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Impact of the COVID-19 pandemic on bariatric surgery in North America – A retrospective analysis of 834,647 patients

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Highlights

- During COVID-19, a 13.8% reduction in bariatric surgery cases occurred.
- Patients undergoing bariatric surgery during COVID-19 had fewer comorbidities.
- COVID-19 had an association with reduced likelihood of Roux-en-Y gastric bypass.
- Despite changes, post-operative outcomes were similar.
Abstract

Background
COVID-19 has transformed surgical care, yet little is known regarding implications for bariatric surgery.

Objectives
We sought to characterize the impact of COVID-19 on bariatric surgery delivery and outcomes.

Setting
The Metabolic and Bariatric Accreditation and Quality Improvement Program (MBSAQIP) collects data from 885 centers in North America.

Methods
The MBSAQIP database was evaluated with two cohorts described: the COVID-19 and the pre-COVID-19, receiving surgery in 2020 and 2015-2019 respectively. Yearly operative trends were characterized and bivariate analysis compared demographics and post-operative outcomes. Multivariable modelling evaluated thirty-day readmission, reintervention, reoperation, and factors associated with undergoing Roux-en-Y gastric bypass (RYGB).

Results
We evaluated 834,647 patients, with 155,830 undergoing bariatric surgery during the 2020 pandemic year. A 12.1% reduction in total cases (177,208 in 2019 vs 155,830 in 2020, p<0.001) and 13.8% reduction in cases per center occurred (204.2 cases/center 2019 vs 176.1 cases/center 2020, p<0.001). Patients receiving bariatric surgery during the pandemic were younger with fewer comorbidities. Use of sleeve gastrectomy increased (74.5% vs 72.5%, p < 0.001) and surgery during COVID-19 was associated with reduced RYGB procedural selection (OR 0.83, 95% CI 0.82-0.84, p < 0.001). Length of stay decreased significantly (1.4 ± 1.4 days vs 1.6 ± 1.4 COVID-19 and Bariatric Surgery Delivery
days, p<0.001), yet post-operative outcomes were similar. After adjusting for comorbidities, patients during COVID-19 had decreased 30-day odds of readmission and reintervention with a small increased odds of reoperation.

Conclusions

The COVID-19 pandemic dramatically changed bariatric surgery delivery. Further studies evaluating the long-term effects of these changes are warranted.

Keywords: COVID-19, bariatric surgery, pandemic, Roux-en-Y gastric bypass, sleeve gastrectomy
1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has drastically transformed delivery of surgical care worldwide\(^{(1)}\). With concerns regarding hospital resources, and COVID-19 perioperative morbidity and mortality, millions of surgical procedures were cancelled in 2020\(^{(1-3)}\). In response, patient selection, surgical techniques, and post-operative care have been affected, with substantial changes across every area of general surgery\(^{(1,4-12)}\). These changes are expected to have pervasive long-term health and care delivery effects\(^{(13-15)}\). Despite substantial evidence across various surgical subspecialties, multi-centered international evaluation of the impact COVID-19 has had on bariatric surgery has not been well characterized. This scarcity of evidence has occurred in spite of patients with obesity being disproportionately affected by COVID-19, alongside concerns that obesity treatments may be overlooked as we recover from the COVID-19 pandemic due to obesity stigma\(^{(16-19)}\).

Early studies evaluating the effect of COVID-19 on bariatric surgery have reported a substantial reduction in procedures performed\(^{(16)}\). Unfortunately, delaying bariatric surgery due to COVID-19 has shown deleterious weight gain and psychological patient effects\(^{(20)}\). Other groups, including our own, have reported ongoing bariatric care delivery with careful patient selection to enable early patient discharge and limit the impact on hospital resources\(^{(21,22)}\). The largest study evaluating bariatric surgery patients during the COVID-19 pandemic has reported similar post-operative outcomes to historic studies but unfortunately did not characterize differences in delivery or patient selection\(^{(18)}\). Better understanding the consequences of COVID-19 on bariatric surgery is required to optimize future delivery during the ongoing COVID-19 waves, and potentially after if COVID-19 can be limited or eradicated.

COVID-19 and Bariatric Surgery Delivery
Herein, we report the largest multi-centered international retrospective cohort study of prospectively collected data evaluating the impact of COVID-19 on delivery of bariatric surgery care in North America. The Metabolic and Bariatric Accreditation and Quality Improvement Program (MBSAQIP) database was used to describe surgical volume, patient demographics, operative technique, and post-operative outcomes for patients undergoing bariatric surgery in accredited North American centers.

2. Materials and Methods

2.1 Data Source:
The 2015-2020 MBSAQIP database was queried to collate data for this study. This data registry prospectively collects key pre-operative, operative, and early post-operative outcomes for patients undergoing bariatric surgery from 885 centers in the United States and Canada. Data within the registry is collected based on well-defined, standardized variables and is subject to frequent review of data integrity and collection practices\(^{(23)}\). This study was exempt from research ethics board review.

2.2 Study Design, Patient Population, and Variable Definitions:
This is a retrospective cohort study of prospectively collected MBSAQIP data. The study’s primary objective was to characterize bariatric surgery delivery, including case volume, during the COVID-19 pandemic compared to prior. Secondary outcomes were to evaluate trends in demographics, surgical technique, and post-operative outcomes for patients undergoing bariatric COVID-19 and Bariatric Surgery Delivery
surgery in North America during the COVID-19 pandemic compared to those prior to COVID-19.

Patients receiving bariatric surgery during the COVID-19 pandemic included any bariatric surgery occurring during the 2020 MBSAQIP year. Pre-COVID-19 patients were categorized by bariatric surgery before those dates and after 2015, when the MBSAQIP database began collecting data. Only patients receiving elective sleeve gastrectomy (SG) or Roux-en-Y gastric bypass (RYGB) were included because they represent the majority of bariatric procedures performed\(^\text{(24)}\). Patients with a history of a previous bariatric surgery and those where the index procedure represented emergency surgery were excluded.

Demographic data were obtained for all patients, including gender, race, and pre-operative body mass index (BMI). Pulmonary comorbidities evaluated were presence of sleep apnea, active smoking, and chronic obstructive pulmonary disease (COPD). Cardiac comorbidities evaluated were hypertension, hyperlipidemia, previous myocardial infarction (MI), previous cardiac surgery, and previous percutaneous coronary intervention (PCI). Other comorbidities evaluated were history of venous thromboembolism (VTE), gastroesophageal reflux disease (GERD), diabetes mellitus (DM), venous stasis, renal insufficiency, dialysis dependency, therapeutic anticoagulation, and chronic steroid use. Information regarding the surgical technique included the operative procedure (SG versus RYGB) and operative time.

Post-operative outcomes evaluated length of inpatient hospital stay (LOS) following bariatric surgery, and outcomes including 30-day readmission to hospital, reoperation, and reintervention.
based on MBSAQIP definitions\textsuperscript{(23)}. Additionally, infectious complications such as the rate of urinary tract infection (UTI), deep, and superficial surgical site infection (SSI), wound disruption, pneumonia, and sepsis are reported. Other post-operative complications evaluated include unplanned intubation, acute renal failure (described as any renal failure requiring dialysis), myocardial infarction (MI), cerebral vascular accidents (CVA), and mortality.

2.3 Statistical Analysis:

All statistical analysis was completed using STATA 17 statistical software (StataCorp, College Station, TX, USA). Categorical data was expressed as absolute values with percentages, while continuous data were expressed as a weighted mean ± standard deviation. Between group differences were evaluated using chi-squared for categorical data and ANOVA for continuous data. Trends were analyzed over time with demographics and surgical technique reported for each year from 2015 to 2020. Due to the MBSAQIP’s large dataset, many statistically significant outcomes occurred; therefore, results presented in text and discussed are those with substantial differences and clinical significance. Specific cases where statistical significance occurred without clinical significance are also highlighted.

To determine independent predictors of post-operative complications, including 30-day readmissions, reinterventions, and reoperations, a non-parsimonious multivariable logistic regression model was developed using a hypothesis-driven purposeful selection methodology. Bivariate 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. Significant variables in the multivariable model were then identified (Wald test p < 0.05)
and linear assumption of continuous variables and multi-collinearity were checked using the variance inflation factors (VIF). Variables with VIF greater than 10 were explored using collinearity diagnostic tests and excluded from the final model if collinear. The Brier Score and the receiver operating characteristic curve were used to assess goodness of fit. This model included the pandemic as an independent variable to assess its effect on post-operative outcomes. A multivariable model was also developed in a similar fashion to evaluate factors independently associated with undergoing RYGB to assist with characterizing delivery of bariatric surgery during COVID-19.

3. Results

3.1 Patient Demographics

Patients undergoing elective bariatric surgery during the COVID-19 pandemic were marginally younger (44.0 ± 11.9 COVID vs. 44.7 ± 12.0 pre-COVID, p < 0.001) and were more likely to be female (81.6% COVID vs 80.2% pre-COVID, p < 0.001) (Table 1). Notably, there was a large decrease in White patients receiving bariatric surgery during the COVID-19 pandemic (67.1% COVID vs 71.7% pre-COVID, p < 0.001), with ensuing increase in African American’s (COVID 19.7% vs pre-COVID 18.2%, p < 0.001, Table 1).

With regards to metabolic comorbidities, patients during the COVID-19 pandemic were less likely to have hypertension (44.4% COVID vs 47.1% pre-COVID, p < 0.001), dyslipidemia (22.4% COVID vs 23.2 pre-COVID, p < 0.001), and were more likely to not require medication for diabetes (77.2% COVID vs 74.6% pre-COVID, p < 0.001). They also had fewer systemic COVID-19 and Bariatric Surgery Delivery
comorbidities including less sleep apnea (36.9% COVID vs 37.4% pre-COVID, p = 0.002), and fewer cardiac comorbidities such as prior MI, prior cardiac surgery, or prior PCI (Table 1).

In terms of operative technique, SG was performed in a higher proportion of patients during the COVID-19 pandemic (74.5% COVID vs 72.5% pre-COVID, p < 0.001, Table 1). Despite that change, operative duration was shorter prior to the COVID-19 pandemic by 3.2 minutes (COVID 89.9 ± 54.5 minutes vs. pre-COVID 86.7 ± 49.8, p < 0.001).

3.2 Trends in Operative Volume Over Time

A total of 834,647 patients were evaluated with 155,830 (18.7%) receiving bariatric surgery during the COVID-19 pandemic. Despite an increasing number of MBSAQIP accredited centers in 2020 (n = 885 centers), the number of elective bariatric surgery cases completed during the COVID-19 pandemic decreased by 21,359 (12.1%) compared to 2019 (n = 868 centers) (Figure 1). The number of cases per MBSAQIP center showed a 13.8% decreased during the COVID-19 pandemic from 204.2 cases/center in 2019 to 176.1 cases/center in 2020 (p<0.001).

3.3 Changes in Patient Selection and Operative Procedure over time

Patient selection from 2015-2020 demonstrates a trend towards bariatric surgery for patients with diet-controlled or no diabetes from 74.0% in 2015 to 77.2% in 2020 (Table 2). Similarly, there has been a trend towards selecting fewer patients with hypertension (48.9% in 2015 vs 44.4% in 2020). For both diabetes and hypertension, patients receiving bariatric surgery during the COVID-19 pandemic (i.e. 2020) had the lowest rates since MBSAQIP has begun collecting data (Table 2). In terms of operative selection there has been an increasing use of SG from 70.2% in COVID-19 and Bariatric Surgery Delivery
2015 to 74.5% in 2020, again with 2020 representing the greatest proportion of SG’s ever reported in MBSAQIP data.

3.4 Bivariate Analysis of Post-Operative Outcomes Comparing Pandemic and Non-Pandemic Cohorts

During the COVID-19 pandemic, LOS was significantly reduced compared to previously (1.4 ± 1.4 days COVID vs 1.6 ± 1.4 days pre-COVID, p<0.001). Patients undergoing bariatric surgery during the COVID-19 pandemic experienced similar post-operative outcomes to those having surgery prior to the pandemic. Reoperation rates within 30 days were statistically similar (1.3% COVID vs 1.3% pre-COVID, p = 0.142) and both reintervention (1.0% COVID vs 1.2% pre-COVID, p < 0.001) and readmission (3.5% COVID vs 3.8% pre-COVID, p < 0.001) were clinically similar despite statistical difference. Overall, none of the post-operative complications had a difference >0.4%, and are unlikely to be clinically significant when comparing those undergoing bariatric surgery during COVID-19 to prior (Table 3).

3.4 Multivariable Logistic Regression of Factors Associated with Post-Operative Complications

Undergoing bariatric surgery during the COVID-19 pandemic was associated with minor decreased in 30-day readmission (OR 0.93, CI 0.91-0.96, p<0.001) and reintervention (OR 0.86, CI 0.82-0.91, p<0.001), and a small increased odds of 30-day reoperation (OR 1.07, CI 1.02-1.13, p = 0.001, Table 4). These differences, while statistically significant, are unlikely to represent clinically significant changes over time. The most significant independent factors associated with increased odds of 30-day readmission, reoperation, and reintervention were undergoing RYGB as opposed to SG, GERD, COPD, prior MI, prior DVT, and pre-operative COVID-19 and Bariatric Surgery Delivery
anticoagulation (Table 4). The models for readmission, reintervention, and reoperation had ROC areas of 0.64, 0.67 and 0.68 and Brier Scores of 0.036, 0.012, and 0.017 respectively.

3.5 Multivariable Logistic Regression Evaluating Predictors of Procedural Selection

When evaluating predictors of undergoing RYGB as opposed to SG, we see few independent predictors (Table 5). However, undergoing bariatric surgery during the COVID-19 pandemic was independently associated with a reduced likelihood of receiving RYGB (OR 0.83, 95% CI 0.82-0.84, p < 0.001). The only patients with greater reduction in RYGB likelihood were those with renal insufficiency and those who were dialysis dependent (Table 5). The model was accurate with an ROC area of 0.76 and Brier Score of 0.16.

4. Discussion

During the COVID-19 pandemic there was a 12.1% reduction in total elective bariatric surgery cases and 13.8% reduction in cases per MBSAQIP accredited center. Less metabolically comorbid patients were selected for elective surgery and there was a greater shift towards SG selection at the expense of RYGB delivery. While unadjusted outcomes were similar between cohorts, multivariable analysis revealed small differences in thirty-day readmission, reintervention, and reoperation.

Beyond the overall reduction in operative volume, patient selection and operative techniques were the most drastic changes during the COVID-19 pandemic. These outcomes partly contradict the recommendations initially proposed by Rubino et al. (2020), suggesting that patients with severe obesity, substantial comorbidities, and risk of deterioration from obesity COVID-19 and Bariatric Surgery Delivery.
related complications should be prioritized for bariatric surgery\(^{(19)}\). Regardless, both the trend towards SG and less comorbid patient selection appears to have begun prior to the COVID-19 pandemic but were emphasised during the pandemic. It is likely that recent data showing favourable outcomes and long-term benefits in patients with obesity but without comorbidities led to selection of these patients during the pandemic considering the limited operative time, hospital occupancy, and post-operative follow-up\(^{(16, 21)}\). Similarly, favourable outcomes, shorter hospital stay, and reduced post-operative complications with SG in recently-published SM-BOSS and SLEEVEPASS trials likely explain its increased use during the COVID-19 pandemic\(^{(25-27)}\). The advent and success of bariatric day surgery, again prior to the COVID-19 pandemic, has also likely contributed to these findings\(^{(28, 29)}\). On the other hand, the reason for increased proportion of surgeries being performed on African American’s during the COVID-19 pandemic is unclear. This may represent a change over time with increased recognition of bariatric surgery benefits for African American’s, or another factor not measured within this study. Future studies evaluating the effect of COVID-19 on bariatric surgery access related to ethnicity may be of interest. Overall, limited acute care resources during the COVID-19 pandemic likely contributed to surgeons and centers directing delivery towards patients more likely to be fit for day or short-stay surgery.

Fortunately, despite changes in delivery, bariatric surgery procedures during the COVID-19 pandemic did not appear to have substantially worse outcomes. However, when adjusting for comorbidities the COVID-19 was associated with decreased odds of readmission and reintervention, and a small increased odds of reoperation. While our study design does not allow us to evaluate reasons for these findings, a potential reason could be earlier discharge during COVID-19 and Bariatric Surgery Delivery.
COVID-19 and increased post-operative management of non-life threatening complications via telehealth solutions\(^{(30,31)}\). Overall, outcomes during the COVID-19 pandemic were similar to prior, which is in keeping with the largest international retrospective study by Singhal et al.\(^{(18)}\). This study and ours support continuation of bariatric surgery during the COVID-19 pandemic with careful patient selection in order to provide care for patients with obesity, who also happen to be at substantial risk of morbidity and mortality from COVID-19\(^{(17,32)}\). Long-term outcomes are warranted and careful scrutiny of these practices is encouraged, especially considering the ongoing trend towards use of SG despite novel studies suggesting that RYGB outperforms SG in terms of long-term weight loss and comorbidity resolution, particularly in patients with super-obesity\(^{(25,33-37)}\).

Considering the decrease in bariatric surgeries performed, the COVID-19 pandemic has created a substantial deficit in care for thousands of patients with obesity. Further, considering the shift towards selecting less comorbid patients who can successfully be managed with SG, patients with super-obesity or substantial comorbidities are likely at a further deficit. Unfortunately, it is these patients that also stand to benefit most from bariatric intervention\(^{(37-39)}\). We hypothesize that as COVID-19 is eliminated or becomes endemic, a transition back towards operating on patients with increased comorbidities may occur. Studies evaluating delivery of bariatric surgery care in the next year will be critical to further evaluate the impact and long-term effect of COVID-19. This would further characterize trends that are specific to COVID-19, and others that have occurred secondary to bariatric surgery optimization over time. Regardless, while surgical delays and deficits are often discussed in the oncologic setting, a similar call to action to COVID-19 and Bariatric Surgery Delivery
prioritize surgical care of patients with obesity is needed considering the social, financial, and functional benefits offered with these interventions\(^{(40-43)}\).

Limitations of this study are primarily related to its retrospective nature and data limitations from MBSAQIP. In this study, the COVID-19 pandemic cohort was defined by any surgery occurring during the 2020 MBSAQIP data collection year. However, as we have all experienced, waves of the pandemic has differed drastically and the effect on bariatric surgery delivery likely also varied during that time. Similarly, the COVID-19 pandemic has had variable effects on different countries, regions, and municipalities; because center specific data is not collected, the variability of those effects could not be evaluated. Additionally, because the COVID-19 pandemic began in 2019, some of the reported patients from 2019 may have also received bariatric surgery during the pandemic. On the other hand, the beginning of 2020 had fewer cases, restrictions, and health care effects than other periods of the year and this temporal variability is summarized as an average throughout the year in this study. Comparing patients receiving bariatric surgery during COVID-19 to all patients from 2015-2019 also presents substantial limitations considering changes that occurred over time; to limit that effect we presented all operative trends by year in order to put differences in context. Finally, as detailed above, the MBSAQIP database does not characterize outpatient management or other changes that likely occurred during the COVID-19 pandemic, which may represent substantial confounders in this study. Data from this study are also limited to 30 days following operation. Studies evaluating the effect of COVID-19 on outpatient management of bariatric surgery patients and long-term outcomes following bariatric surgery during the COVID-19 pandemic are warranted. Despite these limitations, this study characterizes important trends and effects on bariatric surgery in COVID-19 and Bariatric Surgery Delivery.
North America secondary to the COVID-19 pandemic that will prove useful in evaluation of next steps as we continue to improve surgical care in the setting of health care resource limitations.

Understanding the impact that COVID-19 has elicited on bariatric surgery delivery in North America is crucial to evaluating future patient and technique selection. This is especially true as subsequent waves of the COVID-19 pandemic occur. During the COVID-19 pandemic, patients undergoing bariatric surgery have had fewer metabolic comorbidities and received SG at an unprecedented rate. It remains uncertain whether these changes will continue in the future and how these changes will affect future bariatric surgery care. Regardless of COVID-19’s trajectory, a growing trend towards SG has been hastened by the COVID-19 pandemic and ongoing evaluation of long-term outcomes as well as the socioeconomic consequences of this impacted delivery are warranted.

Conclusion

The COVID-19 pandemic has dramatically changed the landscape of bariatric delivery in North America. During the COVID-19 pandemic there was a 13.8% reduction in elective bariatric surgery cases despite increased reporting centers. Patients receiving surgery were less comorbid and more likely to receive SG, while outcomes were similar to prior. Future studies evaluating persistent changes that occur following the COVID-19 pandemic, and further work characterizing the long-term effect of the COVID-19 pandemic on outcomes and the socioeconomic consequences of this impacted delivery are warranted.

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**Figures and Tables:**

**Figure 1.** Total number of elective bariatric surgeries, MBSAQIP reporting centers, and elective bariatric surgeries per center over time.
Table 1. Patient Characteristics comparing patients receiving elective bariatric surgery during the COVID-19 pandemic to those prior to the COVID-19 pandemic.

| Bariatric Surgery Before COVID-19 n = 678,817 | Bariatric Surgery During COVID-19 n = 155,830 | p-value* |
|---------------------------------------------|-----------------------------------------------|----------|
| **Age, years**                              |                                               |          |
| mean ± sd                                   |                                               |          |
| <18                                         | 44.7 ± 12.0                                   | 44.0 ± 11.9 | <0.001 |
|                                             | 1,246 (0.2)                                   | 214 (0.1)  |          |
| 18-29                                       | 77,324 (11.4)                                 | 15,533 (10.0) | <0.001 |
| 30-39                                       | 172,641 (25.4)                                | 37,297 (23.9) |          |
| 40-49                                       | 198,416 (29.2)                                | 45,633 (29.3) |          |
| 50-59                                       | 149,958 (22.1)                                | 36,779 (23.6) |          |
| ≥ 60                                        | 79,244 (11.7)                                 | 20,394 (13.1) |          |
| **Sex**                                     |                                               |          |
| Female                                      | 544,084 (80.2)                                | 127,095 (81.6) | <0.001 |
| Male                                        | 134,591 (19.8)                                | 28,691 (18.4) |          |
| Non-binary                                  | -                                             | 44 (0.03)  |          |
| **BMI, Kg/m²**                              |                                               |          |
| mean ± sd                                   |                                               |          |
| <35                                         | 45.0 ± 7.8                                    | 44.8 ± 7.8 | <0.001 |
|                                             | 29,092 (4.3)                                  | 11,592 (7.6) |          |
| 35-39                                       | 155,489 (23.1)                                | 34,471 (22.5) |          |
| 40-45                                       | 342,772 (50.9)                                | 74,548 (48.5) |          |
| 45-50                                       | 114,297 (17.0)                                | 25,442 (16.6) | <0.001 |
| 50-60                                       | 25,575 (3.8)                                  | 5,754 (3.8)  |          |
| >60                                         | 6,381 (1.0)                                   | 1,772 (1.2)  |          |
| **Race**                                    |                                               |          |
| White                                       | 486,444 (71.7)                                | 104,570 (67.1) | <0.001 |
| American Indian or Alaska Native            | 2,911 (0.4)                                   | 763 (0.5)   |          |
| Asian                                       | 3,528 (0.5)                                   | 894 (0.6)   |          |
| Black or African                            | 123,326 (18.2)                                | 30,748 (19.7) |          |
| Native Hawaiian or Other Pacific Islander   | 1,885 (0.3)                                   | 415 (0.3)   |          |
| Race Combinations*                          | -                                             | 83 (0.1)    |          |
| Other                                       | -                                             | 698 (0.5)   |          |
| Not Reported                                | 60,723 (9.0)                                  | 17,659 (11.3) |          |
| **Smoker**                                  |                                               |          |
| No or diet controlled                       | 506,599 (74.6)                                | 120,266 (77.2) | <0.001 |
| Non-insulin dependent                       | 117,853 (17.4)                                | 25,484 (16.4) |          |
| Insulin dependent                           | 54,365 (8.0)                                  | 10,080 (6.5) |          |
| **Diabetes**                                |                                               |          |
| No or diet controlled                       |                                               |          |
| Non-insulin dependent                       |                                               |          |
| Insulin dependent                           |                                               |          |
| Hypertension                                | 319,802 (47.1)                                | 69,229 (44.4) | <0.001 |
| GERD                                        | 210,785 (31.1)                                | 49,719 (31.9) | <0.001 |
| COPD                                        | 10,358 (1.5)                                  | 1,896 (1.2)  | <0.001 |
| Condition                        | Preoperative (n, %) | Operative (n, %) | p-value |
|--------------------------------|---------------------|-----------------|---------|
| Hyperlipidemia                 | 157,651 (23.2)      | 34,927 (22.4)   | <0.001  |
| Chronic steroid use            | 12,272 (1.8)        | 3,338 (2.1)     | <0.001  |
| Renal insufficiency            | 4,195 (0.6)         | 900 (0.6)       | 0.064   |
| Dialysis dependent             | 2,116 (0.3)         | 496 (0.3)       | 0.647   |
| History of DVT                 | 11,345 (1.7)        | 2,755 (1.8)     | 0.007   |
| History of PE                  | 8,374 (1.2)         | 2,115 (1.4)     | <0.001  |
| Venous stasis                  | 6,200 (0.9)         | 1,104 (0.7)     | <0.001  |
| Pre-operative therapeutic      | 19,581 (2.9)        | 4,514 (2.9)     | 0.733   |
| anticoagulation                 |                     |                 |         |
| Sleep Apnea                    | 253,535 (37.4)      | 57,557 (36.9)   | 0.002   |
| History of MI                  | 8,308 (1.2)         | 1,647 (1.1)     | <0.001  |
| Previous major cardiac surgery | 7,088 (1.0)         | 1,431 (0.9)     | <0.001  |
| Previous PCI                   | 12,601 (1.9)        | 2,332 (1.5)     | <0.001  |
| SG                             | 492,070 (72.5)      | 116,090 (74.5)  | <0.001  |
| RYGB                           | 186,753 (27.5)      | 39,753 (25.5)   | < 0.001 |
| Operative time, minutes        | 86.7 ± 49.8         | 89.9 ± 54.5     | < 0.001 |
| mean ± sd                      |                     |                 |         |

sd, standard deviation; BMI, body mass index; GERD, gastroesophageal reflux disease; COPD, chronic obstructive pulmonary disease; DVT, deep vein thrombosis; PE, pulmonary embolism; MI, myocardial infarction; PCI, percutaneous coronary intervention; SG, Sleeve Gastrectomy; RYGB, Roux-Y Gastric Bypass.

*Data on race combinations or other race was not captured in the MBSAQIP database prior to 2020.

p-values were determined using chi-squared analysis for categorical data & ANOVA for continuous data.
Table 2. Five-Year Demographic and Operative Characteristics for patients receiving elective bariatric surgery during the COVID-19 pandemic to those prior to the COVID-19 pandemic.

|                      | 2015   | 2016   | 2017    | 2018    | 2019    | 2020    |
|----------------------|--------|--------|---------|---------|---------|---------|
| **SG**               | 47,176 | 64,089 | 125,515 | 128,207 | 127,077 | 116,077 |
|                      | (70.2) | (72.9) | (73.3)  | (73.1)  | (71.7)  | (74.5)  |
| **RYGB**             | 20,029 | 23,832 | 45,649  | 47,112  | 50,131  | 39,753  |
|                      | (29.8) | (27.1) | (26.7)  | (26.9)  | (28.3)  | (25.5)  |
| **Total Elective Bariatric Surgeries** | 67,205 | 87,921 | 171,164 | 175,319 | 177,208 | 155,830 |
| **Centers Reporting MBSAQIP Data** | 742 | 791 | 832 | 854 | 868 | 885 |
| **Elective Bariatric Surgeries per MBSAQIP Center** | 90.6 | 111.2 | 205.7 | 205.3 | 204.2 | 176.1 |
| **BMI, Kg/m²**       |        |        |         |         |         |         |
| <35                  | 2,793  | 3,592  | 7,209   | 7,444   | 8,054   | 11,592  |
|                      | (4.2)  | (4.1)  | (4.2)   | (4.3)   | (4.6)   | (7.6)   |
| 35-39                | 14,834 | 19,863 | 39,287  | 40,943  | 40,562  | 34,471  |
|                      | (22.3) | (22.8) | (23.1)  | (23.5)  | (23.1)  | (22.5)  |
| 40-45                | 33,221 | 44,178 | 86,978  | 88,779  | 89,616  | 74,548  |
|                      | (49.9) | (50.8) | (51.1)  | (50.9)  | (51.1)  | (48.5)  |
|      | 45-50       | 50-60       | >60        |
|------|-------------|-------------|-----------|
| Age  |             |             |           |
|      | 12,028 (18.1) | 15,027 (17.3) | 28,806 (16.9) | 29,213 (16.8) | 29,223 (16.7) | 25,442 (16.6) |
|      | 2,690 (4.0)  | 3,524 (4.1)  | 6,378 (3.8)  | 6,574 (3.8)  | 6,436 (3.7)  | 5,754 (3.8)   |
|      | 1,003 (1.5)  | 778 (0.9)    | 1,523 (0.9)  | 1,487 (0.9)  | 1,590 (0.9)  | 1,772 (1.2)   |
|      |             |             |           |             |             |             |
|      | Diabetes    |             |           |             |             |             |
| No or diet controlled | 49,728 (74.0) | 65,438 (74.4) | 127,758 (74.6) | 130,893 (74.7) | 132,791 (74.9) | 120,280 (77.2) |
| Non-insulin dependent | 11,602 (17.3) | 15,234 (17.3) | 29,665 (17.3) | 30,407 (17.3) | 30,947 (17.5) | 25,485 (16.4) |
| Insulin dependent | 5,878 (8.8)  | 7,249 (8.2)  | 13,746 (8.0) | 14,022 (8.0) | 13,471 (7.6) | 10,085 (6.5)  |
|      | Hypertension | 32,888 (48.9) | 42,107 (47.9) | 80,922 (47.3) | 81,976 (46.8) | 81,914 (46.2) | 69,245 (44.4) |
|      | GERD        | 20,775 (30.9) | 27,654 (31.6) | 53,161 (31.1) | 53,694 (30.6) | 55,508 (31.3) | 49,727 (31.9) |

SG, Sleeve Gastrectomy; RYGB, Roux-Y Gastric Bypass; MBSAQIP, Metabolic and Bariatric Accreditation and Quality Improvement Program; BMI, body mass index; GERD, gastroesophageal reflux disease.
### Table 3. Thirty-day post-operative outcomes for patients receiving elective bariatric surgery during the COVID-19 pandemic to those prior to the COVID-19 pandemic.

|                                | Bariatric Surgery Before COVID-19 n = 678,817 | Bariatric Surgery During COVID-19 n = 155,830 | p-value |
|--------------------------------|-----------------------------------------------|-----------------------------------------------|---------|
| Length of Stay (days)          | 1.6 ± 1.4                                     | 1.4 ± 1.4                                     | <0.001 |
| Reoperation                    | 8,791 (1.3)                                   | 2,081 (1.3)                                   | 0.205  |
| Reintervention                 | 8,236 (1.2)                                   | 1,587 (1.0)                                   | <0.001 |
| Readmission                    | 25,600 (3.8)                                  | 5,449 (3.5)                                   | <0.001 |
| UTI                            | 2,291 (0.3)                                   | 523 (0.3)                                     | 0.908  |
| Superficial SSI                | 2,838 (0.4)                                   | 569 (0.4)                                     | 0.022  |
| Deep SSI                       | 435 (0.06)                                    | 118 (0.08)                                    | 0.381  |
| Wound disruption               | 391 (0.06)                                    | 87 (0.06)                                     | 0.001  |
| Pneumonia                      | 1,401 (0.2)                                   | 357 (0.2)                                     | 0.134  |
| Sepsis                         | 770 (0.1)                                     | 226 (0.2)                                     | 0.001  |
| Unplanned intubation           | 870 (0.1)                                     | 250 (0.2)                                     | 0.002  |
| Acute renal failure            | 453 (0.07)                                    | 147 (0.1)                                     | <0.001 |
| MI                             | 168 (0.02)                                    | 47 (0.03)                                     | 0.181  |
| Cerebral vascular accidents    | 92 (0.01)                                     | 27 (0.02)                                     | 0.261  |
| Mortality                      | 595 (0.09)                                    | 196 (0.13)                                    | <0.001 |

UTI, urinary tract infection; SSI, surgical site infection; MI, myocardial infarction.
Table 4. Multivariable logistic regression for 30-day post-operative readmission, reoperation, reintervention, and death following elective bariatric surgery.

| Risk Factor                        | 30-day readmission | 30-day reoperation | 30-day reintervention |
|------------------------------------|--------------------|--------------------|-----------------------|
|                                    | Odds Ratio | 95% confidence interval | p-value | Odds Ratio | 95% confidence interval | p-value | Odds Ratio | 95% confidence interval | p-value |
| COVID-19 Pandemic                  | 0.93       | 0.91-0.96           | <0.001     | 1.07       | 1.02-1.13          | 0.004     | 0.86       | 0.82-0.91          | <0.001   |
| Age                                | 0.96       | 0.95-0.97           | <0.001     | 1.08       | 1.06-1.10          | <0.001     | 0.96       | 0.94-0.98          | <0.001   |
| RYGB                               | 1.53       | 1.49-1.57           | <0.001     | 1.85       | 1.77-1.92          | <0.001     | 2.05       | 1.96-2.14          | <0.001   |
| GERD                               | 1.35       | 1.32-1.39           | <0.001     | 1.30       | 1.25-1.35          | <0.001     | 1.36       | 1.30-1.42          | <0.001   |
| Male gender                        | 0.84       | 0.82-0.87           | <0.001     | 1.03       | 0.98-1.09          | 0.98       | 0.86       | 0.81-0.90          | <0.001   |
| BMI                                | 1.01       | 1.00-1.02           | 0.046      | 0.96       | 0.95-0.98          | <0.001     | 0.99       | 0.98-1.01          | 0.227    |
| Hypertension                       | 1.09       | 1.06-1.12           | <0.001     | 1.06       | 1.01-1.10          | 0.015      | 1.09       | 1.04-1.14          | <0.001   |
| Hyperlipidemia                     | 1.08       | 1.05-1.11           | <0.001     | 0.98       | 0.93-1.03          | 0.434      | 1.00       | 0.95-1.05          | 0.961    |
| Diabetes                           |            |                     |           |            |                     |           |            |                     |         |
| Non-insulin Dependent Insulin      | 0.94       | 0.91-0.97           | <0.001     | 0.92       | 0.87-0.97          | 0.001      | 0.93       | 0.88-0.98          | 0.011    |
| Dependent Insulin                  | 1.30       | 1.25-1.36           | <0.001     | 0.94       | 0.87-1.00          | 0.068      | 1.08       | 1.00-1.56          | 0.038    |
| Previous DVT                       | 1.48       | 1.38-1.59           | <0.001     | 1.41       | 1.25-1.59          | <0.001     | 1.24       | 1.10-1.41          |         |
| Pre-operative therapeutic anticoagulation | 1.62       | 1.53-1.71           | <0.001     | 1.31       | 1.19-1.45          | <0.001     | 1.74       | 1.58-1.92          | <0.001   |
| Operative duration                 | 1.00       | 1.00-1.00           | <0.001     | 1.00       | 1.00-1.01          | <0.001     | 1.00       | 1.00-1.00          | <0.001   |
| History of MI                      | 1.32       | 1.21-1.43           | <0.001     | 1.24       | 1.08-1.43          | 0.002      | 1.64       | 1.44-1.88          | <0.001   |
| Renal insufficiency                | 1.53       | 1.37-1.71           | <0.001     | 1.48       | 1.23-1.78          | <0.001     | 1.21       | 0.99-1.49          | 0.067    |
| Dialysis                           | 1.75       | 1.52-2.02           | <0.001     | 2.16       | 1.71-2.73          | <0.001     | 1.98       | 1.53-2.54          | <0.001   |
| Smoker                             | 1.14       | 1.09-1.18           | <0.001     | 1.23       | 1.55-1.32          | <0.001     | 1.18       | 1.10-1.27          | <0.001   |
| COPD                               | 1.41       | 1.31-1.51           | <0.001     | 1.40       | 1.24-1.58          | <0.001     | 1.25       | 1.09-1.42          | <0.001   |
| Sleep Apnea                        | 1.01       | 0.99-1.04           | 0.285      | 0.98       | 0.94-1.02          | 0.238      | 1.02       | 0.98-1.07          | 0.395    |

RYGB, Roux-en-Y gastric bypass; GERD, gastroesophageal reflux disease; BMI, body mass index; DVT, deep vein thrombosis; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease.
**Table 5. Multivariable logistic regression evaluating predictors of procedural selection (RYGB vs. SG)**

| Risk Factor                          | Odds Ratio | 95% confidence interval | p-value |
|--------------------------------------|------------|-------------------------|---------|
| COVID-19 pandemic                    | 0.83       | 0.82-0.84               | <0.001  |
| Age                                  | 0.94       | 0.94-0.95               | <0.001  |
| Male gender                          | 0.77       | 0.76-0.78               | <0.001  |
| GERD                                 | 1.36       | 1.34-1.37               | <0.001  |
| BMI                                  | 1.03       | 1.03-1.04               | <0.001  |
| Hypertension                         | 1.01       | 0.98-1.02               | 0.108   |
| Hyperlipidemia                       | 1.06       | 1.04-1.07               | <0.001  |
| Diabetes                             |            |                         |         |
| Non-insulin Dependent                | 0.98       | 0.80-1.20               | 0.869   |
| Insulin Dependent                    | 1.27       | 1.02-1.58               | 0.032   |
| Previous DVT                         | 1.03       | 0.98-1.07               | 0.269   |
| Pre-operative therapeutic anticoagulation | 0.86   | 0.83-0.89               | <0.001  |
| History of MI                        | 1.03       | 0.98-1.08               | 0.189   |
| Renal insufficiency                  | 0.82       | 0.76-0.88               | <0.001  |
| Dialysis                             | 0.45       | 0.40-0.50               | <0.001  |
| COPD                                 | 0.91       | 0.87-0.95               | <0.001  |
| Sleep apnea                          | 1.07       | 1.05-1.08               | <0.001  |

GERD, gastroesophageal reflux disease; BMI, body mass index; DVT, deep vein thrombosis; MI, myocardial infarction; COPD, chronic obstructive pulmonary disease.
