported to be approximately 30 cases per surgeon [7]. Surgeons in our program likely overcame LSG learning curve during fellowship training. Our mean operative times for the LSG were 122.9 ± 23.9 min per case, which are comparable to literature reported value of 90 min per case keeping in mind that our operative times included both surgery and anesthesia times [8, 9].

We did not see a significant decrease in the transfer rate from the AH to the TH despite performing more than 800 cases at AH over 5 years (Appendix Table 5). Christou et al. (2013) described his experience with 676 publicly funded cases (558 LRYGB, 29 LSG and 89 gastric band) performed in a 17-bed private hospital in Montréal (Canada) with a dedicated “service corridor” to a tertiary care hospital [10]. Their reported 30-day complication rate was 7.5%, with 1.2% of patients requiring transfer to a tertiary care hospital [10]. We demonstrated comparable results with a transfer rate between 1.5% to 6.2% per year and complication rates from 5.5% to 11% per year (Appendix Table 5). These results are also in agreement with other reported values in literature [11, 12]. The lack of decrease in the proportion of patients requiring transfer from AS to TH despite the surgeons and the program overcoming the required learning curve was surprizing. One possible explanation for this result is that with more experience at the AH we began operating on patients with higher BMI, ASA and EOSS. This may explain the increase in the proportion of patients which required transfer to TH in Year 3.

We demonstrated significantly shorted operative times, OR turnover times and PACU stays at AH compared to TH. These OR efficiencies at AH translate to one additional bariatric surgery case performed per day at AH compared to TH. These findings of greater OR efficiency at ambulatory hospitals have been reported in other studies [13]. Potential explanations for differences in efficiencies between AH and TH in the literature include different teams (nurses, technicians, cleaners) working at the two sites, requirement to participate in "on-call" cases at TH, length of work day and overall perception of how the day is structured [14].

We demonstrated no difference in the total cost of performing LRYGB and LSG in matched cohorts of female patients at AH and TH sites. We excluded concurrent procedures from the cost analysis; thus the lack of difference in total cost may be due to the standardization of the procedure and perioperative care at both AH and TH sites. We did observe, however, that direct labour costs were significantly higher at the AH, while supply and equipment costs were significantly lower at the AH. The nursing costs were the main driver for higher labour costs at AH due to the structure of the post-op care. Patients at AH remained in an "extended PACU" bed rather than a ward bed for the entire length of their hospital stay, and labour costs for nursing were calculated based on the hourly wage of a PACU nurse compared to the hourly wage of a ward nurse. If the labour costs at both sites were equivalent, the average total cost per patient for LRYGB and LSG would be $556 CAD and $954 CAD less expensive, respectively, at AH compared to TH. Recent comparison of LRYGB and LSG being performed in France in the ambulatory versus inpatient setting demonstrated a 14% cost savings in the ambulatory setting (€ 4272.9 $\pm$ 589.7 versus € 4993.7 $\pm$ 695.6) [15]. In our study we did not explore whether the OR at TH was underutilized by performing one fewer bariatric case per day. Future studies should include under or overutilization of the OR time into the cost calculation as maximum utilization of limited OR resources is paramount given the current backlog of surgical cases post COVID-19 pandemic in Ontario [16].

Our study has several limitations. First, our procedure times included both anesthesia and surgical times, which makes it challenging to make direct comparisons to the literature reporting surgery only times. Furthermore, we cannot comment on how the surgical times alone have evolved over time as anesthesia times may have become longer due to COVID precautions in years 4 and 5. Second, our reported mean operative times were likely longer due to the inclusion of concurrent procedures in our analysis. A significantly greater proportion of cases at TH had concurrent procedures, while patients at TH had a higher BMI, ASA and EOSS scores as compared to AH, which may have contributed to the longer mean operative times at the TH. However, a subset analysis of case-matched LRYGB cases without concurrent procedures for patients with ASA $< =3$ and EOSS $< =3$ at AH (n = 394) and TH (n = 53) showed a persistent significant difference in OR times (144 $\pm$ 22 min vs 165 $\pm$ 27 min; $p = 0.041$). Third, our 30-day complication rates are subject to reporting bias as we captured complications documented in our hospital electronic medical records, visits to emergency department and post-operative admissions to other hospitals from Connecting Ontario platform. Visits to walk-in clinics or primary care providers were not captured. Fourth, cost data was provided through our hospital's costing system which relies on clinical documentation of supplies used. As a special program, particular attention was paid to the documentation of bariatric surgery supply components, increasing our confidence that these costs have been accurately captured. However, gaps in data capture for supplies used may have resulted in inaccurate costing of supplies for some of these cases. Further, costs are specific to an encounter at a specific site. Patients who have surgery at one site, but are transferred post op to another site may not have all costs fully represented. Lastly, we did not include the cost of readmissions for a complication in our cost analysis as this was not within the aims of the study. Similarly, future studies looking to compare the cost-effectiveness, rather than the overall costs, of performing bariatric surgery at AH and TH should incorporate the cost of managing chronic obesity-related medical conditions and their relapse following bariatric surgery.

Conclusion

We demonstrated that publicly funded primary LRYGB and LSG can be safely performed at the ambulatory site of a tertiary care hospital with the added advantage of improved OR efficiency, but without significant cost savings. Despite 5-year evolution of our program, the proportion of patients that required transfer from AH to TH for a post-operative complication did not decrease, suggesting that caution should continue to be exercised in performing primary bariatric surgery at an ambulatory hospital without a tertiary care hospital affiliation.

Appendix

Table 1 Patient demographics and their change over time

Variable	AH	TH	*P*-value	Ambulatory hospital site						Tertiary care hospital site			
				Y1	Y2	Y3	Y4	Y5	*P*-value	Y3	Y4	Y5	*P*-value
N	805	109		127	174	177	137	190		52	26	31	
Mean age (SD)	43.1 (10.0)	50.5 (11.4)	< 0.01	41.0 (8.1)	42.0 (9.4)	43.7 (10.1)	43.1 (11.0)	45.0 (10.6)	< 0.01	50.6 (11.0)	53.5 (8.7)	48.0 (11.5)	0.19
Proportion female	0.91	0.78	< 0.01	0.89	0.91	0.95	0.90	0.90	0.61	0.81	0.62	0.87	< 0.01
Mean pre-op BMI (SD)	46.3 (6.0)	51.0 (10.8)	< 0.01	44.8 (5.1)	45.6 (5.2)	45.9 (5.6)	47.9 (6.8)	47.1 (6.8)	< 0.01	50.8 (11.9)	51.8 (10.0)	50.6 (9.9)	0.84
Median ASA (quartiles)	3 (2–3)	3 (3–3)	< 0.01	3 (2–3)	3 (2–3)	3 (2–3)	3 (3–3)	3 (3–3)	< 0.01	3 (3–3)	3 (3–3)	3 (3–3)	0.16
Median EOSS (quartiles)	2 (1–2)	2 (2–3)	< 0.01	2 (1–2)	2 (1–2)	2 (2–2)	2 (1–2)	2 (1–2)	< 0.01	2.5 (2–3)	2 (2–4)	2 (2–3)	0.06

AH ambulatory hospital site, *TH* tertiary care hospital site, *N* number, *SD* standard deviation, *BMI* body mass index (kg/m^2), *ASA* American Society of Anesthesiologists score, *EOSS* Edmonton Obesity Staging System, *Y* year

Table 2 List of patients' obesity related comorbidities. (Total *N* = 914, 805 AH and 109 TH)

Comorbidity	*N* Total (%)	AH (%)	TH (%)	*P*-value
MSK	557 (60.9)	472 (58.6)	85 (80.0)	< 0.01
Cardiac	41 (4.5)	24 (3.0)	17 (15.6)	< 0.01
Type 2 Diabetes Mellitus	179 (19.6)	140 (17.4)	39 (35.8)	< 0.01
CVA	15 (1.6)	12 (1.5)	3 (2.8)	0.57
DVT/PE	21 (2.3)	17 (2.1)	4 (3.7)	0.50
Dyslipidemia	207 (22.6)	170 (21.1)	37 (33.9)	< 0.01
GERD	462 (50.5)	392 (48.7)	70 (64.2)	< 0.01
PCOS	113 (12.4)	104 (12.9)	9 (8.3)	0.22
Infertility	64 (7.0)	59 (7.3)	5 (4.6)	0.39
COPD	28 (3.1)	15 (1.9)	13 (11.9)	< 0.01
Asthma	227 (24.8)	190 (23.6)	37 (33.9)	0.026
Obstructive sleep apnea	720 (78.8)	621 (77.1)	99 (90.8)	< 0.01
Urinary stress incontinence	356 (38.9)	325 (40.4)	31 (28.4)	0.022
Renal disease	87 (9.5)	71 (8.8)	16 (14.7)	0.075
History of Depression	571 (62.5)	495 (61.5)	76 (69.7)	0.12
History of Anxiety	457 (50.0)	403 (50.1)	54 (49.5)	1
History of smoking	472 (51.6)	399 (49.6)	73 (67.0)	< 0.01
History of eating disorder	559 (61.2)	492 (61.1)	67 (61.5)	1
History of excessive drinking	166 (18.2)	149 (18.5)	17 (15.6)	0.54

AH ambulatory hospital site, *TH* tertiary care hospital site, *N* number, *MSK* musculoskeletal diseases, *CVA* cerebrovascular accident, *DVT / PE* deep venous thrombosis / pulmonary embolism, *GERD* gastroesophageal reflux disease, *PCOS* polycystic ovarian syndrome, *COPD* chronic obstructive pulmonary disease

Table 3 Summary of concurrent procedures performed at the time of bariatric surgery. (Total *N* = 914, 805 AH and 109 TH)

Concurrent procedure	Total *N* (%)	AH (%)	TH %	*P*-value
Hiatus Hernia Repair	67 (7.3)	53 (6.6)	14 (12.8)	0.03
Cholecystectomy	11 (1.2)	9 (1.1)	2 (1.8)	0.86
Extensive lysis of adhesions	2 (0.2)	1 (0.1)	1 (0.9)	0.57
Umbilical hernia repair	6 (0.7)	5 (0.6)	1 (0.9)	1
Gastric wedge resection	4 (0.4)	1 (0.1)	3 (0.3)	< 0.01
Ventral hernia repair	2 (0.2)	2 (0.2)	0 (0)	1
Takedown of a fundoplication	2 (0.2)	0 (0)	2 (1.8)	< 0.01
Gastric band removal	2 (0.2)	0 (0)	2 (1.8)	< 0.01
Liver biopsy	2 (0.2)	2 (0.2)	0 (0)	1
Small bowel resection	5 (0.5)	5 (0.6)	0 (0)	0.89

AH ambulatory hospital site, *TH* tertiary care hospital site, *N* number

Table 4 Evolution of operative times (surgical + anesthesia time), OR turnover times, and PACU times over time

Variable	Total	yr 1	yr 2	yr 3	yr 4	yr 5	*p*-value
AH Site							
LRYGB times in min (SD)	150.0 (25.4)	161.2 (24.4)	153.7 (22.9)	149.4 (26.5)	149.0 (23.8)	140.8 (20.5)	< 0.01
LGS times in min (SD)	122.9 (23.9)	124.0 (28.1)	130.3 (17.8)	119.2 (18.7)	118.1 (25.5)	121.5 (32.2)	0.41
Turnover in min (SD)	19.2 (6.0)	21.1 (9.2)	17.4 (5.0)	19.8 (5.7)	19.1 (4.2)	19.3 (5.5)	0.7
PACU times in hrs (SD)	2.4 (0.6)	NA	NA	2.5 (0.7)	2.3 (0.7)	2.4 (0.6)	0.08
Mean LOS post LRYGB (days)	2.0 (0.7)	2.1 (0.5)	2.1 (0.5)	2.1 (1.0)	1.9 (0.4)	1.7 (0.7)	< 0.01
Mean LOS post LGS (days)	2.0 (0.3)	2.0 (0)	2.1 (0.3)	2.0 (0.04)	1.8 (0.4)	2.0 (0.5)	0.15
TH Site							
LRYGB times in min (SD)	178.0 (51.4)	NA	NA	174.6 (43.4)	199.0 (73.1)	165.2 (35.6)	0.72
LGS times in min (SD)	147.1 (34.3)	NA	NA	152.0 (42.9)	152.0 (19.6)	140.1 (36.4)	0.54
Turnover in min (SD)	28.1 (6.1)	NA	NA	26.3 (5.3)	27.4 (5.7)	31.5 (6.4)	< 0.01
PACU times in hrs (SD)	3.1 (1.5)	NA	NA	2.9 (1.2)	3.3 (1.6)	3.3 (1.8)	0.27
Mean LOS post LRYGB (days)	2.1 (3.5)	NA	NA	2.4 (1.2)	3.7 (6.8)	1.9 (0.5)	0.22
Mean LOS post LGS (days)	2.1 (1.0)	NA	NA	1.6 (0.7)	2.4 (0.6)	2.5 (1.4)	0.33

AH ambulatory hospital, *TH* tertiary care hospital, *SD* standard deviation, *LRYGB* laparoscopic Roux-en-Y gastric bypass, *LSG* laparoscopic sleeve gastrectomy, *LOS* length of stay, *PACU* post-anesthesia care unit, *yr* year

Table 5 Evolution of transfer and complication rates over the years. (Year 3 had a patient who had both bleeding and bowel obstructions as reasons for transfer)

Variable	yr 1	yr 2	yr 3	yr 4	yr 5	*p*-value
AH site						
Patients transferred from AH to TH for a post-op complication (x out of n [%])	3/127 (2.4)	8/174 (4.6)	11/177 (6.2)	2/137 (1.5)	5/190 (2.6)	0.14
Cardiac arrhythmia	1		1	1	1	
GI complication	1		1			
Bowel obstruction	1		1*			
Bleeding		6	7	1	4	
Respiratory compilation		2				
Hypotension			1			
No reason reported			1			
Proportion of AH patients with at least 1 complication within 30 days	7/127 (5.5)	15/174 (8.6)	20/177 (11)	11/137 (8.0)	12/190 (6.3)	0.35
Bleeding	1/127 (0.8)	6/174 (3.4)	10/177 (5.6)	6/137 (4.4)	7/190 (3.7)	0.28
Anastomotic leak/Perforation	0/127 (0)	2/174 (1.1)	1/177 (0.6)	0/137 (0)	3/190 (1.6)	0.38
TH site						
Proportion of TH patients with at least 1 complication within 30 days	NA	NA	8/52 (15)	0/26 (0)	1/31 (3.2)	0.032
Bleeding	NA	NA	2/52 (3.8)	0/26 (0)	1/31 (3.2)	0.61
Anastomotic leak/Perforation	NA	NA	0/52 (0)	0/26 (0)	0/31 (0)	NA

AH ambulatory hospital site, *TH* tertiary care hospital site, *GI* gastrointestinal, *yr* year

Table 6 Demographics of cohorts of patients who underwent LRYGB and LSG at AH and TH used in cost analysis

	LRYGB			LSG		
Variable	AH	TH	*P*-value	AH	TH	*P*-value
N	289	35		17	4	
Mean age (SD)	42.5 (10.3)	42.2 (11.7)	0.90	44.9 (8.3)	55.8 (4.6)	0.02
Mean pre-op BMI (SD)	46.8 (6.7)	51.4 (9.3)	< 0.01	47 (5.8)	49 (11.1)	0.60
Median ASA (quartiles)	3 (2–3)	3 (3–3)	0.014	3 (2–3)	3 (3–3)	0.18
Median EOSS (quartiles)	2 (1–2)	2 (2–2)	0.07	2 (2–2)	2 (2–2)	0.30

AH ambulatory hospital site, *TH* tertiary care hospital site, *N* number, *SD* standard deviation, *LRYGB* laparoscopic Roux-en-Y gastric bypass, *LSG* laparoscopic sleeve gastrectomy, *ASA* American Society of Anesthesiologists score, *EOSS* Edmonton Obesity Staging System

Table 7 Breakdown of cost analysis

	LRYGB			LSG		
Variable	AH	TH	*P*-value	AH	TH	*P*-value
N	289	35	NA	17	4	NA
Labour costs						
Mean variable direct labour in CAD (SD)	3316 (766.6)	2760 (1462)	0.03	3455 (806.5)	2501 (491.0)	0.02
Mean fixed direct labour in CAD (SD)	231.5 (54.7)	244.8 (132.3)	0.56	287.1 (115.9)	234.8 (37.88)	0.14
Supply costs						
Mean variable direct patient supply in CAD (SD)	2696 (388.2)	2662 (415)	0.64	2535 (314.2)	2350 (977.6)	0.73
Mean variable direct general supply in CAD (SD)	589.5 (140.4)	884.8 (356.2)	< 0.01	518.4 (95.7)	763.5 (106.4)	0.01
Mean fixed direct equipment in CAD (SD)	199.6 (59.6)	365.8 (123.9)	< 0.01	224.2 (133.7)	327.1 (69.1)	0.06
Other						
Mean variable direct other in CAD (SD)	7.40 (10.6)	37.03 (28.3)	< 0.01	19.03 (13.25)	36.54 (8.07)	0.01
Mean fixed direct other in CAD (SD)	69.63 (14.0)	58.9 (28.1)	0.03	68.48 (13.64)	53.9 (10.97)	0.07
Indirect costs						
Mean indirect variable cost in CAD (SD)	1139 (207.6)	1170 (464.6)	0.71	1083 (220.2)	1039 (175.8)	0.69
Mean indirect variable fixed cost in CAD (SD)	606.2 (109.4)	623.7 (253.8)	0.69	573.6 (107.4)	550.8 (98.29)	0.70
Mean Total cost in CAD (SD)	8855 (1328)	8799 (2729)	0.91	8763 (1449)	7857 (1825)	0.41

AH ambulatory hospital site, *TH* tertiary care hospital site, *CAD* Canadian dollars

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Acquisition of data: Kouzmina, Deghan.
Analysis and interpretation of data: Kouzmina, Zevin.
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Declarations

Ethical Approval Ethical approval was obtained from our Health Sciences and Affiliated Teaching Hospitals Research Ethics Board (SURG-452–18). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study formal consent is not required.

Informed Consent Informed Consent does not apply.

Conflict of Interest Ekaterina Kouzmina, Shaidah Deghan, David Robertson, Cara Reimer, and Boris Zevin have no conflict of interest to declare. This study was supported by the Bariatric Surgery Academic Excellence Fund, Department of Surgery, Queen's University.

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