Should adhesive small bowel obstruction be managed laparoscopically? A National Surgical Quality Improvement Program propensity score analysis

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BACKGROUND: Celiotomy is the most common approach for refractory small bowel obstruction (SBO). Small reviews suggest that a laparoscopic approach is associated with shorter stay and less morbidity. Given the limitations of previous studies, we sought to evaluate outcomes of laparoscopic (L) compared with open (O) adhesiolysis for SBO, using the National Surgical Quality Improvement Program data set.

METHODS: Patients from the American College of Surgeons' National Surgical Quality Improvement Program 2005 to 2009 database who underwent surgery for SBO were stratified based on surgical approach. A propensity score to undergo L instead of O was calculated based on demographics, comorbidities, physiology, and laboratory values. Logistic regression was then used to determine differences in outcomes between those propensity score–matched patients who actually underwent L compared with O surgery.

RESULTS: There were 6,762 patients who underwent adhesiolysis. The propensity score–matching process created 222 matched patients in L and O groups. Laparoscopy was associated with significantly lower rates of any complication (odds ratio [OR] 0.41; 95% confidence interval [CI], 0.28–0.60), including superficial site infections (OR, 0.15; 95% CI, 0.05–0.49), intraoperative transfusion (OR, 0.22; 95% CI, 0.05–0.90), and shorter hospital stay (4 days vs. 10 days; $p < 0.001$). There was no significant difference in operative time, rates of reoperation within 30 days, or mortality.

CONCLUSION: Laparoscopic treatment of SBO is associated with lower rates of postoperative morbidity compared with laparotomy as well as shorter hospital stay. Laparoscopic treatment of surgical SBO is not associated with higher rates of early reoperation and seems to be associated with lower resource use. (*J Trauma Acute Care Surg*. 2014;76: 696–703. Copyright © 2014 by Lippincott Williams & Wilkins)

LEVEL OF EVIDENCE: Therapeutic study, level IV.

KEY WORDS: Small bowel obstruction; celiotomy; laparoscopic surgery; outcomes.

The treatment of small bowel obstruction (SBO) represents a significant health care burden, responsible for approximately 1% of hospital admissions per year at a cost of well more than $1 billion. Therefore, improving care efficiency of SBO patients will significantly reduce resource use and cost for this patient population. Although the traditional intervention for refractory SBO has been open celiotomy, there is an increasing body of literature suggesting that a laparoscopic approach, especially if the obstruction is caused by simple adhesion, is safe and effective. This is particularly relevant given that up to 85% of SBOs are caused by postoperative adhesions,[1] the development of which are associated with the nature of the index procedure.[2] Available literature suggests that the risk of postoperative adhesion is reduced with laparoscopic surgery when compared with the traditional open approach.[3,4] Furthermore, multiple studies have demonstrated that laparoscopic surgery is associated with shorter hospital stay and reduced overall morbidity. For example, in a series of more than 2,000 SBO patients O'Connor and Winter[1] identified that two thirds of the patients were managed laparoscopically,with a success rate of 73.4% if the obstruction was attributable to a single adhesive band with an overall morbidity of 14.8%. Levard et al.[5] performed a 35-center retrospective study of 308 patients undergoing laparoscopic treatment for acute SBO with similar results. Although a preponderance of literature is supportive of laparoscopic treatment for SBO, the data are currently limited to observational and retrospective case series. There are, to date, no randomized or prospective controlled trials comparing open versus laparoscopic surgery for SBO.[6] While there are a number of meta-analyses comparing laparoscopic surgery versus open surgery for SBO,[7–10] these largely rely on pooled data from the aforementioned smaller series. Thus, data on the safety and efficacy of laparoscopy for adhesive SBO remain limited by study heterogeneity in previous meta-analyses and short-term follow-up, with few studies remarking on the need for early reoperation.[8,11–13]

Nevertheless, recent guidelines have begun to incorporate recommendations regarding the use of laparoscopy for SBO. The Eastern Association for Surgery of Trauma practice management guideline now supports the use of laparoscopy in appropriate settings, which may include complex SBO in the context of multiple previous abdominal surgeries.[14] The appropriate setting for laparoscopy depends not only on the patient presentation and their comorbidities but also on surgical experience, training,

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and comfort level. This introduces a degree of confounding and selection bias, which may be difficult to circumvent when comparing outcomes of an open versus a laparoscopic approach, making the implementation of a randomized study prohibitively difficult. Propensity score matching is a statistical technique introduced by Rosenbaum and Rubin[15] to aid in the evaluation of treatment effects when using observational data "collected through the observation of systems as they operate in normal practice, without randomized assignment of interventions," with the objective of controlling for covariates and the influence of confounders. With the use of propensity score matching, multiple covariates can be condensed and summarized as a single value representing the conditional probability of undergoing an intervention. Cases and controls may then be paired based on similar propensity scores and may consequently be treated as comparable, as the distributions of their covariates are balanced.

Our study used propensity score matching to evaluate outcome differences in laparoscopic (L) versus open (O) surgical management of SBO, using data collected as part of the American College of Surgeons' National Surgical Quality Improvement Program (NSQIP).

PATIENTS AND METHODS

Data Acquisition

After obtaining University of Utah Institutional Review Board and American College of Surgeons approval to query, the NSQIP database, deidentified patient information for this study, was obtained for years 2005 to 2009. The initial data set was compiled using DRG International Classification of Disease Diagnosis—9th Rev. codes to select for observations with discharge diagnoses likely to be consistent with the initial clinical presentation of SBO (DRG International Classification of Disease Diagnosis—9th Rev. codes 560.1, 560.2, 560.81, 560.89, 557.1). This was then narrowed by retaining only those records with surgical procedure codes for operative treatment of SBO (current procedural terminology [CPT] codes 44005, 44180, 44238, 49000, 49320, 49329). Finally, all primary, secondary, and tertiary CPT codes remaining with the data set were reviewed, and observations with surgical procedures inconsistent with a primary problem of SBO were removed. This included, but was not limited to, any gynecologic procedure, appendectomy, cholecystectomy, placement of gastrostomy or jejunostomy tube for feeding purposes, or colonic procedures. Had we foregone this last step, we feared we would have retained cases where the primary problem was not an acute adhesive SBO.

Demographics and Perioperative Risk Factors

A robust set of demographic variables, preoperative laboratory values, and comorbid conditions were compared among the L, O, and L converted to O surgical groups (Tables 1 and 2). Operative conditions (emergency surgery, resident participation, and presence of first- or second-year resident) had the potential to affect surgical outcomes and therefore were included in the analysis. As there is no defined CPT code that readily identifies intraoperative conversion from L to O, patients were assumed

TABLE 1. Demographics

	Open (n = 5,506)		Laparoscopic (n = 834)		Laparoscopic to Open (n = 422)		
	n	%	n	%	n	%	*p*
Sex							
Male	2,077	37.7	252	30.2	163	38.6	<0.001
Female	3,429	62.3	582	69.8	259	61.4	
Age, mean and SD	63.4	17.0	57.4	17.3	61.0	16.6	<0.001
<40	504	9.2	133	16.0	47	11.1	<0.001
40–54	1,212	22.0	240	28.8	106	25.1	
55–69	1,556	28.3	230	27.6	123	29.2	
70–79	1,070	19.4	135	16.2	74	17.5	
≥80	1,164	21.1	96	11.5	72	17.1	
Body mass index, mean and SD	25.9	6.6	27.5	7.2	26.4	6.1	<0.001
Underweight (<18.5)	425	8.2	38	4.8	20	5.0	
Normal (18.5–24.9)	2,324	44.8	293	36.8	49	43.1	
Overweight (25–29.9)	1,413	27.3	244	30.6	129	32.2	
Obese (≥30)	1,023	19.7	222	27.9	79	19.7	
Smoker							
No	4,321	78.5	704	84.4	341	80.8	<0.001
Yes	1,185	21.5	130	15.6	81	19.2	
Alcohol							
No	5,341	97.0	817	98.0	408	96.7	0.267
Yes	165	3.0	17	2.0	14	3.3	
Diabetes							
No	4,803	87.2	761	91.3	378	89.6	0.012
Orals	441	8.0	50	6.0	28	6.6	
Insulin	262	4.8	23	2.8	16	3.8	

TABLE 2. Comorbidities, Preoperative Laboratory Values, and Operative Conditions

	Open (n = 5,506)		Laparoscopic (n = 834)		Laparoscopic to Open (n = 422)		
	n	%	n	%	n	%	*p*
Comorbidities							
History of COPD	475	8.6	37	4.4	21	5.0	<0.001
HTN, requiring medication	2,765	50.2	353	42.3	201	47.6	<0.001
History of CHF	6,930	1.7	5	0.6	5	1.2	0.048
MI within 6 mo	46	0.8	4	0.5	5	1.2	0.385
History of PVD	143	2.6	11	1.3	6	1.4	0.032
Renal failure	94	1.7	6	0.7	4	1.0	0.058
History of TIA/CVA	457	8.3	47	5.6	40	9.5	0.017
Disseminated CA	190	3.5	10	1.2	15	3.6	0.002
Steroid use	273	5.0	19	2.3	15	3.6	0.001
Weight loss > 10% 6 mo	266	4.8	20	2.4	17	4.0	0.006
Bleeding disorder	556	10.1	58	7.0	35	8.3	0.010
Functionally depend	654	17.9	99	8.6	22	16.7	<0.001
ASA class							
Class I	136	2.5	38	4.6	15	3.6	<0.001
Class II	1,787	32.5	448	53.8	178	42.4	
Class III	2,827	51.4	315	37.8	199	47.4	
Class IV	732	13.3	32	37.8	27	6.4	
Class V	20	0.4	—	—	1	0.2	
Preoperative patient characteristics							
Surgery 30 d prior	317	6.3	46	5.9	20	5.1	0.636
Preoperative SIRS	1,556	28.3	127	15.2	90	21.3	<0.001
Ascites	433	7.9	48	5.8	38	9.0	0.059
Dyspnea	550	10.0	62	7.4	30	7.1	0.014
Impaired sensorium	102	1.9	7	0.8	3	0.7	0.030
Preoperative laboratory values, mean and SD							
Sodium < 135	820	14.9	93	11.2	54	12.8	0.011
Albumin < 3.0	869	19.3	74	11.3	44	13.5	<0.001
Hematocrit < 30	468	8.6	32	4.0	15	3.6	<0.001
White blood cells > 12	1,317	24.3	126	15.7	83	20.3	<0.001
Platelets < 150	402	7.4	51	6.4	33	8.0	0.482
Creatinine > 1.5	607	11.2	23	2.9	24	5.9	<0.001
BUN > 40	372	6.9	19	2.4	12	3.0	<0.001
International normalized ratio > 1.5	258	7.9	19	4.6	16	7.0	0.053
Operative conditions							
Emergent surgery	2,851	51.8	309	37.1	197	46.7	<0.001
Resident participate	2,686	64.4	358	58.1	184	60.5	0.006
Postgraduate year 1 or 2	378	9.1	64	10.4	27	8.9	0.554

BUN, Blood Urea Nitrogen; CA, Cancer; CHF, Congestive Heart Failure; COPD, Chronic Obstructive Pulmonary, Disease; CVA, Cerebrovascular Accident; HTN, Hypertension; MI, Myocardial Infarction; PVD, Peripheral Vascular Disease; SIRS, System Inflammatory Response; TIA, Transient Ischemic Attack.

to have undergone an L-to-O conversion if CPT codes for both laparoscopic and open procedures were listed in the primary procedure.

Outcomes

The outcomes of interest were defined as follows:

1. Any complication, inclusive of all minor and major morbidities and mortalities.
2. Minor complication, comprising superficial or deep surgical site infection (SSI), pneumonia, unplanned reintubation, urinary tract infection (UTI), and deep venous thrombosis (DVT).
3. Major complications, comprising organ space SSI, pulmonary embolism (PE), wound dehiscence, ventilator dependency for more than 48 hours, transient ischemic attack (TIA)/cerebrovascular accident (CVA), postoperative cardiopulmonary resuscitation (CPR), myocardial infarction (MI), shock, sepsis, postoperative transfusion, or return to the operating room.
4. Mortality within 30 days of the primary procedure and number of postoperative days until death.
5. Operative conditions, constituting total operative time and total anesthesia time.
6. Total hospital length of stay (LOS).

Propensity Score Matching

To overcome differences between the L and O groups patients from the L group were matched 1:1 with a similar patient in the O group based on demographics and perioperative risk factors. Given the low number of observations within the L-to-O conversion group, propensity score matching and analysis concerned only patients that had undergone successful L or O procedures. Logistic regression analysis was performed to evaluate the likelihood of laparoscopic treatment based on demographic, preoperative conditions and laboratory values. A propensity score (probability) of undergoing laparoscopy was calculated for each patient regardless of whether they actually had a laparoscopic procedure. Patients were matched using the radius matching method without replacement, resulting in 222 pairs of L and O.[16] Success of matching was confirmed by reanalysis of potential confounders to ensure that the L and O groups were well balanced.

Statistical Analysis

Demographics and perioperative factors were compared using Pearson's χ^2 test for categorical and one-way analysis of variance for continuous variables. Kruskal-Wallis analysis of variance was used for nonparametric distributions. Comparison of prematching and postmatching outcome measures for L and O groups was performed using Mantel-Haenszel odds ratio for categorical variables and linear regression modeling for continuous variables. Post hoc analysis of the propensity-matched groups removed all observations in which the case was classified contaminated or dirty/infected, resulting in 206 and 196 observations in the L and O groups, respectively. All statistical analyses were performed using Stata 11 (StataCorp, College Station, TX). A p value of less than 0.05 was considered to be statistically significant.

RESULTS

Preoperative and Operative Characteristics

A total of 6,762 patients 18 years and older were analyzed. Eighty-one percent (n = 5,506) underwent laparotomy, while 1,256 underwent laparoscopy, with a conversion rate of 33.6% (n = 422). Those in the L group were younger, more overweight, more likely to be women, and less likely to smoke or carry a diagnosis of diabetes (Table 1). The L group had fewer comorbidities and a lower incidence of systemic inflammatory response syndrome and thus were more frequently categorized as American Society of Anesthesiologists (ASA) I or II compared with patients in O or L-to-O groups (Table 2). Preoperative hematocrit less than 30% and hypoalbuminemia less than 3.0 g/dL were nearly twice as common in the O group. Surgery was considered emergent in 51.8% of the O patients compared with 37.1% of the L patients and 46.7% of the L-to-O operations. Resident participation was significantly more common in laparotomies; however, the prevalence of junior-level resident involvement was not significantly different between the three groups (9.1% vs. 4.6% vs. 7.0%, p = 0.554).

TABLE 3. Post–Propensity Score Matching Demographics

	Open (n = 5,506)		Laparoscopic (n = 834)		
	n	%	n	%	p
Sex					
Male	62	27.9	62	27.9	1.000
Female	160	72.1	160	72.1	
Age, mean and SD					
<40	23	10.4	22	9.9	0.986
40–54	43	19.4	47	21.2	
55–69	68	30.6	65	29.3	
70–79	44	19.8	46	20.7	
≥80	44	19.8	42	18.9	
Body mass index, mean and SD					
Underweight (<18.5)	13	5.9	12	5.4	0.751
Normal (18.5–24.9)	86	38.7	86	38.7	
Overweight (25–29.9)	60	27.0	69	31.1	
Obese (≥30)	63	28.4	55	24.8	
Smoker					
No	191	86.0	31	13.96	0.594
Yes	187	84.2	35	15.8	
Alcohol					
No	215	96.9	7	3.2	1.000
Yes	215	96.9	7	3.2	
Diabetes					
No	196	88.3	196	88.3	0.959
Orals	17	7.7	16	7.2	
Insulin	9	4.1	10	4.5	

Propensity score matching yielded 222 pairs of matched L and O patients. Following matching, patient demographics, comorbidities, ASA class, preoperative laboratory values and clinical symptoms, and operative conditions between these cohorts were not significantly different, indicating that the resulting groups were highly comparable for observable variables (Tables 3 and 4).

Unadjusted Outcomes

An unadjusted complication rate of 32% (n = 1,762) was observed in O patients, which was nearly three times the rate seen in the laparoscopic cohort (Table 5). In L patients, minor and major complications were reported in 6.7% and 9.7%, respectively, as compared with 21.6% and 21.0% in O patients. Nonsignificant differences in complication rates were seen for PE, CVA/TIA, postoperative transfusion, and return to the operating room. Average operative time (71 minutes vs. 62 minutes), anesthesia times (124 minutes vs. 114 minutes), and LOS (10 days vs. 4 days) were also significantly increased for O cases. Unadjusted risk of postoperative mortality for laparotomy (4.5%) was four times that of laparoscopy (1.1%, $p < 0.001$).

Propensity-Matched Outcomes

In the matched cohort, L patients were half as likely to have any postoperative complication compared with O patients (odds ratio [OR], 0.48; 95% confidence interval [CI], 0.30–0.77). This was driven largely by the lower rates of superficial site infections (OR, 0.17; 95% CI, 0.05–0.57), sepsis (OR, 0.30; 95%

TABLE 4. Post-Propensity Score Matching Comorbidities, Pre-Operative Values, and Operative Conditions

	Open (n = 5,506)		Laparoscopic (n = 834)		
	n	%	n	%	*p*
Comorbidities					
History of COPD	17	7.7	18	8.11	0.860
HTN, requiring medications	111	50.0	113	50.9	0.849
History of CHF	1	0.5	3	1.4	0.315
MI within 6 mo	5	2.3	2	0.9	0.253
History of PVD	8	3.6	7	3.2	0.793
Renal failure	3	1.4	2	0.9	0.653
History of TIA/CVA	14	6.3	19	8.6	0.366
Disseminated CA	5	2.3	3	1.4	0.475
Steroid use	10	4.5	8	3.6	0.630
Wt loss >10% 6 mo	5	2.3	6	2.7	0.760
Bleeding disorder	23	10.4	26	11.7	0.650
Functionally depend	37	16.7	36	16.2	0.898
ASA class					
Class I	6	2.7	4	1.8	0.914
Class II	92	41.4	93	41.9	
Class III	107	48.2	106	47.8	
Class IV	17	7.7	19	8.6	
Class V	—	—	—	—	
Preoperative **patient characteristics**					
Surgery 30 d prior	18	8.1	16	7.2	0.721
Preoperative SIRs	37	16.7	41	18.5	0.618
Ascites	9	4.1	10	4.5	0.815
Dyspnea	14	6.3	19	8.6	0.366
Impaired sensorium	4	1.8	3	1.4	0.703
Preoperative laboratory values, mean and SD					
Sodium < 135	30	13.5	36	16.2	0.244
Albumin < 3.0	38	17.1	36	16.2	0.799
Hematocrit < 30	25	11.3	14	6.3	0.065
White blood cells > 12	35	15.8	40	18.0	0.527
Platelets < 150	12	5.4	15	6.8	0.551
Creatinine > 1.5	4	1.8	6	2.7	0.522
BUN > 40	4	1.8	6	2.7	0.522
International normalized ratio > 1.5	8	3.6	12	5.4	0.360
Operative conditions					
Emergent surgery	78	35.1	72	32.4	0.547
Resident participate	137	61.7	140	63.1	0.769
Postgraduate year 1 or 2	32	14.4	29	13.1	0.679

TABLE 5. Unadjusted and Adjusted (Propensity Score) Outcomes; Open vs. Laparoscopic

	Open (n = 5,506)		Laparoscopic (n = 834)			Adjusted OR (95% CI) for Laparoscopic	Adjusted p
	n	%	n	%	Unadjusted p	n = 444 (O, 222; L, 222)	
Any complication	1,762	32.0	104	12.5	<0.001	0.48 (0.30 to 0.77)	0.002
Minor morbidity	1,188	21.6	56	6.7	<0.001	0.43 (0.24 to 0.76)	0.004
Superficial SSI	419	7.6	8	1.0	<0.001	0.17 (0.05 to 0.57)	0.004
Deep SSI	112	2.0	4	0.5	0.018	—	—
Pneumonia	329	6.0	17	2.0	<0.001	0.59 (0.14 to 2.52)	0.480
Unplanned intubation	237	4.3	10	1.2	<0.001	1.26 (0.33 to 4.74)	0.737
UTI	294	5.3	22	2.6	0.008	0.90 (0.36 to 2.25)	0.815
DVT	107	1.9	5	0.6	0.006	0.20 (0.02 to 1.69)	0.139
Major morbidity	1,156	21.0	81	9.7	<0.001	0.56 (0.33 to 0.96)	0.034
Organ SSI	168	3.1	13	1.6	0.016	0.37 (0.10 to 1.40)	0.142
PE	42	0.8	3	0.4	0.196	0.50 (0.04 to 5.53)	0.570
Wound dehiscence	93	1.7	4	0.5	0.008	1.00 (0.06 to 16.09)	1.000
Ventilator > 48 h	366	6.7	9	1.1	<0.001	0.39 (0.12 to 1.26)	0.115
CVA/TIA	15	0.3	4	0.5	0.308	—	—
CPR postoperative	51	0.9	2	0.2	0.042	1.00 (0.06 to 16.09)	1.000
MI	36	0.7	0	0	0.019	—	—
Shock	222	4.0	9	1.1	<0.001	2.02 (0.37 to 11.13)	0.420
Sepsis	374	6.8	23	2.8	<0.001	0.30 (0.12 to 0.76)	0.011
Postoperative transfusion	27	0.5	1	0.1	0.133	—	—
Return to operating room	378	6.9	44	5.3	0.086	1.10 (0.47 to 2.54)	0.830
Operative conditions							
Operative time (median; p5–p95)	71	27–219	62	24–176	<0.001	−8.13 (−19.95 to 3.69)	0.177
Anesthesia time (median; p5–p95)	124	67–283	114	62–231	<0.001	−12.40 (−25.65 to 0.84)	0.066
Nonclean wound	3,316	60.2	319	38.3	<0.001	0.44 (0.29 to 0.67)	<0.001
Mortality	246	4.5	9	1.1	<0.001	1.68 (0.40 to 7.13)	0.480
Days to death (median; p25–p75; coef days)	10	5–17	18	14–21	0.0243	14.33 (9.35 to 19.32)	<0.001
Length of stay (median; p25–p75; coef days)	10	7–15	4	2–8	<0.001	−4.72 (−6.47 to −2.98)	<0.001

CI, 0.12–0.76), and intraoperative transfusion (OR, 0.15; 95% CI, 0.03–0.71) in the minimally invasive group (Fig. 1). Differences between the groups with regard to pneumonia, unplanned intubation, UTI, DVT, organ space infection, wound dehiscence, prolonged ventilator dependence, need for postoperative CPR, and shock did not persist in the matched cohort. Operative and anesthesia times were also similar for both surgical approaches, with a trend toward slightly shorter times for laparoscopy (Table 5). Odds of Class II (clean contaminated), III (contaminated), or IV (dirty/infected) wound classification in laparoscopic versus open cases was 0.44 (95% CI, 0.29–0.67), indicating a greater prevalence of contamination with the open approach. Post hoc analysis considered only observations where the surgical case was classified as clean or clean contaminated and included 206 in the O group and 196 in the L group. Outcome measures were not significantly different among this restricted cohort as compared with the full propensity-matched groups described earlier (not shown).

Postoperative 30-day mortality did not differ significantly between the two matched cohorts, with three deaths in the O group and five in the L group. Average time to death was 2.67 days (range, 2–4 days) among open patients, as compared with 17 days (range, 14–21 days) following a minimally invasive procedure ($p < 0.001$). Total hospital LOS was 4.4 days shorter in the laparoscopic group (8.4 days vs. 12.8 days; $p < 0.001$).

DISCUSSION

NSQIP data reflect the preferential use of celiotomy over laparoscopy in the treatment of adhesive SBO, in line with traditional standard of care. Notable differences exist between cohorts selected for each approach, with those undergoing open surgery likely to be more severely ill. The reasons for the differing approach may be surgeon preference, surgical complexity, or perceived inability to tolerate pneumoninsufflation among more critically ill patients. The matched patient cohorts, however, provided two well-balanced groups for outcome comparison. Our results show that mortality did not differ between laparoscopic and open approaches but overall complication rates were lower for laparoscopy than for open largely owing to lower rates of wound infection, sepsis and transfusion requirements in the laparoscopy group. While rates of more severe complications did not differ between the two groups, the length of hospital stay was considerably lower for laparoscopy. Therefore, our study demonstrates significantly lower resource use by patients who receive

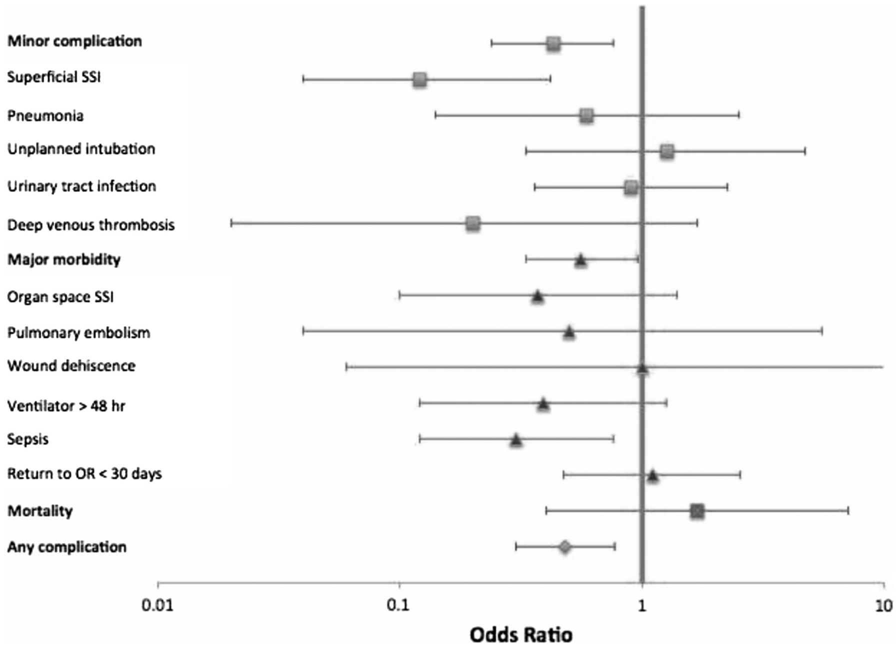

Figure 1. Odds ratios and 95% CIs for Propensity Score adjusted outcomes; open vs. laparoscopic.

their adhesiolysis laparoscopy compared with those having an open procedure.

Several studies suggest that laparoscopic treatment of SBO, particularly those caused by adhesions, leads to a shorter hospital course with reduced morbidity. Our findings are consistent with the literature in that hospital stay for laparoscopic approach was significantly shorter. A frequent critique of laparoscopic surgery is that procedures are more time consuming and therefore offset the costs of shorter hospital courses. However, we found that the length of surgery was not statistically different. Of course, an important contributor to increased cost is postoperative complication. Overall, laparoscopic surgery was half as likely to result in postoperative complication than was open procedure. Minor and major morbidities were reported in 6.7% and 9.7%, respectively, of the laparoscopic group as compared with 21.6% and 21.0% of open group. The laparoscopic group had a statistically significantly lower incidence of superficial site infections, sepsis, and intraoperative transfusion. While we did not estimate costs in this study, the implications of a shorter stay and reduced complications for laparoscopic surgery are that costs should be reduced compared with open.

Limitations

Limitations of NSQIP include the omission of some relevant patient history, for example, of previous abdominal surgery. Aspects of clinical decision making, such as use of preoperative imaging, is likewise not captured by the data set. In addition, as all absolute dates have been systematically removed from the NSQIP database, there is no way to divide total LOS into preoperative and postoperative portions that might account for a trial of conservative management for SBO. In our analysis, wound classification is treated as an outcome, although this could represent a preoperative condition as well. For example, an obstruction with associated perforation could preferentially lead to selection of open operation rather than laparoscopic operation. So wound classification may reflect either a preexisting independent variable contributing to choice of surgery and risk of postoperative complication, or it may reflect an intraoperative complication that did not exist before and was caused by the type of intervention selected. Without more information regarding the etiology of the contamination, there may be no reliable way to determine whether this was the cause or effect of the procedure chosen, and this is not captured by the data. To ensure that contamination was not a confounder in our analysis, we performed the analysis excluding contaminated or dirty/infected cases and found that there was no difference in our findings, indicating that the presence of preoperative intra-abdominal contamination was not biasing our results.

Perhaps, most importantly, the reporting window for postoperative complication within NSQIP is limited to 30 days. In addition, since NSQIP data are collected only for participating hospitals, readmission to nonparticipating hospitals may not be captured, although within the 30-day window. An inherent difficulty in evaluating outcomes involves a selection bias that may be difficult to detect and adjust for and that may make the implementation of a future randomized study prohibitive. That is, factors such as surgeon experience, which may influence the selection of the operative approach, are not recorded in the data set. Contraindications to laparoscopy or reasons for conversion to an open procedure are likewise unrecorded. Although participation by residents in a particular case is captured in the data, attending surgeon experience and institutional volume are not. Although resident participation in a procedure may serve as a proxy for facility type, this is similarly not directly recorded in the data. As with any retrospective investigation relying on previously captured data, our study also relies on the integrity of the data collection process. Misclassification of diagnoses, primary intervention, and so on are shortcomings that have been minimized by the standardized definitions and data collection process formalized by NSQIP. Despite these limitations, NSQIP data provide a large, standardized database that specifies, in a uniform manner, a large number of relevant perioperative and patient variables collected for a diverse, multicenter population of both patients and surgeons.

As far as the particular covariates chosen for our model are concerned, many variables used to evaluate preoperative risk factors and comorbidities can be subjective and somewhat vague. ASA scores, for example, do not necessarily account for the presence of multiple systemic diseases. The term *systemic disease* is itself open to subjective interpretation. Other variables may result from isolated organ system dysfunction or may represent aspects of multiorgan disease or secondary and indirect effects arising from a separate primary process.

Estimates of treatment effects obtained from observational studies are innately weakened owing to the possibility of hidden bias and the lack of randomness in selection. Propensity score analysis attempts to address this problem but assumes that all confounders are included and accounted for as observed covariates. Hidden bias remains a real possibility as undiscovered confounders remain unobserved and unmeasured. While randomized assignment may often be relied on to distribute unobserved covariates equally across groups, no such procedure exists for nonrandom assignment to ensure that unobserved factors do not distort outcome measurements. The matching process itself, whereby cases and controls with similar propensities are paired, often excludes outliers in either group. This may result in a study population that is more homogeneous than is encountered in practice and therefore may limit the generalizability of results. The matching process also dramatically reduces total sample size, which limits overall power, therefore subjecting our analysis to the risk of Type II error.

CONCLUSION

Overall, laparoscopy was associated with significantly lower rates of any complication, namely superficial site infections, intraoperative transfusion, and shorter hospital stay. There was no significant difference in operative time, rates of reoperation within 30 days, or mortality. These results support the use of laparoscopy in the management of adhesive small bowel obstruction as a safe and effective approach. Fruitful avenues for additional research include longer-term follow-up for SBO recurrence with the two approaches and investigation of patient factors associated with conversion of laparoscopic to open surgery. In an era of health care reform and desire to reduce health care costs, preferring a laparoscopic approach to bowel obstruction where feasible may make a substantial financial impact; however, further studies specifically evaluating the long-term cost-effectiveness of the laparoscopic approach are warranted.

AUTHORSHIP

S.L. contributed in the study design, data analysis, data interpretation, writing, and final revisions. K.B. contributed in the literature search, data interpretation, and writing. J.F.D. contributed in the data interpretation and writing. R.N. contributed in the study design, data analysis, data interpretation and critical revision.

DISCLOSURE

The authors declare no conflicts of interest.

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