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Comparison of outcomes following laparoscopic and open treatment of emergent small bowel obstruction: an 11-year analysis of ACS NSQIP

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Abstract

Background Small bowel obstruction (SBO) continues to be a common indication for acute care surgery. While open procedures are still widely used for treatment, laparoscopic procedures may have important advantages in certain patient populations. We aim to analyze differences in outcomes between the two for treatment of bowel obstruction.

Methods The American College of Surgeons National Surgical Quality Improvement Program was used to find patients that underwent emergent or non-elective surgery for SBO. Propensity matching was used to create comparable groups. Logistic regression was used to assess differences in the primary outcome of interest, return to operating room, and morbidity and mortality outcomes. Logistic regression was also used to assess the contribution of various preoperative demographic and comorbidity characteristics to 30-day mortality.

Results A total of 24,028 patients underwent surgery for SBO from 2005 to 2011. Of those, 3391 were laparoscopic. Propensity matching resulted in 6782 matched patients. Laparoscopic cases had significantly decreased odds of experiencing any morbidity and wound complications compared to open cases in bowel-resection and adhesiolysis-only cases. There was no significant difference found for odds of returning to operating room. Laparoscopic cases resulted in significantly shorter hospital stays than open cases (7.18 vs.10.84 days, $p<0.0001$). Increasing age, American Society of Anesthesiologists class greater than three, and the presence of respiratory comorbidities resulted in increased odds of mortality. Underweight body mass index (BMI) (<18.5) increased odds of mortality while greater than normal BMI (>25) decreased odds of mortality.

Conclusions Analysis of emergent SBO cases between 2005 and 2015 demonstrates that laparoscopy is not utilized as often as open approaches in surgical treatment. Laparoscopic surgery resulted in reduced postoperative morbidity and significantly shorter hospital stays compared to open intervention and was not associated with significant differences in odds of reoperation compared to open surgery.

Keywords Small bowel obstruction · Laparoscopic surgery · Propensity score matching · NSQIP · Regression modeling

Small bowel obstruction (SBO) continues to be a common reason for hospital admission and surgery in the United States, with over 2 million hospitalizations between 1998 and 2010 and nearly 90% of cases presenting emergently [1]. In a recent study of emergency surgeries in the United States, small bowel resection was among the more expensive procedures and was the second and fourth most common cause of mortality and morbidity, respectively [2]. The costs and complications associated with surgical treatment of SBO constitute a large public health burden, with rates of major complications and 30-day mortality approaching 20 and 4%, respectively [3]. Adhesions from previous surgery account for the most frequent etiology in 65–80% of SBOs [4].

There is potential to improve outcomes by implementing minimally invasive surgical techniques in eligible patients. In fact, retrospective studies have reported benefits of laparoscopy such as less postoperative pain, reduced hospital length of stay (LOS), and fewer complications [3–5]. Moreover, studies involving the prospectively collected American

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College of Surgeons National Surgical Quality Improvement Program (ACS NSQIP) have indeed found that laparoscopic treatment of SBO resulted in lower rates of 30-day morbidity and improved LOS; however, these studies have been limited to 4–5-year cohorts [6–8].

Despite its benefits, laparoscopic surgery for bowel obstruction also poses important challenges, including the potential for bowel injury during the placement of trocars into a distended abdomen and tissue handling of compromised and distended bowel. These situations have the potential to increase the risk of bowel injury and need for conversion and reoperation in patients undergoing minimally invasive surgery for SBO. Recently, a study has shown that certain laparoscopic procedures for SBO are associated with a higher likelihood of operative bowel injury needing further intervention [9]. In fact, conversion to open during surgery for SBO occurs in almost a third of cases started laparoscopically [10, 11]; however, it is unclear how much of this is due to repair of an iatrogenic injury versus the need to perform a bowel resection due to the cause of the obstruction.

As increasing evidence regarding the benefits and complications of laparoscopic treatment of bowel obstruction accumulates and laparoscopy takes more of a foothold in acute care surgery, continued long-term study of surgical approaches to SBO is necessary to better define the optimal treatment. To this end, we used the ACS NSQIP data set from 2005 to 2015 to perform a decade-long propensity-matched analysis of laparoscopic and open cases. Our goal was to compare the incidence of return to operating room (ROR), LOS, 30-day morbidity, and 30-day mortality between the two approaches for SBO. We also wanted to identify patient characteristics that are associated with increased mortality following these procedures and to look at the difference in outcomes for bowel-resection versus adhesiolysis-only procedures.

Methods

Data source

Institutional Review Board approval was obtained. The ACS NSQIP database collects de-identified information on patient risk factors, surgical procedures, and 30-day postoperative mortality and morbidity outcomes from participating hospitals [12]. The ACS NSQIP database entries were compiled from 2005 to 2015. NSQIP's data have been validated with rigorous quality control measures and through numerous studies.

Inclusion criteria

Patients aged 18 years or older undergoing emergent, non-elective SBO surgeries were extracted from the complete NSQIP 2005–2015 data set. SBO cases were first selected by International Classification of Disease Diagnosis—9th Rev. (ICD-9) codes: 560.0, 560.1, 560.2, 560.31, 560.81, 560.89, and 560.9. Cases were then filtered to keep CPT codes of interest. Retained open procedure codes were 44005 (freeing of bowel adhesion), 44050 (reduce bowel obstruction), 44120 (enterectomy), 44125 (enterectomy with enterostomy), 44130 (bowel to bowel fusion), 44615 (intestinal stricturoplasty), and 49000 (exploration of abdomen). Laparoscopic procedure codes were 44180 (laparoscopic enterolysis) and 44202 (laparoscopic enterectomy). Patients below the age of 18 and those with missing data were excluded from the study.

Predictor variables

The primary predictor variable in this study was surgical procedure type, specifically laparoscopic procedure versus open procedure. Data were also collected for demographic covariates including sex, age, and body mass index (BMI). BMI was first calculated, and a new variable was created to classify patients as underweight (BMI < 18.5), normal weight (BMI 18.5–24.9), overweight (BMI 25–29.9), class I obese (BMI 30–34.9), class II obese (BMI 35–39.9), or class III obese (BMI > 40).

Preoperative comorbidity data were collected for the following variables: diabetes, dyspnea, current smoker within 1 year, history of severe chronic obstructive pulmonary disease (COPD), current pneumonia, neurological dysfunction, steroid use, ascites, American Society of Anesthesiologists (ASA) class, and preoperative cardiac comorbidity. Neurological dysfunction was a composite variable created for any of the following conditions: impaired sensorium, comatose for more than 24 h, hemiplegia, paraplegia, quadriplegia, history of transient ischemic attacks, history of cerebrovascular accident/stroke with neurological deficit, or tumor involving the central nervous system. Preoperative cardiac comorbidity was a composite variable created for any of the following conditions: congestive heart failure within 30 days before surgery, history of myocardial infarction within 6 months before surgery, history of angina 1 month before surgery, hypertension requiring medication, previous percutaneous coronary intervention, or previous cardiac surgery.

Outcomes of interest

The primary outcome of the study was ROR within 30 days of the primary procedure. Other outcomes of interest include 30-day postoperative mortality, 30-day postoperative morbidity outcomes, and LOS.

Statistical analysis

First, the data set was stratified into the two surgery procedure types—laparoscopic and open procedures. The laparoscopic and open procedure groups were compared for significant differences using Chi square tests for categorical variables and Student's *t* tests for continuous variables. A *p* value less than 0.05 was considered statistically significant. All statistical analyses were performed in SAS Enterprise Guide 7.1 (SAS Institute Inc., Cary, NC, USA).

Propensity score matching

A 1:1 nearest neighbor matching was performed to address non-random differences between the open and laparoscopic procedure groups. Each case was assigned a propensity score, which was the probability of receiving a laparoscopic procedure. Propensity scores were calculated based on the following variables: sex, age, BMI, diabetes, ascites, ASA class, preoperative cardiac comorbidity, current smoker within 1 year, dyspnea, ventilator dependence, history of severe COPD, current pneumonia, steroid use, and neurologic dysfunction.

After matching, multivariate logistic regressions were performed to assess the impact of laparoscopic versus open procedure on outcome variables without the influence of selection bias. The analyses modeled the occurrence of ROR, intraoperative transfusions, mortality, other morbidity outcomes, and LOS. For each outcome variable, an odds ratio (OR), 95% confidence intervals (CI), and *p* value were calculated. Odds ratios quantify the effect of a given predictor variable on the likelihood of a patient experiencing a particular outcome. In this paper, the odds ratios for propensity matched results represent the outcomes of the open procedure group compared to those of the laparoscopic procedure group.

Contributors to mortality

OR, CI, and *p* values were also calculated to study the impact of preoperative characteristics on 30-day postoperative mortality. The final unmatched cohort was used to study the influence of age, BMI, sex, ASA class, diabetes, dyspnea, smoking, history of severe COPD, current pneumonia, neurological dysfunction, steroid use, ascites, and preoperative cardiac risk.

Bowel-resection and adhesiolysis-only cases

To address the differences in outcomes for bowel-resection and adhesiolysis-only (bowel resection versus adhesiolysis-only) surgeries, the cohort of emergent, non-elective SBO surgeries was separated into bowel-resection and adhesiolysis-only groups based on CPT codes. Bowel-resection CPT codes were 44120 (enterectomy), 44125 (enterectomy with enterostomy), 44130 (bowel to bowel fusion), 44615 (intestinal stricturoplasty), and 44202 (laparoscopic enterectomy). Adhesiolysis-only CPT codes were 44005 (freeing of bowel adhesion), 44050 (reduce bowel obstruction), 49000 (exploration of abdomen), and 44180 (laparoscopic enterolysis). Each group was divided into laparoscopic and open groups which were then propensity matched using the same process detailed previously. Multivariate logistic regressions were repeated for the bowel-resection and adhesiolysis-only groups, and ORs, CIs, and *p* values were calculated for each outcome variable.

Results

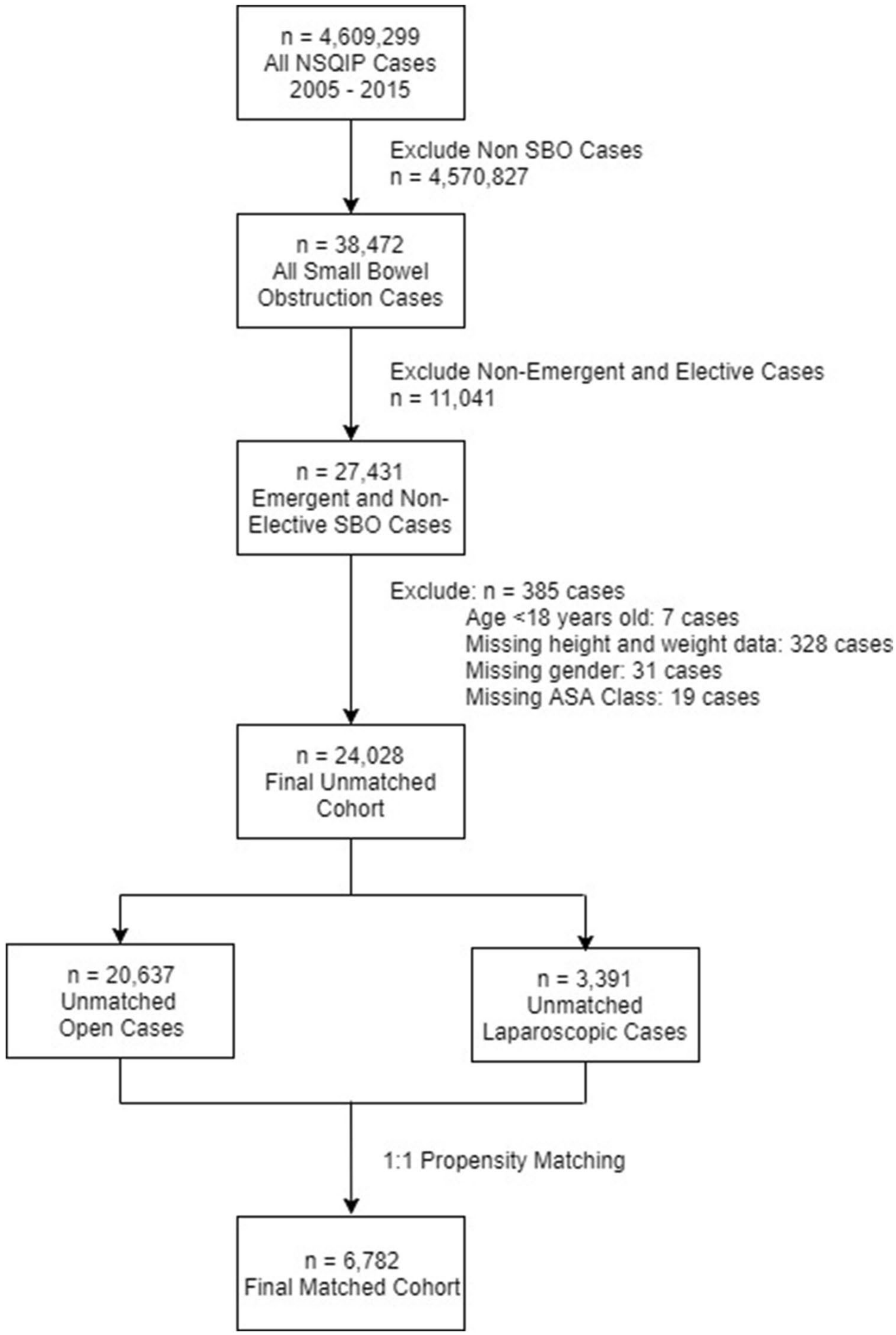
Preoperative characteristics

A total of 24,028 cases in the NSQIP database met inclusion criteria and comprised the unmatched data set. Of those cases, 3391 patients underwent laparoscopic procedures and 20,637 patients underwent open procedures (Fig. 1). Patient demographic and comorbidity data are presented in Table 1. Patients in the laparoscopic groups were younger, heavier, more likely to be female, and more likely to have an ASA class of 1 or 2. They were also less likely to have diabetes, dyspnea, smoking history, COPD, pneumonia, neurological dysfunction, steroid use, ascites, or preoperative cardiac risk. Following 1:1 propensity matching, there were 6782 cases in the SBO matched cohort. After propensity matching, patient demographics, ASA class, and comorbidities were no longer significantly different between the laparoscopic and open procedure groups. The lack of significant differences in the preoperative characteristics demonstrated that the procedural groups were comparable.

Propensity matched outcomes

In the matched cohort of 6782 cases, open procedure patients did not have statistically greater odds of ROR (Table 2). However, they had significantly higher odds of mortality and experiencing any morbidity following the procedure. Open surgery patients were nearly four times as likely to experience any wound complication than laparoscopic procedure patients (OR 3.826, $p < 0.0001$) and were

Fig. 1 Emergent SBO cohort isolation and matching



more than two times as likely to experience organ space infection, unplanned intubation, ventilator use greater than 48 h, myocardial infarction, shock, sepsis, and intraoperative transfusion ($p < 0.05$ for all). Laparoscopic patients had significantly shorter hospital stays compared to open patients (7.18 days vs. 10.84 days, $p < 0.0001$).

Contributors to mortality

The unmatched data set ($n = 24{,}048$) was used to calculate OR for the outcome of 30-day postoperative mortality (Table 3). Patients > 60 years old were nearly three times as likely to experience mortality than patients < 30 years old (OR 2.898, $p = 0.0016$). While a BMI of less than 18.5 was

Table 1 Patient demographics and comorbidities before and after matching

	Unmatched cases ($N=24{,}028$)			Matched Cases ($N=6782$)		
	Laparoscopic ($N=3391$)	Open ($N=20{,}637$)		Laparoscopic ($N=3391$)	Open ($N=3391$)	
Age (average, SD)	60.56 (17.25)	63.89 (17.20)	$\boldsymbol{p<0.0001}$	60.59 (17.25)	60.88 (17.79)	$p=0.8607$
<30	4.63	3.98		4.63	4.98	
30–45	16.48	11.51		16.48	16.43	
46–60	27.10	24.75		27.10	26.45	
>60	51.78	59.76		51.78	52.14	
BMI[a] (average, SD)	26.39 (7.18)	25.70 (7.06)	$\boldsymbol{p<0.0001}$	26.39 (7.18)	26.24 (7.02)	$p=0.8962$
<18.5	7.52	9.56		7.52	7.28	
18.5–24.9	38.87	42.69		38.87	39.87	
25–29.9	30.52	27.20		30.52	30.49	
30–34.9	12.65	12.14		12.65	12.68	
35–39.9	6.28	4.69		6.28	5.93	
>40	4.16	3.73		4.16	3.75	
Sex (%)			$\boldsymbol{p<0.0001}$			$p=0.8195$
Female	64.23	58.89		64.23	64.49	
Male	35.77	41.11		35.77	35.51	
ASA[b] class (%)			$\boldsymbol{p<0.0001}$			$p=0.9446$
1-No disturb	4.22	2.71		4.22	4.07	
2-Mild disturb	42.49	28.56		42.49	43.41	
3-Severe disturb	45.41	51.32		45.41	44.65	
4-Life threat	7.76	16.72		7.76	7.73	
5-Moribund	0.12	0.70		0.12	0.15	
Diabetes (%)			$\boldsymbol{p<0.0001}$			$p=0.5014$
No	88.73	86.08		88.73	89.30	
Insulin	4.01	5.56		4.01	4.16	
Non-insulin	7.26	8.36		7.25	6.55	
Dyspnea (%)			$\boldsymbol{p<0.0001}$			$p=0.3922$
No	95.61	91.72		95.61	96.14	
At rest	0.65	1.99		0.65	0.44	
Moderate exertion	3.75	6.28		3.75	3.42	
Current smoker (%)			$\boldsymbol{p<0.0001}$			$p=0.7628$
No	84.34	80.04		84.36	84.61	
Yes	15.66	19.96		15.66	15.39	
Severe COPD[c] (%)			$\boldsymbol{p<0.0001}$			$p=0.6112$
No	93.78	90.71		93.78	94.07	
Yes	6.22	9.29		6.22	5.93	
Current pneumonia (%)			$\boldsymbol{p=0.0436}$			$p=0.1561$
No	98.41	97.40		98.41	99.09	
Yes	1.59	2.60		1.59	0.91	
Neurological dysfunction[d] (%)			$\boldsymbol{p<0.0001}$			$p=0.8226$
No	95.61	91.11		95.61	95.81	
Yes	4.39	8.89		4.39	4.19	
Steroid use (%)			$\boldsymbol{p<0.0001}$			$p=0.2311$
No	96.28	85.62		96.28	96.82	
Yes	3.72	5.81		3.72	3.18	
Ascites (%)			$\boldsymbol{p<0.0001}$			$p=0.8842$
No	97.17	95.04		97.17	97.11	
Yes	2.83	4.96		2.83	2.89	

Table 1 (continued)

	Unmatched cases ($N = 24{,}028$)			Matched Cases ($N = 6782$)		
	Laparoscopic ($N = 3391$)	Open ($N = 20{,}637$)		Laparoscopic ($N = 3391$)	Open ($N = 3391$)	
Preoperative cardiac risk[e] (%)			$\boldsymbol{p < 0.0001}$			$p = 0.6225$
No	55.74	46.92		55.74	56.79	
Yes	44.26	53.08		44.26	43.21	

Significant *p*-values are given in bold

[a]Body mass index

[b]American Society of Anesthesiologists

[c]Chronic obstructive pulmonary disease

[d]Composite variable for the presence of impaired sensorium, comatose for more than 24 h, hemiplegia, paraplegia, quadriplegia, history of transient ischemic attacks, history of cerebrovascular accident/stroke with neurological deficit, or tumor involving the central nervous system

[e]Composite variable for the presence of congestive heart failure within 30 days before surgery, history of myocardial infarction within 6 months before surgery, history of angina 1 month before surgery, hypertension requiring medication, previous percutaneous coronary intervention, or previous cardiac surgery

associated with increased odds of mortality, BMI classes 25–29.9, 30–34.9, and > 40 all had significantly decreased odds compared to the normal BMI range of 18.5–24.9. ASA classes 3, 4, and 5 had significantly increased odds of mortality as well. Other comorbidities associated with significantly greater odds were dyspnea, history of severe COPD, current pneumonia, neurological dysfunction, and ascites.

Bowel-resection and adhesiolysis-only outcomes

Bowel-resection and adhesiolysis-only groups were created using the final unmatched cohort of all emergent and non-elective SBO surgeries ($n = 24{,}028$). Of those, 8800 cases were bowelresection and 15,228 cases were adhesiolysis-only. 1:1 propensity matching created a bowel-resection group of 970 total laparoscopic and open cases and an adhesiolysis-only group of 5810 total laparoscopic and open cases.

Similar to the propensity matched group for all SBO cases, the bowel-resection propensity matched results demonstrated that the open procedure group had significantly higher odds of experiencing any wound complication and any morbidity, but it did not have statistically increased odds of ROR or mortality (Tables 4, 5). Within the bowel-resection group, open procedures had increased odds of resulting in any wound complication (OR 1.724, $p = 0.0120$). Open resections were more than five times as likely to experience wound dehiscence (OR 5.084, $p = 0.0364$) but did not differ from the laparoscopic group for odds of experiencing superficial or deep surgical site infections (SSI). Open adhesiolysis-only cases were at significantly greater odds of experiencing superficial SSI, deep SSI, and wound dehiscence. Patients undergoing open adhesiolysis-only cases were also significantly more likely to have occurrences of pneumonia, deep vein thrombosis, urinary tract infection, shock, sepsis, and intraoperative transfusion. Increased odds in these outcomes were not seen in the open bowel-resection procedure patients.

Discussion

Our study examines 11 consecutive years of data in ACS NSQIP, and demonstrates an association between laparoscopic intervention and decreased postoperative mortality, morbidity, and LOS compared to open surgery for the treatment of bowel obstruction with an adjusted OR 3.826 (95% CI 3.012–4.910, $p < 0.0001$) based on our propensity matching. However, our results do not demonstrate a significant difference in rates of ROR. The latter is an important determinant of severe complication or morbidity (Clavien–Dindo grade 3 or higher) [13]. While the sample confirms that open surgical approaches are still the most frequently used for SBO treatment, using laparoscopic techniques treatment may help reduce complication rates in select patients. Indeed, the results of our long-term study are supported by the past literature showing decreased LOS, time to bowel function, lower complications, and lower mortality [5–10].

Several prior reports have studied the comparative effectiveness of laparoscopic and open surgical treatment of SBO [3, 14–16]. Li et al. found laparoscopic adhesiolysis to have a lower overall complication rate than open adhesiolysis via meta-analysis [17], as did Wullstein [15] and Kelly [3]. In our own analysis, we found a significantly lower rate of pneumonia, unplanned intubation, sepsis, shock, and in-hospital mortality in patients treated with laparoscopic surgery, which is entirely consistent with the findings by Byrne et al. in their institutional analysis [18]. However, our results

Table 2 Propensity matched surgical outcomes of open versus laparoscopic cohorts

Outcome	Odds ratios of open versus laparoscopic surgery for small bowel obstruction		
	OR	95% CI	p value
Return to OR[a]	1.154	(0.927–1.437)	$p=0.2003$
Any wound complication[b]	**3.826**	**(3.012–4.910)**	$p<0.0001$
Morbidity (any complication)	**2.485**	**(2.189–2.825)**	$p<0.0001$
Mortality (within 30 days)	**1.642**	**(1.177–2.311)**	$p=0.0038$
Organ space infection	**2.478**	**(1.752–3.565)**	$p<0.0001$
Superficial SSI[c]	**3.539**	**(2.679–4.745)**	$p<0.0001$
Deep SSI[c]	**4.398**	**(2.577–8.018)**	$p<0.0001$
Wound dehiscence	**3.731**	**(2.081–7.190)**	$p<0.0001$
Pneumonia	**1.846**	**(1.401–2.449)**	$p<0.0001$
Unplanned intubation	**2.117**	**(1.500-3.032)**	$p<0.0001$
DVT[d]	**1.761**	**(1.113–2.842)**	$p=0.0175$
PE[e]	1.440	(0.765–2.780)	$p=0.2636$
Ventilator > 48 h	**2.813**	**(2.060–3.900)**	$p<0.0001$
UTI[f]	**1.371**	**(1.021–1.848)**	$p=0.0371$
CVA/TIA[g]	2.670	(0.772–12.199)	$p=0.1471$
Postoperative CPR[h]	1.739	(0.931–3.368)	$p=0.0888$
MI[i]	**2.410**	**(1.184–5.288)**	$p=0.0197$
Shock	**2.317**	**(1.598–3.420)**	$p<0.0001$
Sepsis	**2.054**	**(1.586–2.680)**	$p<0.0001$
Intraoperative transfusion	**2.347**	**(1.804–3.081)**	$p<0.0001$
Length of hospital stay—days (SD)	**LAP 7.18 (9.93)**	**OPEN 10.84 (9.48)**	$p<0.0001$

Significant *p*-values are given in bold

[a]Operating room

[b]Composite variable for occurrence of superficial incisional SSI, deep incisional SSI, or wound disruption

[c]Surgical site infection

[d]Deep vein thrombosis

[e]Pulmonary embolism

[f]Urinary tract infection

[g]Cerebrovascular accident/transient ischemia attack

[h]Cardiopulmonary resuscitation

[i]Myocardial infarction

indicate a major benefit in all wound complications from a laparoscopic approach, a finding not seen in their study. This is likely due to their inclusion of laparoscopic-to-open conversion cases within the laparoscopic group. Wound complications alone constitute a large portion of the morbidity outcomes in our study. In their study of SBO adhesiolysis, Lombardo et al. found increased odds of superficial SSI in patients who underwent open surgery, but found no difference in occurrence of deep SSI and wound dehiscence [6]. Sharma et al. found increased odds of wound infection in the setting of emergent open bowel resections [8]. Our analysis demonstrated that open groups had consistently higher odds of experiencing wound complications when studying the entire matched SBO treatment cohort (OR 3.826, $p<0.0001$) as well as the bowel-resection (OR 1.724, $p=0.0120$) and adhesiolysis-only subsets (OR 3.583, $p<0.0001$).

One of the cited benefits of laparoscopic surgery is shortened hospital stays [6, 8, 15, 19–21]. Our results support current literature and indicate that laparoscopic groups had significantly shorter LOS than open groups after analysis of the entire matched cohort (7.18 vs. 10.84 days, $p<0.0001$), the bowel-resection matched cohort (9.83 vs. 12.70 days, $p<0.0001$), and the adhesiolysis-only matched cohort (6.74 vs. 10.03 days, $p<0.0001$). These results are consistent with those reported by authors in retrospective series. For example, Khaikin et al. observed a quicker return to first bowel movement in patients treated with laparoscopy for SBO [22], while Wullstein et al. showed earlier resumption of regular diet [15]. Our results mirror those of these authors, as well as Kelly et al. [3] and Mancini et al. [14], both of whom who showed a significant reduction in mean LOS in patients

Table 3 Odds of 30-day mortality, $n=24{,}208$

	OR	95% CI	*p* value
Age			
< 30 years old	Reference		
30–45 years old	1.127	(0.553–2.493)	$p=0.7529$
46–60 years old	1.505	(0.804–3.145)	$p=0.2356$
> 60 years old	**2.898**	**(1.577–5.983)**	$\mathbf{p=0.0016}$
BMI[a]			
< 18.5	**1.380**	**(1.142–1.661)**	$\mathbf{p=0.0008}$
18.5–24.9	Reference		
25–29.9	**0.685**	**(0.581–0.804)**	$\mathbf{p<0.0001}$
30–34.9	**0.645**	**(0.513–0.805)**	$\mathbf{p=0.0001}$
35–39.9	1.781	(0.563–1.061)	$p=0.1255$
> 40	**0.609**	**(0.418–0.863)**	$\mathbf{p=0.0072}$
Sex			
Female	Reference		
Male	1.103	(0.971–1.252)	$p=0.1291$
ASA[b] class			
1-No disturb	Reference		
2-Mild disturb	2.537	(0.545–45.156)	$p=0.3666$
3-Severe disturb	**14.240**	**(3.171–250.952)**	$\mathbf{p=0.0083}$
4-Life threat	**48.272**	**(10.722–851.333)**	$\mathbf{p=0.0001}$
5-Moribund	**147.972**	**(31.354–> 999.999)**	$\mathbf{p<0.0001}$
Diabetes			
No	Reference		
Insulin	1.202	(0.960–1.494)	$p=0.1022$
Non-insulin	0.895	(0.720–1.103)	$p=0.3065$
Dyspnea			
No	Reference		
At rest	**1.954**	**(1.479–2.559)**	$\mathbf{p<0.0001}$
Moderate exertion	**1.276**	**(1.043–1.552)**	$\mathbf{p=0.0161}$
Smoke			
No	Reference		
Yes	0.872	(0.735–1.032)	$p=0.1150$
Severe COPD[c]			
No	Reference		
Yes	**1.239**	**(1.041–1.470)**	$\mathbf{p=0.0149}$
Current pneumonia			
No	Reference		
Yes	**2.039**	**(1.4454–2.828)**	$\mathbf{p<0.0001}$
Neurological dysfunction[d]			
No	Reference		
Yes	**1.849**	**(1.478–2.032)**	$\mathbf{p<0.0001}$
Steroid use			
No	Reference		
Yes	1.031	(0.820–1.284)	$p=0.7904$
Ascites			
No	Reference		
Yes	**2.006**	**(1.614–2.475)**	$\mathbf{p<0.0001}$
Preoperative cardiac risk[e]			
No	Reference		
Yes	1.212	(0.979–1.508)	$p=0.0808$

Table 3 (continued)

Significant *p*-values are given in bold

[a]Body mass index

[b]American Society of Anesthesiologists

[c]Chronic obstructive pulmonary disease

[d]Composite variable for the presence of impaired sensorium, comatose for more than 24 h, hemiplegia, paraplegia, quadriplegia, history of transient ischemic attacks, history of cerebrovascular accident/stroke with neurological deficit, or tumor involving the central nervous system

[e]Composite variable for the presence of congestive heart failure within 30 days before surgery, history of myocardial infarction within 6 months before surgery, history of angina 1 month before surgery, hypertension requiring medication, previous percutaneous coronary intervention, or previous cardiac surgery

undergoing laparoscopic approach to bowel obstruction, as compared to open surgery.

Prior to propensity matching, patients in the open surgery group were significantly more likely to be older, more obese, have a higher ASA class, and have a respiratory, neurological, or cardiac comorbidity. Assignment of these high-risk patients to open procedures may simply be due to the preferences of individual surgeons or the belief that certain comorbidities contraindicate the use of laparoscopic intervention. Without matching, this open cohort had significantly increased morbidity, mortality, LOS, and ROR in univariate analysis (data not shown). Propensity matching helped create statistically balanced groups to alleviate the bias of procedure assignment.

In contrast to many of the above studies, we further analyzed whether these benefits of laparoscopic treatment of bowel obstruction remained if we only looked at bowel-resection versus adhesiolysis-only cases. We found that when resection was involved in laparoscopic bowel obstruction treatment, overall morbidity, overall wound complication, respiratory outcomes (unplanned intubation and ventilator > 48 h), and LOS had odds ratios favoring laparoscopy. However, unlike the combined cohort, overall mortality, organ space infections, DVTs, pneumonia, myocardial infarction, shock, sepsis, and blood transfusion requirement all dropped off in significance, indicating somewhat limited benefit in laparoscopy for bowel obstruction when bowel resection is added to the procedure. Margentehaler et al. have shown that mortality is higher in patients requiring resection of bowel versus adhesiolysis for treatment of a bowel obstruction [23]. According to Behman et al., some of these increased morbidities are due to an increased odds of bowel injury requiring intervention in the laparoscopic group [9]. Interestingly, a 2016 systematic review revealed statistical equivalence of iatrogenic enterotomies between laparoscopic and open groups, indicating a lack of association between laparoscopy for SBO and bowel injury [24]. Byrne et al. removed patients that underwent bowel

Table 4 Propensity matched surgical outcomes in open versus laparoscopic bowel-resection cohorts

Outcome	Odds ratios of open versus laparoscopic bowel resection		
	OR	95% CI	p value
Return to OR[a]	0.897	(0.527–1.521)	$p=0.6871$
Any wound complication[b]	**1.724**	**(1.132–2.656)**	$p=0.0120$
Morbidity (any complication)	**1.819**	**(1.383–2.399)**	$p<0.0001$
Mortality (within 30 days)	0.863	(0.400-1.837)	$p=0.7016$
Organ space infection	1.847	(0.983–3.601)	$p=0.0619$
Superficial SSI[c]	0.534	(0.960–2.485)	$p=0.0766$
Deep SSI[c]	1.681	(0.619–4.974)	$p=0.3185$
Wound dehiscence	**5.084**	**(1.331–33.187)**	$p=0.0364$
Pneumonia	1.447	(0.727–2.957)	$p=0.2974$
Unplanned intubation	**2.150**	**(1.026–4.813)**	$p=0.0495$
DVT[d]	1.772	(0.752–4.473)	$p=0.2014$
PE[e]	1.506	(0.428–5.922)	$p=0.5278$
Ventilator > 48 h	**2.664**	**(1.475–5.507)**	$p=0.0017$
UTI[f]	1.100	(0.600-2.029)	$p=0.7577$
CVA/TIA[g]	3.006	(0.160-439.113)	$p=0.5011$
Postoperative CPR[h]	2.214	(0.531–12.361)	$p=0.2997$
MI[i]	3.006	(0.160-439.113)	$p=0.5011$
Shock	1.076	(0.505–2.310)	$p=0.8481$
Sepsis	1.063	(0.655–1.728)	$p=0.8055$
Intraoperative transfusion	1.526	(0.957–2.464)	$p=0.0786$
Length of hospital stay—days (SD)	**LAP 9.83 (7.95)**	**OPEN 12.70 (11.77)**	$p<0.0001$

Significant p-values are given in bold

[a]Operating room

[b]Composite variable for occurrence of superficial incisional SSI, deep incisional SSI, or wound disruption

[c]Surgical site infection

[d]Deep vein thrombosis

[e]Pulmonary embolism

[f]Urinary tract infection

[g]Cerebrovascular accident/transient ischemia attack

[h]Cardiopulmonary resuscitation

[i]Myocardial infarction

resection in a sensitivity analysis, and found that outcomes still trended toward laparoscopy [18]. However, since all of the laparoscopic cases were converted to open for bowel resection, they were unable to compare open to laparoscopic bowel-resection outcomes.

Studying factors that contribute to mortality could help identify severely ill patients that are at higher risk of experiencing severe complications and thus impact procedure group assignment. The association of increased age [25, 26] and high ASA class [25–27] have been thoroughly documented in the context of emergent surgery and was also demonstrated in our calculated odds ratios based on the final unmatched cohort of SBO surgeries in our study. Jeppeson et al. studied emergent open SBO treatment and found increased odds of mortality in patients with COPD, metabolic disorders (diabetes or thyroid disease), and cardiovascular disease [27]. While we found COPD to have a significant association, there were not significantly increased odds of mortality in patients with diabetes or preoperative cardiovascular risk. Our analysis demonstrated that dyspnea, either at rest or with moderate exertion, was associated with increased odds of mortality. However, Margenthaler et al. found only dyspnea at rest to have this relationship [23].

The role of obesity in mortality outcomes in the setting of SBO treatment is still unclear. Jeppeson et al. did not find significantly increased incidence of morbidity and mortality in patients with BMI > 25 following emergency open interventions for SBO [27]. In line with findings by Al-Temimi et al., we found that while underweight BMIs increased odds of mortality, BMI classes greater than normal had decreasing odds of mortality with increasing BMI class [25]. In fact, the morbidly obese group had the lowest odds of mortality (OR 0.609, $p=0.0072$) compared to the normal BMI group. The 35–39.9 BMI group was the only group other

Table 5 Propensity matched surgical outcomes in open versus laparoscopic adhesiolysis-only cohorts

Outcome	Odds ratios of open versus laparoscopic non-resectional treatment		
	OR	95% CI	p value
Return to OR[a]	0.975	(0.757–1.256)	$p=0.8465$
Any wound complication[b]	**3.583**	**(2.610–5.014)**	**$p<0.0001$**
Morbidity (any complication)	**2.153**	**(1.855–2.505)**	**$p<0.0001$**
Mortality (within 30 days)	1.348	(0.899–2.037)	$p=0.1511$
Organ space infection	1.596	(1.006–2.573)	$p=0.0502$
Superficial SSI[c]	**4.037**	**(2.765–6.070)**	**$p<0.0001$**
Deep SSI[c]	**3.244**	**(1.596–7.284)**	**$p=0.0021$**
Wound dehiscence	**2.100**	**(1.045–4.485)**	**$p=0.0436$**
Pneumonia	**1.752**	**(1.289-2.400)**	**$p=0.0004$**
Unplanned intubation	**1.774**	**(1.188–2.688)**	**$p=0.0058$**
DVT[d]	**1.912**	**(1.123–3.355)**	**$p=0.0195$**
PE[e]	1.503	(0.730–3.209)	$p=0.2754$
Ventilator > 48 h	**2.440**	**(1.679–3.614)**	**$p<0.0001$**
UTI[f]	**1.634**	**(1.174–2.294)**	**$p=0.0040$**
CVA/TIA[g]	2.002	(0.528–9.493)	$p=0.3266$
Postoperative CPR[h]	1.077	(0.503–2.325)	$p=0.8471$
MI[i]	1.805	(0.848–4.071)	$p=0.1352$
Shock	**2.296**	**(1.460–3.710)**	**$p=0.0005$**
Sepsis	**1.958**	**(1.406–2.758)**	**$p<0.0001$**
Intraoperative transfusion	**1.693**	**(1.189–2.436)**	**$p=0.0039$**
Length of hospital stay—days (SD)	**LAP 6.74 (10.16)**	**OPEN 10.03 (9.74)**	**$p<0.0001$**

Significant *p*-values are given in bold

[a]Operating room

[b]Composite variable for occurrence of superficial incisional SSI, deep incisional SSI, or wound disruption

[c]Surgical site infection

[d]Deep vein thrombosis

[e]Pulmonary embolism

[f]Urinary tract infection

[g]Cerebrovascular accident/transient ischemia attack

[h]Cardiopulmonary resuscitation

[i]Myocardial infarction

than underweight BMI to have higher odds of mortality, but the OR was not significant. This seeming "obesity paradox" in which increasing BMIs confer protective advantage to patients has been studied widely in settings of cardiovascular function and malignancy [28, 29]. In the setting orthopedic hip surgery, Zhang et al. found that morbid obesity protected against 30-day mortality in the setting of non-urgent hip surgery [30]. While the obesity paradox is still poorly understood, some theories base the improved outcomes on susceptibility to the adverse effects of inflammatory mediators. Patients with low BMIs may be malnourished and have less stored protein and thus use those available resources more quickly. Obese patients alternatively may be less prone to frank manifestations of inflammatory processes [31].

While NSQIP is a large database available for analysis of a nationwide sample, it has certain important limitations. Our study was limited by its retrospective nature and its dependence on the integrity of data collection and coding which could result in incorrect or incomplete information. NSQIP does not collect information on bowel injury outcomes, namely postoperative ileus, return of bowel function, and recurrence of small bowel obstruction, which would be beneficial in comparing the effectiveness of these interventions. The NSQIP database is also limited to 30-day morbidity and mortality outcomes. Thus, we were unable to study long-term complications or benefits following these procedures. In addition, not all hospitals participate in NSQIP, therefore, generalization of conclusions must be performed with caution.

An important limitation of NSQIP and of our study is the lack of granularity of the data with respect to the specifics of an operation. For example, although NSQIP allows identification of cases that were initiated laparoscopically or open, we are not able to classify cases based on whether they were converted from laparoscopic to open, nor were we able to assess the reasons for conversion. We, therefore, performed an "intention-to-treat" analysis, comparing the decision to begin a procedure with laparoscopy or laparotomy. An important concern in retrospective cohort studies is the presence of selection bias toward open surgery for "sicker" patients and toward laparoscopy for "less sick" patients. Although our methods of multivariable and propensity adjustment can address potential confounders, it cannot address variables such as differences in perioperative care. NSQIP does not provide surgeon or hospital specific data, so the individual surgeon's experience and level of ability are unavailable. Selection bias toward laparoscopy by surgeons and institutions who are more skilled and comfortable with laparoscopy could potentially account for improved outcome in this group, but this could not be quantified in our study. Additionally, the occurrence of intraoperative and missed enterotomies is not available in NSQIP.

Use of propensity matching was essential to reducing the assignment bias between the open and laparoscopic groups. However, factors may remain that were not addressed in the matching and continue to influence the assignments and outcomes. For example, information on previous abdominal surgery was unavailable in the NSQIP database and that surgical history is considered to be a contraindication to laparoscopy by some surgeons. Additionally, using the matching procedure limited the sample size with laparoscopic procedures being the limiting factor. These limitations, ranging from available information available in the NSQIP database to possibly biased assignment of patients to surgical groups, have the potential to affect and alter results and conclusions presented in this study.

Conclusions

In this retrospective analysis, laparoscopic intervention for emergent SBO treatment was found to result in decreased odds of experiencing any complication compared to open intervention. Laparoscopic bowel-resection and adhesiolysis-only surgeries resulted in significantly decreased odds of any wound complication, any morbidity, unplanned intubation, and ventilator use greater than 48 h. Laparoscopy also resulted in significantly shorter hospital stays and presumably decreased costs but no significant differences in the odds of ROR. These results demonstrate that laparoscopic approaches should be given more attention as a primary treatment of SBO, and its increased use could result in decreased hospital costs if implemented in appropriate patient populations.

Compliance with ethical standards

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References

1. Coe TM, Chang DC, Sicklick JK (2015) Small bowel volvulus in the adult populace of the United States: results from a population-based study. Am J Surg 210:201–210. e2
2. Scott JW, Olufajo OA, Brat GA, Rose JA, Zogg CK, Haider AH, Salim A, Havens JM (2016) Use of national burden to define operative emergency general surgery. JAMA Surg 151:e160480
3. Kelly KN, Iannuzzi JC, Rickles AS, Garimella V, Monson JR, Fleming FJ (2014) Laparotomy for small-bowel obstruction: first choice or last resort for adhesiolysis? A laparoscopic approach for small-bowel obstruction reduces 30-day complications. Surg Endosc 28:65–73
4. Catena F, Di Saverio S, Kelly MD, Biffl WL, Ansaloni L, Mandalà V, Velmahos GC, Sartelli M, Tugnoli G, Lupo M, Mandalà S, Pinna AD, Sugarbaker PH, Van Goor H, Moore EE, Jeekel J (2011) Bologna guidelines for diagnosis and management of adhesive small bowel obstruction (ASBO): 2010 evidence-based guidelines of the World Society of Emergency Surgery. World J Emerg Surg 6:21
5. Gutt CN, Oniu T, Schemmer P, Mehrabi A, Büchler MW (2004) Fewer adhesions induced by laparoscopic surgery? Surg Endosc 18:898–906
6. Lombardo S, Baum K, Filho JD, Nirula R (2014) Should adhesive small bowel obstruction be managed laparoscopically? A National Surgical Quality Improvement Program propensity score analysis. J Trauma Acute Care Surg 76:696–703
7. Daly SC, Popoff AM, Fogg L, Francescatti AB, Myers JA, Millikan KW, Deziel DJ, Luu MB (2014) Minimally invasive technique leads to decreased morbidity and mortality in small bowel resections compared to an open technique: an ACS-NSQIP identified target for improvement. J Gastrointest Surg 18:1171–1175
8. Sharma R, Reddy S, Thoman D, Grotts J, Ferrigno L (2015) Laparoscopic versus open bowel resection in emergency small bowel obstruction: analysis of the national surgical quality improvement program database. J Laparoendosc Adv Surg Tech A 25:625–630
9. Behman R, Nathens AB, Byrne JP, Mason S, Look Hong N, Karanicolas PJ (2017) Laparoscopic surgery for adhesive small bowel obstruction is associated with a higher risk of bowel injury: a population-based analysis of 8584 patients. Ann Surg 266:489–498
10. O'Connor DB, Winter DC (2010) Bowel obstruction following appendectomy: a protective role implied for laparoscopy? Ann Surg 251:1190–1191
11. Ghosheh B, Salameh JR (2007) Laparoscopic approach to acute small bowel obstruction: review of 1061 cases. Surg Endosc 21:1945–1949
12. Fuchshuber PR, Greif W, Tidwell CR, Klemm MS, Frydel C, Wali A, Rosas E, Clopp MP (2012) The power of the National Surgical Quality Improvement Program–achieving a zero pneumonia rate in general surgery patients. Perm J 16:39–45
13. Dindo D, Demartines N, Clavien PA (2004) Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann Surg 240:205–213
14. Mancini GJ, Petroski GF, Lin WC, Sporn E, Miedema BW, Thaler K (2008) Nationwide impact of laparoscopic lysis of adhesions in the management of intestinal obstruction in the US. J Am Coll Surg 207:520–526

15. Wullstein C, Gross E (2003) Laparoscopic compared with conventional treatment of acute adhesive small bowel obstruction. Br J Surg 90:1147–1151
16. Johnson KN, Chapital AB, Harold KL, Merritt MV, Johnson DJ (2012) Laparoscopic management of acute small bowel obstruction: evaluating the need for resection. J Trauma Acute Care Surg 72:25–30
17. Li MZ, Lian L, Xiao LB, Wu WH, He YL, Song XM (2012) Laparoscopic versus open adhesiolysis in patients with adhesive small bowel obstruction: a systematic review and meta-analysis. Am J Surg 204:779–786
18. Byrne J, Saleh F, Ambrosini L, Quereshy F, Jackson TD, Okrainec A (2015) Laparoscopic versus open surgical management of adhesive small bowel obstruction: a comparison of outcomes. Surg Endosc 29:2525–2532
19. Johnson KN, Chapital AB, Harold KL, Merritt MV, Johnson DJ (2012) Laparoscopic management of acute small bowel obstruction: evaluating the need for resection. J Trauma Acute Care Surg 72:25–31,317
20. Davies SW, Gillen JR, Guidry CA, Newhook TE, Pope NH, Hranjec T, Sawyer RG, Hallowell PT (2014) A comparative analysis between laparoscopic and open adhesiolysis at a tertiary care center. Am Surg 80:261–269
21. Grafen FC, Neuhaus V, Schob O, Turina M (2010) Management of acute small bowel obstruction from intestinal adhesions: indications for laparoscopic surgery in a community teaching hospital. Langenbecks Arch Surg 395:57–63
22. Khaikin M, Schneidereit N, Cera S, Sands D, Efron J, Weiss EG, Nogueras JJ, Vernava AM 3rd, Wexner SD (2007) Laparoscopic vs. open surgery for acute adhesive small-bowel obstruction: patients' outcome and cost-effectiveness. Surg Endosc 21:742–746
23. Margenthaler JA, Longo WE, Virgo KS, Johnson FE, Grossmann EM, Schifftner TL, Henderson WG, Khuri SF (2006) Risk factors for adverse outcomes following surgery for small bowel obstruction. Ann Surg 243:456–464
24. Sajid MS, Khawaja AH, Sains P, Singh KK, Baig MK (2016) A systematic review comparing laparoscopic vs open adhesiolysis in patients with adhesional small bowel obstruction. Am J Surg 212:138–150
25. Al-Temimi MH, Griffee M, Enniss TM, Preston R, Vargo D, Overton S, Kimball E, Barton R, Nirula R (2012) When is death inevitable after emergency laparotomy? Analysis of the American College of Surgeons National Surgical Quality Improvement Program database. J Am Coll Surg 215:503–511
26. Symons NR, Moorthy K, Almoudaris AM, Bottle A, Aylin P, Vincent CA, Faiz OD (2013) Mortality in high-risk emergency general surgical admissions. Br J Surg 100:1318–1325
27. Jeppesen MH, Tolstrup MB, Kehlet Watt S, Gogenur I (2016) Risk factors affecting morbidity and mortality following emergency laparotomy for small bowel obstruction: a retrospective cohort study. Int J Surg 28:63–68
28. Hamaguchi S et al (2010) Body mass index is an independent predictor of long-term outcomes in patients hospitalized with heart failure in Japan. Circ J 74(12):2605–2611
29. Schiffmann J et al (2018) Obesity paradox in prostate cancer: increased body mass index was associated with decreased risk of metastases after surgery in 13,667 patients. World J Urol. https://doi.org/10.1007/s00345-018-2240-8
30. Zhang JC et al (2018) Can patient selection explain the obesity paradox in orthopaedic hip surgery? An analysis of the ACS-NSQIP registry. Clin Orthop Relat Res 476(5):964–973
31. Park J et al (2014) Obesity paradox in end-stage kidney disease patients. Prog Cardiovasc Dis 56(4):415–425