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# Lasting Impact of COVID-19 on Bariatric Surgery Delivery in North America: A Retrospective International Cohort Study of 349,209 Patients in 902 Centers

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**Abstract:** COVID-19 resulted in dramatic changes to the delivery of bariatric surgery; however, the lasting effect on current and future delivery remains uncharacterized. We sought to characterize differences and trends in bariatric surgery care and outcomes between 2020 and 2021. The Metabolic and Bariatric Accreditation and Quality Improvement Program (MBSAQIP) collects data from 902 centers in North America. The MBSAQIP database was evaluated, including patients undergoing sleeve gastrectomy (SG) and Roux-en-Y gastric bypass (RYGB) with two cohorts described: those receiving surgery in 2020 and those in 2021. Patient selection, operative techniques, and outcomes were compared using bivariate analysis. Multivariable modelling evaluated factors including operative year, independently associated with serious complications and mortality. We evaluated 349,209 patients, with 154,960 (44.4% undergoing bariatric surgery during 2020 compared to 194,249 (55.6%) in 2021. This represents a 20.2% year-to-year increase in total cases, and a 20.7% increase in cases per center (178.5 cases/center in 2020 vs. 215.4 cases/center in 2021). Patients receiving bariatric surgery during 2021 were statistically younger with fewer comorbidities compared to 2020; however, differences were small and groups appeared clinically similar. Length of stay continued to decrease ($1.4 \pm 1.1$ days 2020 vs. $1.3 \pm 1.2$ days 2021, $p < 0.001$), yet post-operative outcomes remained similar. Bariatric surgical volumes have increased but may still remain inadequate to meet demand, while trends towards selecting younger, healthier patients for bariatric surgery continue. Efforts to recover from the effects of COVID-19 are ongoing, and long-term evaluation of outcomes following these changes will remain important.

**Keywords:** COVID-19; bariatric surgery; pandemic; Roux-en-Y gastric bypass; sleeve gastrectomy



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## 1. Introduction

The coronavirus disease 2019 (COVID-19) virus led to dramatic changes in bariatric surgical delivery [1–4]. Compared to previous years, patients receiving bariatric interventions in 2020 were younger, had less metabolic comorbidities, and were more likely to receive sleeve gastrectomy (SG) as opposed to Roux-en-Y gastric bypass (RYGB) [2]. More recent data has suggested that postoperative but not preoperative COVID-19 infection, presumably with less virulent viral strains, was associated with worse post-operative bariatric outcomes [5]. Despite changes to bariatric surgery delivery, two large studies evaluating bariatric outcomes during this period provided reassuring data supporting equivalent outcomes for pre- and post- COVID-19 eras [2,6]. However, these studies highlighted two potentially concerning trends: the first being that surgical volumes decreased by 13.8%, and the second that patients with severe metabolic comorbidities associated with obesity were disproportionately underserved. While these changes to bariatric surgical delivery

were noted early during the pandemic era, the persistent effect of COVID-19 on patient selection, technical delivery, and operative outcomes remains uncharacterized.

Although data on the persistent effect from COVID-19 are not well described in bariatric surgery, growing evidence from other surgical specialties continues to demonstrate a persistent COVID-19 effect on waiting lists, patient selection, and operative technique utilization [7]. Vascular surgery in the United Kingdom continues to report long waiting lists, a reduction in aneurysm screening, and an increase in aneurysm size thresholds for intervention [8]. Similarly, massive case-load backlogs have persisted across most, if not all, surgical specialties, forcing surgeons to triage patients accordingly [9,10]. Characterizing these triage decisions and the persistent impact of COVID-19 on bariatric surgery is crucial to inform current practice and address ongoing post-COVID-19 surgical recovery plans.

This study aims to provide a multi-center international cohort study comparing bariatric surgery delivery and outcomes in 2020 to 2021. This study serves as a follow up to the 2020 report using the Metabolic and Bariatric Accreditation and Quality Improvement Program (MBSAQIP) database that demonstrated a dramatic reduction in bariatric surgical cases and trends towards selecting healthier patients and applying SG more frequently during the COVID-19-affected year of 2020 [2]. Evaluating surgical volumes over time and persistent surgical trends will remain critical to reducing the backlog of surgical cases and to continue delivering optimal bariatric surgical care.

## 2. Materials and Methods

### *2.1. Data Source*

This study analyzes data from the 2020 and 2021 MBSAQIP database, which collects pre-operative, operative, and early (30-day) post-operative outcomes for patients undergoing bariatric surgery. MBSAQIP data is prospectively collected from 902 bariatric surgery-accredited centers in the United States and Canada based on standardized variables and is subject to frequent review of data integrity and collection practices [11]. This study was exempt from ethics board review.

### *2.2. Study Design, Patient Population, and Variable Definitions*

This is a retrospective cohort study of prospectively collected data. The study's primary aim was to evaluate demographics, operative approaches, and early post-operative outcomes for patients receiving operations during 2020 compared to 2021. The purpose of this analysis was to determine whether trends in patient and operative selection that occurred in 2020 during the COVID-19 pandemic continued, remained static, or persisted during 2021. Additionally, secondary outcomes evaluated whether operative year was an independent predictor of serious complications or mortality.

Patients receiving elective SG or RYGB during the 2020 and 2021 years were included in this analysis with cohorts described by the operative year. Only patients receiving SG or RYGB were included to allow comparison to prior studies, to limit heterogeneity, and because they represent the two primary bariatric procedures performed in North America [12].

Demographics compared between cohorts included age, gender, race, and pre-operative body mass index (BMI). We also characterized metabolic, cardiac, pulmonary, and other comorbidities. Metabolic and cardiac comorbidities included diabetes mellitus (DM), hyperlipidemia, hypertension, prior myocardial infarction (MI) or cardiac surgery, and prior percutaneous coronary intervention (PCI). Pulmonary comorbidities included smoking status in the last year, pre-operative sleep apnea, and chronic obstructive pulmonary disease (COPD). Additionally, we present patient's pre-operative history of venous thromboembolism (VTE), gastroesophageal reflux disease (GERD), venous stasis, renal insufficiency, dialysis dependency, and therapeutic anticoagulation. In terms of procedural details collected in this study, we define the proportion of SG and RYGB, and operative time.

Peri-operative morbidity and mortality is described by complications occurring within 30 days of bariatric surgery. Outcomes included length of hospital stay (LOS), and 30-day

reoperation, reintervention, and readmission based on MBSAQIP definitions [11]. We also tabulated infectious complications such as deep surgical site infection (SSI), wound disruption, sepsis, pneumonia, and the need for unplanned intubation. Other complications evaluated include acute kidney injury, myocardial infarction (MI), cerebral vascular accidents (CVA), and mortality. We also define and evaluate integrated complications, including post-operative bleeding, anastomotic leak, and serious complications as defined in the Appendix A. Finally, mortality differences are presented.

### *2.3. Statistical Analysis*

All statistical analysis was completed using STATA 17 statistical software (StataCorp, College Station, TX, USA). We report categorical data as absolute values with percentages, while continuous data are expressed as a weighted mean ± standard deviation unless otherwise specified. Between-group differences were evaluated using the chi-squared test for categorical data and ANOVA for continuous data.

To control for confounders and evaluate independent predictors of serious complications and mortality, a non-parsimonious multivariable logistic regression model was developed using a hypothesis-driven purposeful selection methodology. Bivariable analysis of variables with a $p$-value < 0.1 or from variables previously deemed clinically relevant to our primary outcome were used to generate a preliminary main effects model. This model included the operative year (2021 vs. 2020) as an independent variable to assess its independent effect on post-operative outcomes. Model accuracy was interrogated using the Brier score and the Receiver operating characteristic (ROC).

## 3. Results

### *3.1. Patient Demographics*

We evaluated a total of 349,209 patients undergoing elective SG and RYGB, with 154,960 (44.4%) receiving surgery in 2020 compared to 194,249 (55.6%) in 2021. Compared to patients receiving operations in 2020, patients in 2021 were younger (43.9 ± 11.9 years in 2020 vs. 42.4 ± 11.7 years in 2021; $p < 0.001$), with more being 18–50 and fewer >50 years old (Table 1). In 2021, there was also significantly more females (81.6% in 2020 vs. 83.0% in 2021; $p < 0.001$). There was also a small and potentially clinically insignificant increase in the number of functionally independent patients (99.5% in 2020 vs. 99.6% in 2021; $p < 0.001$). In 2021, patients were also more likely ASA class 2–3 and less likely to be class 3–4, and were significantly less likely to be active smokers (6.8% in 2020 vs. 6.5% in 2021; $p < 0.001$). Patients in 2021 were also less likely to have diabetes, hypertension, dyslipidemia, COPD, renal insufficiency, venous stasis, sleep apnea, and were less likely to be anticoagulated pre-operatively (Table 1). Their cardiac history was also less significant, including fewer prior MIs, cardiac surgeries, and PCI (Table 1). It should be highlighted that many of these differences were subtle and potentially of no clinical significance, despite the statistical difference.

**Table 1.** Patient characteristics comparing patients receiving bariatric surgery during 2020 compared to 2021.

| | **Patients Operated on in 2020** ***n* = 154,960** ***n* (%)** | **Patients Operated on in 2021** ***n* = 194,249** ***n* (%)** | ***p*-Value** |
|---|---|---|---|
| Age, years | | | |
| mean ± sd | 43.9 ± 11.9 | 42.4 ± 11.7 | <0.001 |
| <18 | 290 (0.2) | 392 (0.2) | |
| 18–29 | 17,276 (11.2) | 22,644 (11.7) | |
| 30–39 | 41,774 (30.0) | 54,460 (28.0) | <0.001 |
| 40–49 | 45,190 (29.2) | 57,050 (29.4) | |
| 50–59 | 33,666 (21.7) | 41,087 (21.2) | |
| ≥60 | 16,764 (10.8) | 18,616 (9.6) | |

**Table 1.** *Cont.*

| | **Patients Operated on in 2020** ***n* = 154,960** ***n* (%)** | **Patients Operated on in 2021** ***n* = 194,249** ***n* (%)** | ***p*-Value** |
|---|---|---|---|
| Gender | | | |
| Female | 126,373 (81.6) | 161,232 (83.0) | <0.001 |
| BMI, Kg/m$^2$ | | | |
| mean ± sd | 44.7 ± 7.7 | 44.8 ± 7.7 | 0.154 |
| <35 | 7652 (4.9) | 9792 (5.0) | |
| 35–39 | 36,024 (23.3) | 45,424 (23.4) | |
| 40–45 | 47,505 (30.7) | 59,467 (30.6) | 0.392 |
| 45–50 | 31,070 (20.1) | 39,007 (20.1) | |
| 50–60 | 27,752 (16.6) | 32,015 (16.5) | |
| >60 | 6953 (4.5) | 8539 (4.4) | |
| Functional Status | | | |
| Independent | 153,928 (99.5) | 193,222 (99.6) | <0.001 |
| Partially dependent | 816 (0.5) | 849 (0.4) | |
| Fully dependent | 39 (0.03) | 30 (0.02) | |
| ASA Category | | | |
| 1–2 | 30,377 (19.7) | 37,259 (19.2) | <0.001 |
| 3 | 118,275 (76.6) | 150,100 (77.3) | |
| 4–5 | 5859 (3.8) | 6721 (3.5) | |
| Smoker | 10,598 (6.8) | 12,569 (6.5) | <0.001 |
| Diabetes | | | |
| No or diet-controlled | 119,598 (77.2) | 152,450 (78.5) | |
| Non-insulin-dependent | 25,371 (16.4) | 30,490 (15.7) | <0.001 |
| Insulin-dependent | 9991 (6.5) | 11,309 (5.8) | |
| Hypertension | 68,785 (44.4) | 83,068 (42.8) | <0.001 |
| GERD | 49,307 (31.8) | 62,747 (32.3) | 0.062 |
| COPD | 1870 (1.2) | 2156 (1.1) | 0.008 |
| Hyperlipidemia | 34,675 (22.4) | 41,878 (21.6) | <0.001 |
| Renal insufficiency | 879 (0.6) | 989 (0.5) | 0.019 |
| Dialysis dependent | 483 (0.3) | 559 (0.3) | 0.198 |
| History of DVT | 3984 (2.6) | 4863 (2.5) | 0.207 |
| Venous stasis | 1090 (0.7) | 1142(0.6) | <0.001 |
| Pre-operative therapeutic anticoagulation | 4458 (2.9) | 5141 (2.7) | <0.001 |
| Sleep apnea | 57,197 (36.9) | 69,163 (35.6) | <0.001 |
| History of MI | 1624 (1.1) | 1849 (1.0) | 0.004 |
| Previous major cardiac surgery | 1413 (0.9) | 1552 (0.8) | <0.001 |
| Previous PCI | 2302 (1.5) | 2341 (1.2) | <0.001 |
| SG | 108,554 (70.1) | 135,041 (69.5) | 0.001 |
| RYGB | 46,406 (30.0) | 59,208 (30.5) | 0.001 |
| Operative time, minutes | | | |
| mean ± sd | 89.7 ± 54.1 | 88.6 ± 53.3 | <0.001 |

sd, standard deviation; BMI, body mass index; GERD, gastroesophageal reflux disease; COPD, chronic obstructive pulmonary disease; DVT, deep vein thrombosis; MI, myocardial infarction; PCI, percutaneous coronary intervention; SG, Sleeve Gastrectomy; RYGB, Roux-en-Y Gastric Bypass. *p*-values were determined using chi-squared analysis for categorical data and ANOVA for continuous data.

In terms of operative procedures, there was a small but statistically significant increase in RYGB in 2021 compared to 2020 (30% in 2020 vs. 30.5% in 2021; $p = 0.001$). Additionally, there was a reduction in operative time from 89.7 ± 54.1 min in 2020 to 83.9 ± 53.3 in 2021 ($p < 0.001$; Table 1).

### 3.2. Operative Volume

From 2020 to 2021, there was a 20.2% increase in SG and RYGB cases performed (154,960 in 2020 vs. 194,249 in 2021). There was an increase in MBSAQIP-accredited centers, from 885 in 2020 to 902 in 2021. Controlling for this change, there appears to be a 20.7% increase in bariatric surgery cases per center (178.5 cases/center in 2020 vs. 215.4 cases/center in 2021). Compared to previously published data from Verhoeff et al. (2022), we note that the increased total number of operative cases in 2021 represents the largest number of cases captured in MBSAQIP history. Additionally, the 215.4 cases/center in 2021 represents a higher number of cases per center compared to 2017–2019, which ranged from 204.2 cases/center to 205.7 cases/center (Figure 1; data previously reported by Verhoeff et al., 2022) [2].

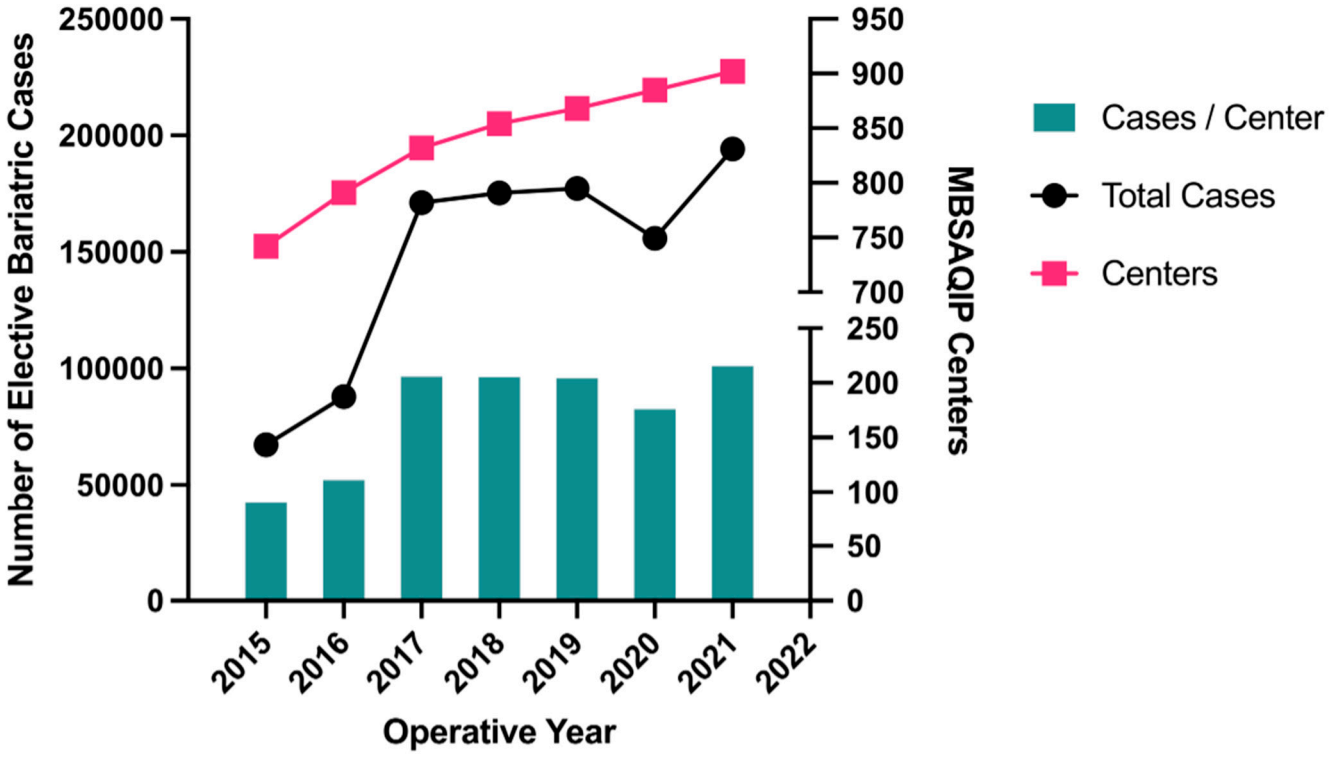


**Figure 1.** Total elective sleeve gastrectomy and Roux-en-Y Gastric bypasses operative cases and cases per center completed at accredited Metabolic and Bariatric Accreditation and Quality Improvement Program (MBSAQIP) centers from 2015 to 2021.

### 3.3. Bivariate Analysis of Post-Operative Outcomes Comparing Patients without Peri-Operative COVID-19 to Those with Pre- or Post-Operative COVID-19

Comparing early post-operative outcomes for patients undergoing bariatric surgery in 2020 and 2021, a small but significant reduction in length of stay was recognized (1.4 ± 1.2 in 2020 vs. 1.3 ± 1.2 in 2021; $p < 0.001$). There were small (<1%) differences in reintervention, readmission, and deep SSI rates between years, but, clinically, all post-operative outcomes were similar between years (Table 2). Importantly, considering the potential pulmonary and venous thromboembolism complications associated with COVID-19, there was no difference in pneumonia, unplanned intubation, or VTE between 2020 and 2021 (Table 2).

**Table 2.** Thirty-day post-operative outcomes for patients receiving bariatric surgery during 2020 compared to 2021.

| | **Patients Operated on in 2020** | **Patients Operated on in 2021** | |
|---|---|---|---|
| | ***n* = 154,960** | ***n* = 194,249** | ***p*-Value** |
| | ***n* (%)** | ***n* (%)** | |
| Length of stay (days) | 1.4 ± 1.2 | 1.3 ± 1.2 | <0.001 |
| Reoperation | 1666 (1.1) | 2099 (1.1) | 0.877 |
| Reintervention | 1205 (0.8) | 1640 (0.8) | 0.029 |
| Readmission | 4736 (3.1) | 6212 (3.2) | 0.017 |
| Deep SSI | 545 (0.35) | 770 (0.4) | 0.032 |
| Wound disruption | 79 (0.05) | 109 (0.06) | 0.124 |
| Sepsis | 157 (0.1) | 229 (0.1) | 0.143 |
| Pneumonia | 338 (0.2) | 406 (0.2) | 0.562 |
| Unplanned intubation | 155 (0.1) | 173 (0.1) | 0.185 |
| VTE | 611 (0.4) | 706 (0.4) | 0.140 |
| Acute kidney injury | 165 (0.1) | 180 (0.1) | 0.197 |
| MI | 176 (0.1) | 215 (0.1) | 0.799 |
| Cerebral vascular accidents | 18 (0.01) | 31 (0.02) | 0.282 |
| Leak | 425 (0.3) | 543 (0.3) | 0.768 |
| Bleed | 1548 (1.0) | 1835 (0.9) | 0.104 |
| Serious complication | 4883 (3.2) | 6074 (3.1) | 0.683 |
| Mortality | 104 (0.07) | 143 (0.07) | 0.473 |

SSI, surgical site infection; MI, myocardial infarction; VTE, venous thromboembolism.

### *3.4. Multivariable Logistic Regression Evaluating Predictors of Serious Complications and Mortality*

Multivariable modelling evaluating serious complications demonstrated that, in patients undergoing operations in 2020 and 2021, partially dependent functional status (OR 1.72, CI 1.42–2.08; $p < 0.001$), RYGB compared to SG (OR 2.04, CI 1.89–2.19; $p < 0.001$), prior VTE (OR 1.92, CI 1.76–2.09; $p < 0.001$), and renal insufficiency (OR 2.19, CI 1.85–2.68; $p < 0.001$) were the most substantial independent predictors. Other substantial contributors to serious complications included age, GERD, hypertension, diabetes, COPD, history of MI, and Black race, which were significantly associated with increased odds of serious complications. No protective factors were elucidated (Table 3). Notably, operative year was not a significant contributor to serious complications. The model had a Brier score of 0.03 and ROC of 0.67.

Evaluation of factors independently associated with mortality found prior MI (OR 3.52, CI 2.21–5.61, $p < 0.001$) and partially dependent functional status (OR 2.66, CI 1.41–5.04; $p = 0.003$) to be the most strongly associated factors. Additionally, BMI, age, diabetes, prior VTE, renal insufficiency, Black race, and RYGB were independently associated with mortality (Table 4), while female gender was protective (OR 0.39, CI 0.30–0.51; $p < 0.001$). Again, operative year was not an independent predictor. This model had a Brier score of 0.0007 and ROC of 0.82.

**Table 3.** Multivariable logistic regression evaluating predictors of serious complications.

| Risk Factor | Odds Ratio | 95% Confidence Interval | *p*-Value |
|---|---|---|---|
| 2021 operative year (compared to 2020) | 1.00 | 0.96–1.04 | 0.995 |
| Age | 1.06 | 1.03–1.08 | <0.001 |
| Female gender | 1.00 | 0.92–1.08 | 0.961 |
| GERD | 1.24 | 1.16–1.33 | <0.001 |
| BMI | 1.00 | 0.99–1.00 | <0.001 |
| Hypertension | 1.13 | 1.08–1.18 | <0.001 |
| Hyperlipidemia | 1.04 | 0.99–1.09 | 0.165 |
| Diabetes | | | |
| Non-insulin-dependent | 0.95 | 0.90–1.01 | 0.078 |
| Insulin-dependent | 1.10 | 1.02–1.18 | 0.015 |
| Previous VTE | 1.92 | 1.76–2.09 | <0.001 |
| History of MI | 1.62 | 1.41–1.86 | <0.001 |
| Renal insufficiency | 2.19 | 1.85–2.58 | <0.001 |
| COPD | 1.47 | 1.29–1.68 | <0.001 |
| Operative duration | 1.00 | 1.00–1.00 | <0.001 |
| Sleep apnea | 1.00 | 0.96–1.04 | 0.886 |
| Race category | | | |
| Black (compared to White) | 1.30 | 1.24–1.37 | <0.001 |
| Other (compared to White) | 0.95 | 0.89–1.01 | 0.078 |
| RYGB (compared to SG) | 2.04 | 1.89–2.19 | <0.001 |
| Functional status | | | |
| Partially dependent | 1.72 | 1.42–2.08 | <0.001 |
| Dependent | 2.07 | 0.87–4.93 | 0.099 |

GERD, gastroesophageal reflux disease; BMI, body mass index; VTE, venous thromboembolism; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease; RYGB, Roux-en-Y Gastric Bypass; SG, Sleeve gastrectomy.

**Table 4.** Multivariable logistic regression evaluating predictors of mortality.

| Risk Factor | Odds Ratio | 95% Confidence Interval | *p*-Value |
|---|---|---|---|
| 2021 operative year (compared to 2020) | 1.20 | 0.93–1.55 | 0.150 |
| Age | 1.84 | 1.62–2.09 | <0.001 |
| Female gender | 0.39 | 0.30–0.51 | <0.001 |
| GERD | 1.29 | 0.99–1.68 | 0.053 |
| BMI | 1.05 | 1.03–1.07 | <0.001 |
| Hyperlipidemia | 0.98 | 0.73–1.33 | 0.901 |
| Diabetes | | | |
| Non-insulin-dependent | 1.05 | 0.75–1.47 | 0.758 |
| Insulin-dependent | 1.52 | 1.05–2.21 | 0.028 |
| Previous VTE | 2.35 | 1.56–3.54 | <0.001 |
| History of MI | 3.52 | 2.21–5.61 | <0.001 |
| Renal insufficiency | 2.20 | 1.13–4.29 | 0.021 |

**Table 4.** *Cont.*

| Risk Factor | Odds Ratio | 95% Confidence Interval | *p*-Value |
|---|---|---|---|
| COPD | 1.36 | 0.76–2.43 | 0.304 |
| Operative duration | 1.00 | 1.00–1.00 | <0.001 |
| Sleep apnea | 0.73 | 0.56–0.96 | 0.023 |
| Race category | | | |
| Black (compared to White) | 1.40 | 1.03–1.91 | 0.034 |
| Other (compared to White) | 0.92 | 0.59–1.44 | 0.723 |
| RYGB (compared to SG) | 1.54 | 1.16–2.05 | 0.003 |
| Functional status | | | |
| Partially dependent | 2.66 | 1.41–5.04 | 0.003 |

GERD, gastroesophageal reflux disease; BMI, body mass index; VTE, venous thromboembolism; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease; RYGB, Roux-en-Y Gastric Bypass; SG, Sleeve gastrectomy. Dependent functional status was omitted due to collinearity.

## 4. Discussion

Fortunately, the 2021 operative year demonstrated a dramatic 20.7% increase in bariatric surgery cases per MBSAQIP-accredited center, signaling the start of a post-pandemic recovery with respect to bariatric delivery. However, it remains unclear whether these increases are adequate to replace deficits from 2020 and respond to the growing bariatric surgery need. Clinically, only small differences in patient selection occurred in 2021, meaning trends towards performing surgery on younger patients with fewer comorbidities have persisted but not worsened. With continued evidence supporting equivalent perioperative outcomes, a need to further increase bariatric surgical volumes and continue offering procedures to those living with severe obesity and related complications is needed.

The first major finding of this study is that gross (or absolute) operative volumes appear superficially to have increased over the past year. While the 20.7% increase in cases per center is substantial, and a welcome improvement to the 13.8% reduction in 2020 demonstrated by our group previously, evaluating historic MBSAQIP data and the current landscape of obesity cases offers greater context to these volumes [2]. Although this represents the highest number of cases per MBSAQIP center, evaluating the trend over time shows that the increase compared to pre-COVID-19 levels is small. The small rise in cases has occurred in the context of significantly increased incidence of obesity during the COVID-19 era and substantial evidence demonstrating an increased risk of acquiring or experiencing complications from COVID-19 for patients with obesity [13–16]. Additionally, considering the recently published American Society for Metabolic and Bariatric Surgery (ASMBS) and International Federation for the Surgery of Obesity and Metabolic Disorders (IFSO) recommendations to expand indications for bariatric surgery, the need for bariatric surgery and number of candidates has never been higher. Considering these points, and already concerning increase in obesity prior to the COVID-19 pandemic, we hypothesize that the 2021 increases, while promising, will continue to fail to meet the demand of bariatric surgery in North America. As the most robust long-term treatment for obesity and its related complications, ongoing advocacy to increase bariatric surgery resources is certainly required.

Several key points not evaluated in this study and not collected by the MBSAQIP, but of interest to the field, remain, including the impact of provider burn out on bariatric surgery care, the impact of COVID-19 on medical tourism, and the effect COVID-19 had on cost of bariatric surgery worldwide. First, as discussed above, since COVID-19 began, there was initially a dramatic reduction in procedures followed by what appears to be a substantial recovery period. However, it is well described that surgeon burn out has been high during and since the COVID-19 pandemic, leading us to question whether ongoing increased volumes will remain feasible [17,18]. Additionally, while medical tourism is likely

to have reduced during the height of COVID-19 due to lockdowns and travel restrictions, it remains unclear whether a growing number of patients are contemplating or pursuing medical tourism during this recovery period since COVID-19 due to the now prolonged waitlists. Many patients and providers have raised concerns regarding physical and psychological wellbeing of patients on long waitlists since the COVID-19 pandemic [19,20]. Additionally, due to lockdowns and reduced medical tourism, many international medical tourism destinations have reduced their prices, which may have led to a post-COVID increase in bariatric surgery medical tourism. As an effect of that, it remains unclear how waitlists domestically or costs of services domestically have been impacted. These questions remain unanswered, yet are of significant interest to the field and should be evaluated in the near future.

Similar to case volume data, the small differences in patient selection between 2020 and 2021 likely under-report the story, requiring further context to understand. The largest prior study evaluating trends in bariatric surgery delivery during the COVID-19 era compared 2020 to previous years and demonstrated a significant shift towards treating younger, healthier patients, leading to a reduction in hospital stay without substantial changes in 30-day complications [2]. Therefore, although differences in patient selection between 2020 and 2021 are small and may represent clinical equipoise, in the context of an ongoing trend since COVID-19, they likely represent a continuation of overt decision making to perform bariatric surgery on younger patients with fewer comorbidities. The reasons for such are likely multifactorial. Increasing utilization and data to support same-day discharge SG and RYGB continue to add confidence for safely performing day-surgery for comparatively healthier patients [21,22]. This offers substantial cost and resource savings, both of which have remained limited in the COVID-19 era [23]. Reassuringly, the data from this study continue to support ongoing safety of continuing bariatric surgical delivery, which should support ongoing expanded implementation to reduce significant wait-lists.

Notably, it is surprising to see that the increased rate of SG recognized during the start of COVID-19 did not continue in the past year and may have even slightly reverted. We hypothesize that expansion of day surgery procedures beyond SG, with increasing evidence for same-day discharge RYGB, may explain these findings. Several studies in the last two years have reported safety for RYGB as a day surgery procedure, giving surgeons confidence to complete the procedure while maintaining the resource benefits from same-day discharge [21,22,24–26]. It will be interesting to evaluate how RYGB and SG will be utilized in lower-risk patients who are selected for same-day discharge in the coming years.

These findings and ongoing trends require consideration by bariatric surgeons. Considering recently published ASMBS and IFSO guidelines on indications for bariatric surgery, suggesting that patients with lower BMI may benefit from intervention, these trends towards selecting relatively healthier patients are likely to continue [27]. Despite demonstrated benefits of bariatric surgery with lower operative risks, we suggest careful scrutiny of these practices. It is also known that patients with severe obesity and related comorbidities stand to achieve the greatest relative benefits from bariatric intervention, despite slightly increased risk of perioperative complications [28–35]. In the endeavor to reduce perioperative complications we should not shy away from offering surgical intervention to higher-risk patients who stand to gain most benefit from metabolic procedures [36–39].

Despite findings, limitations of this study should be recognized. First, the COVID-19 pandemic has had heterogeneous effects over time and within different regions; this study evaluates the overall impact on bariatric surgery in North America but the MBSAQIP does not collect center specific data limiting conclusions that can be made about individual regions or time-periods during the years evaluated. Additionally, the MBSAQIP does not collect data for other continents, and extrapolating these results to other regions should be cautioned. MBSAQIP data are also limited to 30 days after surgery and do not characterize changes to outpatient or pre-operative management meaning that long term outcomes or novel perioperative management techniques like early outpatient follow-up are not captured. Despite these limitations, this study offers a follow up evaluation of the persistent

impact COVID-19 has had on bariatric surgery delivery. We believe the study will prove useful in evaluation of the next steps as we continue to improve surgical care in the setting of increasing need for bariatric surgical intervention and health care resource limitations.

The COVID-19 pandemic represents possibly the greatest barrier to effective bariatric surgical delivery in the last decade. Understanding the trends that have persisted since the beginning of the COVID-19 era will remain critical as we adapt to a new era of health care. Beyond ensuring that bariatric surgical volumes recover and respond to the growing need, we must ensure appropriate patient and procedural selection. Ongoing evaluation of long-term outcomes for these patients and the socioeconomic consequences of these changes will remain critical to ensure optimal impact from bariatric surgery.

## 5. Conclusions

The COVID-19 pandemic elicited several changes to delivery of bariatric surgical care, with trends that have slowed but still continue. Although 2021 represented a dramatic increase in bariatric surgical cases compared to 2020, volumes may still lag behind bariatric surgery demand. Trends towards intervening on younger, healthier patients persist and remain similar to 2020, yet the trend towards SG has reduced. Ongoing evaluation of the long-term impact from these changes will remain of interest as we continue to recover from the COVID-19 era.

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## Appendix A

Data collection definitions:

Serious complication—Defined by any of: cardiac complications, pneumonia, acute renal failure, reoperation, reintervention, venous thromboembolism, deep surgical site infection, wound disruption, sepsis, unplanned intubation, leak, bleed, and cerebral vascular accident.

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