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Research Paper

Prior bariatric surgery is associated with lower mortality and resource utilization following small bowel obstruction☆

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A R T I C L E I N F O

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A B S T R A C T

Background: Small bowel obstruction (SBO) is a complication of bariatric surgery. However, outcomes of surgical intervention for SBO among patients with prior bariatric surgery remain ill-defined. We used a nationally representative cohort to characterize the outcomes of the SBO management approach in patients with a prior bariatric operation.
Methods: All adult hospitalizations for SBO were tabulated from the 2018–2020 National Readmissions Database. Patients with a prior history of bariatric surgery comprised the Bariatric cohort (others: Non-Bariatric). Multivariable models were subsequently developed to evaluate the association of prior bariatric surgery with outcomes of interest.
Results: Of an estimated 299,983 hospitalizations for SBO, 15,788 (5.3 %) had a history of prior bariatric surgery. Compared to Non-Bariatric, Bariatric patients were younger (54 [46–62] vs 57 [47–64] years, $P < 0.001$) and were more frequently privately insured (45.1 vs 39.4 %, $P < 0.001$). On average, the Bariatric more frequently underwent operative management, relative to Non-Bariatric (44.8 vs 29.7 %, $P < 0.001$). Following risk adjustment, among those surgically managed, Bariatric demonstrated lower odds of mortality (Adjusted Odds Ratio [AOR] 0.69, 95 % Confidence Interval [CI] 0.55–0.87) compared to Non-Bariatric. Bariatric also demonstrated lower odds of infectious and renal complications. Furthermore, the Bariatric cohort had lower costs, length of stay, and non-home discharge.
Conclusions: Patients with prior bariatric surgery demonstrated a lower likelihood of mortality, decreased complications, and reduced resource utilization, relative to others. As the incidence of bariatric surgery continues to rise, future work is needed to minimize the incidence of SBO among these patients, especially in the current era of value-based healthcare.

Introduction

Acute small bowel obstruction (SBO) accounts for an estimated 16 % of all general surgical admissions, with attributable annual healthcare expenditures exceeding $2.3 billion [1]. With nearly 70 % of SBO cases caused by intestinal adhesions, most cases are sequelae of prior abdominal operations [2]. Adhesive SBO can progress to small bowel strangulation, which is associated with an increased risk of mortality and may ultimately require bowel resection [3].

With roughly 200,000 bariatric operations performed in the US each year and a reported postoperative SBO rate of ~4.5 %, surgeons are increasingly likely to manage such patients [4]. As a result of prior abdominal instrumentation, patients may develop internal hernias or adhesions that necessitate urgent treatment post-bariatric surgery [5]. Previous work examining bowel resection for colorectal cancer, has shown patients with prior metabolic surgery to exhibit reduced odds of cardiovascular, gastrointestinal, and infectious complications postoperatively [6]. Although early surgical management of SBO has been associated with improved mortality, data evaluating outcomes among individuals with a history of metabolic surgery remain sparse [7,8].

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In the present national study, we characterized the association of prior metabolic surgery with management approach as well as acute clinical and financial outcomes of hospitalizations for SBO. We hypothesized patients to be more likely to receive operative treatment for SBO relative to others. We further hypothesized prior bariatric surgery to be linked with reduced odds of in-hospital mortality, perioperative complications, costs, and non-elective readmissions.

Methods

All non-elective adult (≥18 years) hospitalizations for acute SBO were tabulated from the 2018–2020 Nationwide Readmissions Database (NRD) using previously reported *International Classification of Diseases, 10th Revision* (*ICD-10*) codes (Supplemental Table S1). The NRD is the largest publicly available, all-payer readmissions database in the US and captures >60 % of all hospitalizations using survey weighing methodology [9]. Additionally, the NRD utilizes unique patient identifiers to track readmissions within each state and calendar year.

To reduce the heterogeneity of the group, we limited the analysis to patients <70 years of age and without a concomitant diagnosis of malignancy. Records entailing inter-hospital transfer, bariatric operation during the same admission, or missing key data were excluded from the analysis (Fig. 1). Patients with prior metabolic surgery, identified by the ICD-10 code Z98.84, comprised the *Bariatric* cohort (others: *non-Bariatric*), with italicized names representing patient groups for the purpose of comparison.

Patient and hospital characteristics, including time from hospital admission to surgery, were defined according to the NRD data dictionary. Operative management included lysis of adhesions, small bowel resection, exploratory laparotomy, and emergency hernia repair. The van Walraven modification of the Elixhauser Comorbidity Index was used to estimate the burden of chronic conditions [10]. Hospitalization costs were calculated by applying center-specific cost-to-charge ratios to overall charges, with adjustment for inflation to the 2020 Personal Health Index [11].

Relevant comorbidities and complications were identified using *ICD-10* codes reported elsewhere [12,13]. Perioperative complications included blood transfusion as well gastrointestinal (anastomotic leak, bleeding, postprocedural obstruction), cardiac (arrest, arrhythmia, tamponade), infectious (sepsis, surgical site infection), cerebrovascular (stroke), renal (acute kidney injury), respiratory (acute respiratory distressed syndrome, prolonged ventilation ≥96 h, pneumothorax) and thrombotic (pulmonary embolism, deep vein thrombosis) complications. Non-home discharge was defined as patient disposition to a skilled nursing facility, intermediate care center, or short-term hospital.

The primary study outcome was in-hospital mortality. Secondary outcomes included perioperative complications, length of stay (LOS), inpatient costs, non-home discharge, and 30-day non-elective readmission.

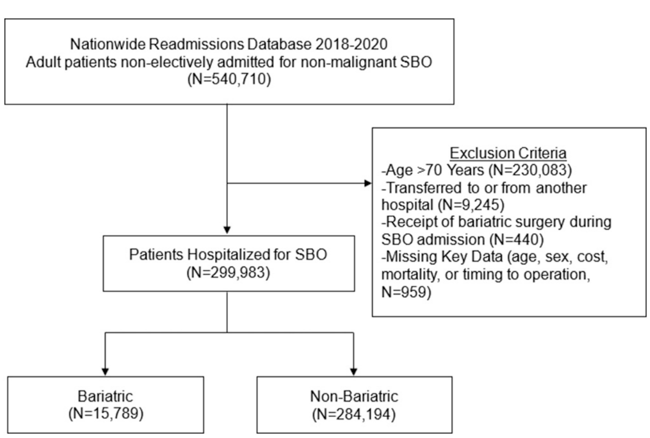

Fig. 1. Flow Diagram of study cohorts and survey-weighted sample size. SBO, Small Bowel Obstruction.

Categorical variables are expressed as group proportions (%), while continuous data are shown as medians with interquartile range (IQR). Pearson's χ^2 and Mann-Whitney *U* tests were utilized to assess the significance of intergroup differences for categorical and continuous variables, respectively. Entropy balancing was employed to generate groups with comparable characteristics. More robust than propensity score matching, entropy balancing generates sample weights to minimize differences in the distribution of covariates while retaining the full sample [14]. Logistic and linear regression models were then developed to assess the independent association of prior metabolic surgery with outcomes of interest. Model covariates were selected using automated elastic net regularization to minimize model collinearity and improve out-of-sample generalizability [15]. Logistic and linear regression outputs are reported as adjusted odds ratios (AOR) and beta coefficients (β), respectively, both with 95 % Confidence Intervals (95 % CI).

A subgroup analysis was performed among only those receiving an operation to further increase the homogeneity of the population. A linear regression model was constructed to evaluate risk-adjusted time from admission to surgery between *Bariatric* and *non-Bariatric* groups. The marginal risk-adjusted probability of mortality attributable to the timing of surgery was evaluated using an interaction term in the regression model. A second subgroup analysis was performed excluding patients admitted for SBO within 90 days of bariatric surgery (*Early SBO Bariatric*, others: *Late SBO Bariatric*) to minimize the effects of early complications acutely related to the operation.

An α of 0.05 was set for statistical significance. All statistical analyses were performed using Stata 16.1 (StataCorp, College Station, TX). This study was deemed exempt from full review by the Institutional Review Board at the University of California, Los Angeles, due to the deidentified nature of the NRD.

Results

Demographics and clinical characteristics

Of an estimated 299,983 patients hospitalized for SBO, 15,788 (5.3 %) comprised the *Bariatric* cohort, with detailed comparisons shown in Table 1. Relative to others, *Bariatric* patients were younger (54 [46–62] vs 57 [47–64] years, $P < 0.001$), more often female (83.8 vs 50.7 %, $P < 0.001$) and privately insured (45.1 vs 39.4 %, $P < 0.001$). Further, the *Bariatric* cohort demonstrated a lower prevalence of chronic liver disease (4.5 vs 6.5 %, $P < 0.001$), congestive heart failure (5.1 vs 6.5 %, P < 0.001) and peripheral vascular disease (3.5 vs 4.6 %, $P < 0.001$), compared to *non-Bariatric*. However, *Bariatric* more commonly had chronic lung disease relative to others (18.2 vs 15.8 %, $P < 0.001$).

Bariatric patients more frequently underwent operative management (44.8 vs 29.7 %, $P < 0.001$). Patients with a history of bariatric surgery more frequently received care at centers classified as metropolitan teaching hospitals (68.6 vs 71.9 %, P < 0.001).

Unadjusted outcomes

On bivariate comparison, patients in the *Bariatric* cohort demonstrated a significantly lower incidence of in-hospital mortality (1.1 vs 2.2 %, $P < 0.001$). Further, *Bariatric* less frequently experienced gastrointestinal (3.0 vs 3.5 %, $P < 0.001$), cardiac (0.8 vs 2.0 %, P < 0.001), infectious (5.0 vs 9.5 %, P < 0.001), renal (7.0 vs 15.5 %, P < 0.001) and respiratory (3.3 vs 5.4 %, $P < 0.001$) complications, relative to *non-Bariatric*. Additionally, *Bariatric* patients exhibited shorter LOS (3 [2–5] vs 4 [2–7] days, $P < 0.001$) and higher index hospitalization costs (9500 [$5400 - $16,100] vs $8500 [$4900 - $18,100], $P < 0.001$). Compared to others, patients from the *Bariatric* cohort more often underwent non-home discharge (7.0 vs 12.0 %, $P < 0.001$, Table 2).

Among patients managed operatively, *Bariatric* experienced shorter

Table 1
Patient, operative, and hospital characteristics of patients undergoing treatment for small bowel obstruction (SBO) grouped by history of bariatric surgery.

	Bariatric (n = 15,788)	Non-bariatric (n = 284,194)	P-Value
Age (years, median [IQR])	54 [46–62]	57 [47–64]	<0.001
Female (%)	83.8	50.7	<0.001
Elixhauser Comorbidity Index (median [IQR])	2 [1–4]	2 [1–3]	<0.001
Insurance coverage (%)			<0.001
Private	45.1	39.4	
Medicare	33.7	35.5	
Medicaid	15.2	16.6	
Other payer	6.0	8.5	
Income percentile (%)			<0.001
76–100 %	17.9	19.5	
51–75 %	25.9	24.1	
26–50 %	30.0	27.4	
0–25 %	26.6	29.0	
Comorbidities (%)			
Cardiac arrhythmias	9.5	10.3	0.03
Chronic liver disease	4.5	6.5	<0.001
Chronic lung disease	18.2	15.8	<0.001
Coagulopathy	3.0	3.8	<0.001
Congestive heart failure	5.1	6.5	<0.001
Diabetes	18.9	17.8	0.01
Hypertension	45.8	44.1	0.01
Late-stage kidney disease	1.0	2.3	<0.001
Peripheral vascular disease	3.5	4.6	<0.001
Pulmonary hypertension	1.1	1.4	0.11
Management (%)			<0.001
Nonoperative	55.2	70.3	
Operative	44.8	29.7	
Operative type (%)			
Exploratory laparotomy	7.7	92.3	<0.001
Hernia repair	7.5	92.5	<0.001
Lysis of adhesions	10.0	90.0	<0.001
Small bowel resection	5.0	95.0	0.23
Teaching location (%)			<0.001
Non-metropolitan	7.3	10.0	
Metropolitan nonteaching	20.8	21.4	
Metropolitan teaching	68.6	71.9	

Patients with a history of bariatric surgery comprised the *Bariatric* cohort (others: *Non-Bariatric*).
**IQR*, Interquartile Range.

Table 2
Unadjusted outcomes of patients hospitalized for small bowel obstruction (SBO) with and without prior bariatric surgery.

	Bariatric (n = 15,788)	Non-bariatric (n = 284,194)	P-Value
Clinical outcomes			
In-hospital mortality (%)	1.1	2.2	<0.001
Complications (%)			
Blood transfusion	3.2	3.5	0.17
Cardiac	0.8	2.0	<0.001
Gastrointestinal	3.0	3.5	0.02
Infectious	5.0	9.5	<0.001
Renal	7.0	15.5	<0.001
Respiratory	3.3	5.4	<0.001
Thromboembolic	0.5	0.6	0.10
Resource utilization			
Cost ($1000 s, median [IQR])	9.5 [5.4–16.1]	8.5 [4.9–18.1]	<0.001
Length of Stay (days, median [IQR])	3 [2–5]	4 [2–7]	<0.001
Non-home Discharge (%)	7.0	12.0	<0.001
30-day Readmission (%)	10.9	10.6	0.29

**IQR*, Interquartile Range.

time to surgery relative to *Non-Bariatric* (1 [0–1] vs 1 [1–2] days, P < 0.001).

Risk-adjusted outcomes

Following risk adjustment, prior metabolic surgery remained associated with decreased odds of in-hospital mortality (AOR 0.69, 95%CI 0.55–0.87, ref.: non-Bariatric). Prior bariatric surgery was linked with reduced odds of infectious (AOR 0.54, 95%CI 0.49–0.61) and renal complications (AOR 0.53, 95%CI 0.48–0.58). Further, prior metabolic surgery was associated with reduced length of stay (β −1.94 days, 95% CI -2.10–1.78 days), costs (β -$4400, 95%CI -$4900–3800), and lower odds of non-home discharge (AOR 0.74, 95%CI 0.66–0.84, Table 3, Fig. 2).

Risk-adjusted outcomes among operatively managed patients

When evaluating only those managed operatively, prior bariatric surgery remained associated with lower in-hospital mortality (AOR 0.59, 95%CI 0.42–0.85) compared to others. In assessing the association of operative timing, incremental delay of operation was independently linked with 1.18 adjusted odds of in-hospital mortality per day (95%CI 1.14–1.22, Fig. 3). However, the risk-adjusted mortality among patients with prior metabolic surgery remained unchanged with increasing time to surgery, while the likelihood of mortality increased significantly among *non-Bariatric*.

Additionally, a history of bariatric surgery was associated with reduced odds of gastrointestinal (AOR 0.63, 95%CI 0.53–0.74), renal (AOR 0.48, 95%CI 0.42–0.54), and infectious (AOR 0.44, 95%CI 0.38–0.52) complications. Such associations remained despite the further exclusion of *Early SBO Bariatric* patients (Supplemental Table 3). Patients with prior bariatric surgery demonstrated decreased LOS (β −3.76 days, 95%CI -4.04–3.47 days) and hospitalization expenditures (β -$8800, 95%CI -$9800–$7900), as well as reduced odds of non-home discharge (AOR 0.62, 95%CI 0.52–0.73, Supplemental Table 2).

Discussion

Given the nationwide surge in metabolic operations, a contemporary characterization of hospitalization outcomes for SBO, is increasingly relevant. In the present study, we noted patients with a history of bariatric surgery to be more frequently managed surgically for SBO, compared to others. Interestingly, among patients receiving surgery for

Table 3
Adjusted outcomes of patients treated for small bowel obstruction (SBO) with and without prior bariatric surgery. Outcomes are reported as Adjusted Odds Ratio (AOR) or β coefficient with 95 % confidence interval (95 % CI). CI, Confidence Interval.

	Estimate (AOR/β)	*95 % CI*	*P-Value*
Clinical outcomes			
In-hospital mortality	0.69	0.55–0.87	0.01
Complications			
Blood transfusion	0.86	0.76–0.99	0.03
Cardiac	0.65	0.50–0.83	<0.001
Gastrointestinal	0.79	0.69–0.90	<0.001
Infectious	0.54	0.49–0.61	<0.001
Renal	0.53	0.48–0.58	<0.001
Respiratory	0.69	0.60–0.78	<0.001
Thromboembolic	0.81	0.60–1.11	0.19
Resource utilization			
Cost ($1000s)	−4.36	−4.88 to −3.83	<0.001
Length of stay (days)	−1.94	−2.10 to −1.78	<0.001
Non-home discharge	0.74	0.66–0.84	<0.001
30-day Readmission (%)	1.02	0.95–1.10	0.60

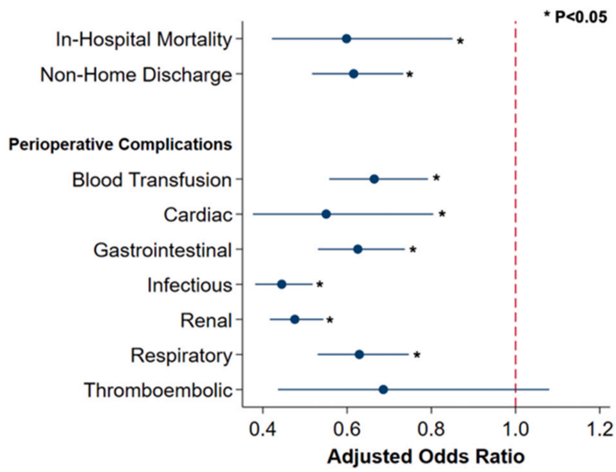

Fig. 2. Risk-adjusted association of prior bariatric surgery with outcomes of interest. Reference: Non-Bariatric.

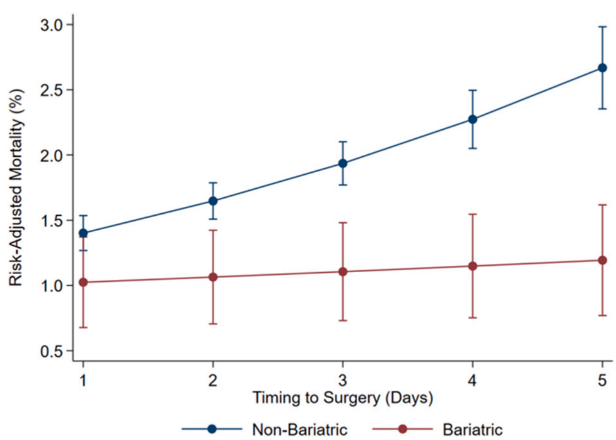

Fig. 3. Differential impact of timing to operative procedure in patients with small bowel obstruction stratified by history of bariatric surgery.

SBO, individuals with prior bariatric surgery demonstrated reduced odds of in-hospital mortality as well as decreased gastrointestinal, infectious, and renal complications. Additionally, these patients exhibited reduced hospitalization costs, duration of stay, and likelihood of non-home discharge compared to those without prior bariatric surgery. Several of these findings warrant further discussion.

In the present study, we demonstrate patients with prior metabolic surgery more frequently underwent surgical management for SBO. Given previous abdominal instrumentation, it is plausible that surgeons have a greater index of suspicion for adhesions or an internal hernia to be a cause of obstruction. While nonoperative management is increasingly utilized for stable patients, emergent laparoscopic exploration in the case of an acute abdomen following bariatric operations has yielded improved long-term outcomes [16]. We additionally demonstrated prior metabolic surgery status to be associated with reduced delays to operative management, aligning with recent 2022 Operative management in Bariatric Acute abdomen (OBA) guidelines for laparoscopic exploration within 12–24 h in this population [17]. In the emergent setting, the altered anatomy of post-bariatric surgery patients necessitates vigilant monitoring for SBO [4,18]. It is likely that increased monitoring can lead to a timely diagnosis, prompting an operation. Taken together, these factors may influence surgeons' preference for definitive operative management over medical interventions with observation. Moreover, our analysis showed metabolic surgery status to be associated with a notably reduced risk of mortality as well as gastrointestinal, infectious, and renal complications following SBO. This may be, in part, attributable to the fact that patients with prior bariatric surgery have been evaluated for surgical candidacy and ultimately deemed fit for the bariatric operation [19–21]. Indeed, rigorous preoperative testing is intended to mitigate potential risks of hypotension, respiratory distress, internal bleeding, and gastrointestinal leaks during the bariatric operation [17]. Despite the emergent nature of SBO, such optimization may confer improved outcomes in those with a history of bariatric surgery.

Significantly altered gastrointestinal anatomy in patients with prior bariatric surgery may result in known complications in the early postoperative period, which may include the development of ulcers, anastomotic strictures, leaks, bleeding, and dense adhesions [22]. Close postoperative monitoring among bariatric surgical patients may further facilitate early detection of issues that may ultimately result in advanced SBO, resulting in improved outcomes [23]. However, such reduced mortality and complications persisted despite the further exclusion of patients presenting with SBO within 90 days of the index operation. Our findings may underscore the efficacy of existing care paradigms that comprehensively improve clinical outcomes for bariatric patients, including established programs for patient education that may increase overall health literacy and greater collective experience with the treatment of bariatric patients in the contemporary era [24,25]. Indeed, upon marginal analysis of the timing of surgery among operatively managed SBO patients, those with prior bariatric surgery had similar odds of in-hospital mortality regardless of delay in operation, while non-bariatric patients experienced an incremental rise in predicted mortality. Considerable literature has demonstrated improved clinical outcomes for patients with prior bariatric surgery across a myriad of operations [6,26]. This may be attributable to the metabolic benefits provided by bariatric surgery, including improvements to insulin sensitivity and reduced inflammation [27]. Bariatric surgery has also been linked with numerous cardiovascular benefits, which can minimize risks of coronary artery disease, heart failure, and cerebrovascular events [28]. Although patients with late SBO development demonstrate lower odds of mortality and complications, further work is needed to guide identification and shared decision-making processes.

We demonstrate operative management to have lower costs among bariatric surgical patients compared to others, as evidenced by a $4400 decrement in inpatient costs and nearly 2 fewer days in the hospital. Although we find unadjusted costs to be paradoxically greater among those with prior bariatric surgery relative to others, such costs are lower following robust risk adjustment for key factors. Importantly, this finding adjusts for operative management, Elixhauser Comorbidity Index, and payer type, among other covariates, which are known to be associated independently with greater costs. Thus, we demonstrate prior bariatric surgery to be independently linked to lower costs following hospitalization for SBO. These findings are consistent with prior work reporting a $10,000 risk-adjusted decrease in hospitalization costs and an estimated 4-day reduction in length of stay among patients with inflammatory bowel disease who have had previous bariatric surgery [29]. Reduced odds of complications in post-bariatric surgery patients may, in part, explain the noted lower resource use in this group. Additionally, the choice of many surgeons to reduce delays in operative management of patients with a history of metabolic surgery may minimize costs as well as length of stay [30]. Furthermore, patients with a history of bariatric surgery who were surgically managed for SBO had lower odds of non-home discharge. Significant literature has identified impaired functional status to be the greatest predictor of non-home discharge [31]. Given the lower risks of complications in patients with a history of bariatric surgery, it is plausible such patients have better functional status than non-bariatric counterparts, which may contribute to a shorter recovery time and facilitate home discharge. To optimize cost-effective care, further research on long-term resource utilization beyond acute hospitalization for SBO is needed.

The present study has several important limitations. Due to its retrospective and observational design, we could not evaluate causality of observed associations nor ascertain the etiology of SBO for the patients in the cohort. Given that the NRD is an administrative database and only reports procedural timing in units of days, granular study of the time to surgery is limited. The inability to determine specific metabolic procedures that patients underwent presents another limitation. Furthermore, hospital practice patterns, such as standardized care pathways and rapid recovery protocols, could not be examined. Considering the limitations in granularity of clinical data, the scope of the present work is to provide a population-based analysis of the largest cohort of patients with prior metabolic surgery undergoing management for SBO. Given recent guidelines recommending operative management for patients with prior bariatric surgery which have been based on single-center analyses, our national study demonstrates the safety and efficacy of operative management in this population.

In the present study, our risk-adjusted findings highlight the association of prior bariatric surgery with reduced mortality, perioperative complications, and decreased resource utilization in SBO management. Despite the growing popularity of nonsurgical management for acute SBO, our findings highlight the safety and importance of early operative intervention among patients with a history of metabolic surgery in a contemporary national cohort. Future studies considering the type of bariatric surgery the patient received and the improvement in BMI at the time of treatment will supplement the current practice of SBO management. Additionally, standardized care practices in minimizing adverse complications among patients experiencing SBO without a history of metabolic surgery are warranted to improve outcomes within this patient cohort.

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Ethics approval statement

The data that support the findings of this study are available from the Healthcare Cost and Utilization Project (HCUP). Restrictions apply to the availability of these data, which were used with permission for this study. Data are available from the authors with the permission of the Healthcare Cost and Utilization Project. This study was exempt from full review by the Institutional Review Board at the University of California, Los Angeles, due to the deidentified nature of the Nationwide Readmissions Database.

CRediT authorship contribution statement

Konmal Ali: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. **Nam Yong Cho:** Data curation, Methodology, Validation, Writing – review & editing. **Amulya Vadlakonda:** Conceptualization, Data curation, Writing – review & editing. **Sara Sakowitz:** Methodology, Writing – review & editing. **Shineui Kim:** Conceptualization, Methodology, Writing – review & editing. **Nikhil Chervu:** Writing – review & editing. **Joseph Hadaya:** Supervision, Writing – review & editing. **Peyman Benharash:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors have no related conflicts of interest or disclosures to report.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sopen.2024.02.011.

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