Surg Endosc (2014) 28:65–73
DOI 10.1007/s00464-013-3162-6

Laparotomy for small-bowel obstruction: first choice or last resort for adhesiolysis? A laparoscopic approach for small-bowel obstruction reduces 30-day complications

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Received: 26 April 2013 / Accepted: 31 July 2013 / Published online: 4 September 2013

Abstract
Introduction Small-bowel obstruction (SBO) requiring adhesiolysis is a frequent and costly problem in the United States with limited evidence regarding the most effective and safest surgical management. This study examines whether patients treated with laparoscopy for SBO have better 30-day surgical outcomes than their counterparts undergoing open procedures.
Methods Patients with a diagnosis of adhesive SBO were selected from the ACS National Surgical Quality Improvement Program database from 2005 to 2010. Cases were classified as either laparoscopic or open adhesiolysis groups using Common Procedural Terminology codes. Chi square and Student's *t* test were used to compare patient and surgical characteristics with 30-day outcomes, including major complications, incisional complications, and mortality. Factors with $p < 0.1$ were included in the multivariable logistic regression for each outcome. A propensity score analysis for probability of being a laparoscopic case was used to address residual selection bias. A two-sided p value <0.05 was considered significant.
Results Of the 9,619 SBO included in the analysis, 14.9 % adhesiolysis procedures were performed laparoscopically. Patients undergoing laparoscopic procedures had shorter mean operative times (77.2 vs. 94.2 min, $p < 0.0001$) and decreased postoperative length of stay (4.7 vs. 9.9 days, $p < 0.0001$). After controlling for comorbidities and surgical factors, patients having laparoscopic adhesiolysis were less likely to develop major complications [odds ratio (OR) = 0.7, 95 % confidence interval (CI) 0.58–0.85, $p < 0.0001$] and incisional complications (OR = 0.22, 95 % CI 0.15–0.33, $p < 0.0001$). The 30-day mortality was 1.3 % in the laparoscopic group versus 4.7 % in the open group (OR = 0.55, 95 % CI 0.33–0.85, $p = 0.024$).
Conclusions Laparoscopic adhesiolysis requires a specific skill set and may not be appropriate in all patients. Notwithstanding this, the laparoscopic approach demonstrates a benefit in 30-day morbidity and mortality even after controlling for preoperative patient characteristics. Given these findings in more than 9,000 patients and consistent rates of SBO requiring surgical intervention in the United States, increasing the use of laparoscopy could be a feasible way of to decrease costs and improving outcomes in this population.

Keywords Adhesions · Complications · Bowel · Abdominal

Presented at the SAGES 2013 Annual Meeting, April 17–20, 2013, Baltimore, MD.

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Small-bowel obstruction (SBO) requiring adhesiolysis is a frequent and costly problem in the United States. In 2005, ~119 per 100,000 hospitalized patients had adhesiolysis-related disease and although the incidence has remained fairly constant during the past two decades, estimated yearly costs exceeded $2.3 billion in 2005 and continue to increase [1, 2]. Multiple studies have demonstrated that the majority of patients presenting with SBO secondary to adhesions have a history of one or more abdominal or pelvic operations [3–6]. A wide variety of operations, even those most commonly performed laparoscopically, are frequently implicated as the etiology of adhesive SBO, including appendectomy, gynecological procedures, cholecystectomy, colorectal resections, bariatric operations, and other laparotomies [3, 5–8]. Despite the high frequency of SBO, there is still a paucity of data on the best means of treating this long-term postoperative complication. Conservative measures often are employed initially, but studies have documented failure rates from 20 to 73 %, frequently necessitating the need for operative intervention [9].

Currently, open adhesiolysis is accepted as the standard surgical intervention for adhesive SBO; however, since the first successful laparoscopic adhesiolysis was completed in the early 1990s, many small-scale studies have found this to be a feasible, safe, and potentially less morbid operation if performed in the hands of an experienced surgeon [5–7, 10–17]. In a recent systematic review of 29 studies with 2,005 total patients undergoing laparoscopic management of acute SBO, O'Connor et al. [18] found that 64 % of the operations were completed without conversion to an open procedure with a postoperative morbidity of 14.8 % and mortality of 1.5 %. Despite these findings, no randomized, controlled or prospective, clinical trials have compared the open and laparoscopic approaches for adhesiolysis, indicating that more evidence is needed [19]. This current study examined whether laparoscopic adhesiolysis is associated with lower 30-day mortality, major complication rates, and incisional complication rates than traditional open adhesiolysis.

Materials and methods

The American College of Surgeons National Surgical Quality Improvement Program (NSQIP) includes a systematically and voluntarily collected clinical database of surgical cases at hundreds of hospitals across the United States. Further details regarding NSQIPs parameters, outcomes, data abstraction, and sampling strategy have been previously reported [20]. Briefly, a surgical clinical reviewer collects patient demographics, preoperative comorbidities and labs, intraoperative variables, and 30-day outcomes through chart review and written or verbal communication with patients. The case sampling strategy requires that hospitals capture at least 20 % of each subspecialty's volume and occurs in consecutive 8-day cycles where NSQIP requires the first 40 general surgery cases to be reported [21]. High-volume procedures (herniorrhaphy, lumpectomy, cholecystectomy) are limited to three procedures each per cycle to increase the number of eligible major procedures captured [22].

The 2005–2010 NSQIP database was queried for patients with a diagnosis of intestinal or peritoneal adhesions with obstruction based on *International Classification of Disease, Ninth Revision* codes (ICD-9 = 560.8) [23]. Patients with this primary diagnosis were cross-referenced with Current Procedural Terminology (CPT) codes to identify patients undergoing open or laparoscopic adhesiolysis for their SBO [24]. Case selection was limited to CPT codes for open adhesiolysis (44005), laparoscopic adhesiolysis (44180), or exploratory laparotomy (49000) with either open or laparoscopic adhesiolysis coded as the other primary procedure. Patients with open (44120) or laparoscopic (44202) small-bowel resection in addition to adhesiolysis were included. Patients with secondary codes for other major gastrointestinal resections (gastrectomy, colectomy, pancreatectomy, hepatectomy) and hernia repair were excluded to keep the population more homogeneous.

Patient demographic characteristics, such as age, sex, and race (white, black, other/unknown), were included in the analysis. Preoperative functional status was related to the patient's ability to perform activities of daily living in the 30 days before surgery and was defined as either dependent or independent. Patient's comorbidities were grouped according to organ system (cardiac, pulmonary, renal, hepatic, neurologic) for analysis. Additional factors considered and grouped categorically were diabetes mellitus requiring oral medication or insulin, body mass index (BMI) >30, >10 % body weight lost in the 6 months preceding surgery, steroid use for chronic conditions, smoking within the past year, chemotherapy within 30 days, radiation within 90 days, disseminated cancer, bleeding disorder, preoperative anemia (hematocrit <36), hypoalbuminemia (albumin <3.5 g/dL), and transfusion >4 U of pRBC in the 72 h before surgery.

Patients with an American Society of Anesthesiologists (ASA) class 3, 4, and 5 were compared categorically to ASA class 1 and 2. A wound class of I (clean) and II (clean contaminated) were grouped and compared to a wound class of III (contaminated) and IV (dirty/infected). Patients were considered to have preoperative systemic inflammatory response syndrome (SIRS) if they had two or more of the following at the same time: temperature >38 °C or <36 °C, heart rate >90 beats/min, respiratory rate >20 breaths/min, white blood cell count >12,000 or <4,000, or anion gap acidosis. Sepsis was considered if the patient had SIRS and a documented infection (positive cultures). Septic shock occurred with documented sepsis and organ or circulatory dysfunction.

Operative characteristics included laparoscopic or open surgery and the presence or absence of a small bowel resection as defined by CPT codes. A case was considered emergent when performed as soon as possible and within 12 h of hospital presentation or development of symptoms. Operative time was recorded in minutes and included as a continuous variable. Postoperative length of stay was also continuous and recorded as days from operation to discharge.

Mortality included any death within 30 days. Postoperative complications occurring within 30 days of surgery were classified as either major or incisional and identified by the affected organ system. This methodology for classification of outcomes has been previously described [21]. Major complications included respiratory (pneumonia, reintubation, or failure to wean from ventilator), cardiac (cardiac arrest requiring CPR, myocardial infarction), renal failure (acute or progressive renal failure), venous thromboembolism (deep venous thrombosis or pulmonary embolism), sepsis or septic shock, organ space infection, neurological (coma >24 h, stroke/cerebrovascular accident), or return to the operating room. Incisional complications included any superficial or deep surgical site infection and wound disruption or dehiscence.

Patient and operative characteristics were compared with 30-day mortality, major complications, and incisional complications using Chi square and Student's *t* tests as appropriate to the data. Factors with a p value <0.1 on univariate analysis were included in the multivariable logistic regression for each outcome. A two-sided p value <0.05 was considered significant. Assignment to operative approach was nonrandom creating the potential for residual confounding due to case selection. A propensity score was utilized in the analysis to adjust for this potential case selection bias. The propensity score was developed through a forward stepwise regression aimed at maximizing predictive ability for a laparoscopic approach using entrance criteria of $p \leq 0.1$ and exit criteria of $p \geq 0.05$ and was assessed using a c-statistic. The propensity score had good predictive ability with a c-statistic = 0.74. Factors included in the propensity score were sex, race, ASA class, BMI >30, hypoalbuminemia, emergency case status, smoking status, steroid use, chemotherapy, radiation, or disseminated cancer, cardiac comorbidity, year of surgery, preoperative sepsis, and small-bowel resection. The propensity score was included as a covariate in the multivariable models for the primary endpoints of mortality and major complications. It did not significantly alter the effect estimate for incisional complications and was thus not included in the final multivariable model. All analyses were performed using IBM SPSS Statistics software, Version 19 (© 2010 SPSS, Inc).

Results

A total of 9,619 patients underwent adhesiolysis between 2005 and 2010. Of these cases, 1,434 (14.9 %) were performed laparoscopically. Patient and operative characteristics are shown in Table 1. The laparoscopic group was more likely to be female, younger, independent in functional status, have a BMI >30, and have fewer preoperative comorbidities and septic events. The mean operative time for laparoscopic adhesiolysis was shorter than for open adhesiolysis (77.2 ± 51.9 vs. 94.2 ± 67.8, $p < 0.0001$). Open operations were more frequently emergent (51.1 vs. 39.3 %, $p < 0.0001$) and required a higher percentage of small bowel resections (31.5 vs. 8.1 %). Mean postoperative length of stay was significantly shorter in the laparoscopic group compared with the open group (4.7 ± 5.8 vs. 9.9 ± 9.1, $p < 0.0001$). Despite differences in the overall laparoscopic and open groups, when these groups were subdivided into quintiles based on their propensity for laparoscopic surgery, they were balanced with respect to patient comorbidities and operative characteristics (see Table 3 in Appendix).

There was a total of 3,282 postoperative complications (incisional, major, and death) within 30-days of surgery affecting 2,548 patients (26.5 % of total group). Table 2 summarizes the rates and composition of 30-day postoperative complications and the crude odds ratios (OD) for laparoscopic versus open surgery. On univariate analysis laparoscopic procedures decreased the relative odds of incisional infection by 84 % and the relative odds of major complication by 61 % compared with open procedures. Differences in major complications between the laparoscopic and open groups were primarily driven by decreased respiratory complications, sepsis or septic shock, organ space infection, and venous thromboembolism in the laparoscopic group. The overall 30-day mortality rate for all patients was 4.2 %. On univariate analysis patients undergoing laparoscopic adhesiolysis had 0.26 times the relative odds of mortality within 30 days compared with patients undergoing open adhesiolysis.

On multivariable analysis, the effect of operative approach on postoperative complications was adjusted for patient and surgical characteristics. Figure 1 displays the adjusted ORs for 30-day mortality, major complications, and incisional complications with the covariates used in each model listed below. The laparoscopic adhesiolysis group had a 49 % reduction in the relative adjusted odds of 30-day mortality compared with the open group (OR = 0.55, 95 % confidence interval (CI) 0.33–0.92, $p = 0.024$). After adjustment, the laparoscopic approach also was independently associated with a significant decrease in postoperative incisional complications (OR = 0.22, 95 % CI 0.15–0.33, $p < 0.0001$) and major complications (OR = 0.7, 95 % CI 0.58–0.85, $p < 0.0001$).

Discussion

This study demonstrated a significant reduction in 30-day mortality, major complications, and incisional complications

Table 1 Patient and operative characteristics by surgical approach

	Total population	Open adhesiolysis	Laparoscopic adhesiolysis	*p*
Patient characteristics				
Total group	9,619	8,185 (85.1)	1434 (14.9)	
Male sex	3,567 (37.1)	3,109 (38)	458 (32)	<0.0001
Mean age, year (±SD)	62.7 (±17.1)	63.5 (±17)	58.2 (±17.3)	<0.0001
Race				
White	7,083 (73.6)	5,927 (72.4)	1,156 (80.6)	<0.0001
Black	1,467 (15.3)	1,328 (16.2)	139 (9.7)	–
Other/unknown	1069 (11.1)	930 (11.4)	139 (9.7)	–
Cardiac comorbidity	1,145 (11.9)	1,002 (12.2)	143 (10)	0.014
Pulmonary comorbidity	933 (9.7)	848 (10.4)	85 (5.9)	<0.0001
Hepatic insufficiency	666 (6.9)	600 (7.3)	66 (4.6)	<0.0001
Renal insufficiency	256 (2.7)	236 (2.9)	20 (1.4)	0.001
Neurological comorbidity	908 (9.4)	813 (9.9)	95 (6.6)	<0.0001
Bleeding disorders	925 (9.6)	833 (10.2)	92 (6.4)	<0.0001
Chemotherapy, radiation, or disseminated cancer[a]	403 (4.2)	379 (4.6)	24 (6)	<0.0001
Diabetes mellitus	1,187 (12.3)	1,057 (12.9)	130 (9.1)	<0.0001
ASA class III, IV, V	5,954 (62)	5309 (65)	645 (45)	<0.0001
Dependent functional status	1,562 (16.2)	1,431 (17.5)	131 (9.1)	<0.0001
BMI $\geq$ 30	1,947 (21.3)	1,577 (20.3)	370 (26.8)	<0.0001
>10 % weight loss in prior 6 months	416 (4.3)	380 (4.6)	36 (2.5)	<0.0001
Current smoker with 1 year	1,948 (20.3)	1,726 (21.1)	222 (15.5)	<0.0001
>2 drinks/day in 2 weeks before surgery	260 (2.7)	232 (2.8)	28 (2)	0.057
Steroids for chronic condition	413 (4.3)	381 (4.7)	32 (2.2)	<0.0001
Preoperative HCT $\leq$ 36	3,425 (36.2)	2,960 (36.7)	465 (33.4)	0.019
Transfusion of >4 units pRBC within 72 h of surgery	33 (0.3)	29 (0.4)	4 (0.3)	0.653
Preoperative sepsis				
None	7,173 (74.6)	5,965 (72.9)	1,208 (84.2)	<0.0001
Sepsis/septic shock	436 (4.5)	413 (5.0)	23 (1.6)	–
SIRS	2,010 (20.9)	1,807 (22.1)	203 (14.2)	–
Wound class III, IV	1,411 (14.7)	1,299 (15.9)	112 (7.8)	<0.0001
Operative characteristics				
Emergency operation	4748 (49.4)	4185 (51.1)	563 (39.3)	<0.0001
Operative time (±SD)	91.7 (±65.9)	94.2 (±67.8)	77.2 (±51.9)	<0.0001
Small bowel resection	2,693 (28.0)	2,577 (31.5)	116 (8.1)	<0.0001
Postoperative length of stay, days (±SD)	9.1 (±8.9)	9.9 (±9.1)	4.7 (±5.8)	<0.0001

Results are presented as number (% of group), unless otherwise indicated

ASA American Society of Anesthesiologists, *HCT* hematocrit, *SIRS* systemic inflammatory response syndrome, *SD* standard deviation

[a] Chemotherapy within past 30 days, radiation therapy within past 90 days

associated with laparoscopic adhesiolysis compared with open adhesiolysis for the treatment of acute SBO. Whereas laparotomy has long been considered the standard of care in patients with SBO requiring operation, a minimally invasive approach to adhesiolysis that could potentially reduce post-operative pain and recovery time is appealing. Still the concern remains whether laparoscopic trocars can be placed safely and the operation executed efficiently without injury to dilated bowel. Notably, we found that this is not a procedure, open or laparoscopic, with low morbidity and mortality. Our overall rates of major complications and 30-day mortality in patients undergoing surgical adhesiolysis were

Table 2 Thirty-day postoperative complications by operative approach

	Total population $n = 9{,}619$	Open adhesiolysis $n = 8{,}185$	Laparoscopic adhesiolysis $n = 1{,}434$	Crude OR with 95 % CI	p
Incisional complication	915 (9.5)	887 (10.8)	28 (2)	0.16 (0.11, 0.24)	<0.0001
Major complication	1,962 (20.4)	1,818 (22.2)	144 (10)	0.39 (0.33, 0.47)	<0.0001
Respiratory	959 (10.0)	920 (11.2)	39 (2.7)	0.22 (0.16, 0.31)	<0.0001
Cardiac	146 (1.5)	137 (1.7)	9 (0.6)	0.37 (0.19, 0.73)	0.003
Organ space infection	274 (2.8)	253 (3.1)	21 (1.5)	0.47 (0.3, 0.73)	0.001
Sepsis/septic shock	873 (9.1)	821 (10.0)	52 (3.6)	0.34 (0.25, 0.45)	<0.0001
Renal failure	137 (1.4)	131 (1.6)	6 (0.4)	0.26 (0.11, 0.59)	<0.0001
VTE	220 (2.3)	207 (2.5)	13 (0.9)	0.35 (0.2, 0.62)	<0.0001
Neurological	42 (0.4)	38 (0.5)	4 (0.3)	0.6 (0.21, 1.68)	0.326
Return to operating room	588 (6.1)	517 (6.3)	71 (5)	0.77 (0.6, 1)	0.047
30-day mortality	405 (4.2)	387 (4.7)	18 (1.3)	0.26 (0.16, 0.41)	<0.0001

Univariate analysis results are presented as number (% within group), except for crude ORs (95 % CI). Patients may have more than one complication

Respiratory complication: pneumonia, reintubation, failure to wean from ventilator for > 48 h; cardiac complication: cardiac arrest requiring CPR or myocardial infarction; renal failure: acute or progressive renal failure; VTE: deep venous thrombosis or pulmonary embolism; neurological complication: coma >24 h, stroke/cerebrovascular accident; incisional complication: superficial or deep surgical site infection, wound disruption

CI confidence interval, *VTE* venous thromboembolic event

20.4 and 4.2 %, respectively. For an operation that is frequently performed across numerous specialties, these numbers likely reflect a notable burden on the healthcare system.

Similarly, Khaikin et al. [7] noted a 45 % postoperative morbidity for patients undergoing laparotomy for acute SBO, and Suter et al. [5] found that conversion from laparoscopic to open adhesiolysis was associated with an increase in postoperative complications from 12.7 to 55.5 % ($p < 0.001$). We found slightly lower rates of overall postoperative morbidity in the open adhesiolysis group with 22.2 % of patients having major complications and 10.8 % reporting incisional complications. Postoperative morbidity from laparoscopic adhesiolysis has been reported between 12.7 and 19.2 % and varies largely based on the complications included in this figure [5, 7, 10, 14, 15, 18, 25]. Our laparoscopic group's complication rate was slightly lower than previously reported rates (10 % major complications and 2 % incisional complications) and had 0.7 times the relative adjusted odds of a major complication and 0.22 times the relative adjusted odds of incisional complication compared with the open group.

This observed marked decrease in complications for laparoscopic cases might well account for much of the reduction in observed 30-day mortality. We found an unadjusted 30-day mortality rate of 4.7 % in the open adhesiolysis group compared with 1.3 % in the laparoscopic adhesiolysis group. Early studies on laparoscopic adhesiolysis quote mortality rates at 2.3 %, rising to 5.5 % in patients requiring conversion to an open procedure [5, 10]. Larger more recent studies are consistent with our findings and have shown mortality for laparoscopic adhesiolysis and open adhesiolysis to be 1.5–1.7 and 3.4 % respectively [18, 26]. With the documented stable rates of ~300,000 yearly operations for SBO during the past two decades in the United States [2], our observed 45 % reduction in the relative adjusted odds of 30-day mortality associated with laparoscopic compared to open adhesiolysis could have a significant impact on both patient outcomes and healthcare system utilization.

The use of laparoscopy for adhesion-related disease is becoming more common, but it still has not been widely adopted. Mancini et al. [26] reported 11.4 % of cases were performed laparoscopically in the NIS database, slightly lower than our findings that 14.9 % of overall operations for adhesiolysis were performed laparoscopically. Given the evolution of training and the increasing comfort of many surgeons with laparoscopic techniques, it is not surprising that our data from 2005 to 2010 may have slightly higher rates than those from 2002. In fact, we noted during the course of 6 years within our data that the

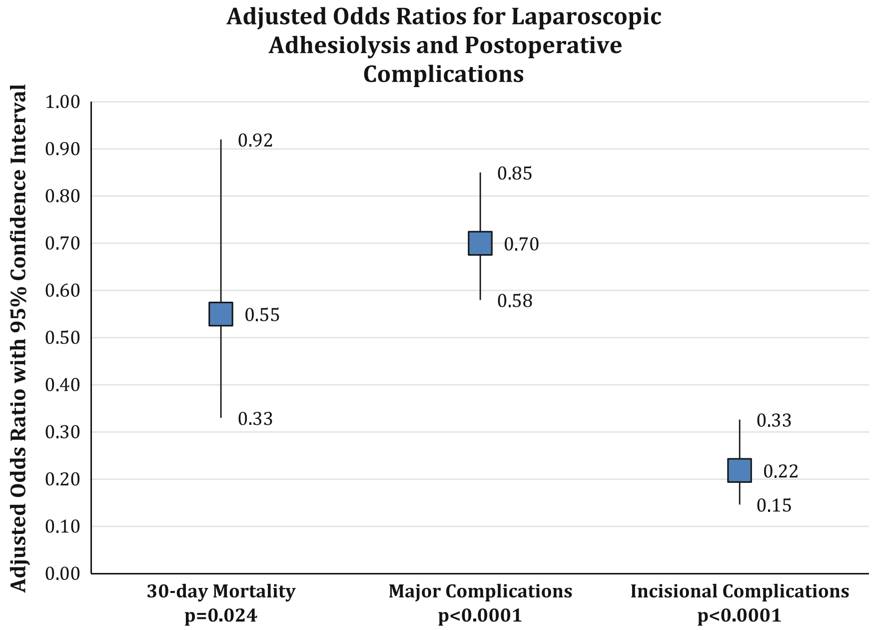

Fig. 1 30-day mortality was adjusted for age, sex, race, patient comorbidities (pulmonary, cardiac, renal, neurologic, hepatic), ASA class, diabetes, bleeding disorders, functional status, preoperative sepsis, steroid use, current smoking status, wound class, anemia, preoperative transfusion, >10 % preoperative weight loss, chemotherapy/radiation/disseminated cancer, BMI >30, operative time, emergency case status, small bowel resection, and propensity for laparoscopy Major complications were adjusted for age, sex, race, patient comorbidities (pulmonary, cardiac, renal, neurologic, hepatic), ASA class, diabetes, bleeding disorders, functional status, preoperative sepsis, steroid use, current smoking status, wound class, anemia, preoperative transfusion, >10 % preoperative weight loss, operative time small-bowel resection, and propensity for laparoscopy incisional complications were adjusted for age, race, pulmonary comorbidities, renal insufficiency, wound class, ASA class, RMI >30, smoking status, bleeding disorders, diabetes, steroid use, operative time, and small bowel resection

laparoscopic rate went from 4.8 % in 2005 to 17.3 % in 2010.

It is important to recognize several of the limitations of this study and the NSQIP database. Given that assignment to the laparoscopic group was nonrandom, there is concern that overall healthier individuals are more likely to be selected for laparoscopic surgery than their debilitated, sicker counterparts. We noted that patients undergoing laparoscopic adhesiolysis were more likely to be younger, female, healthier (lower ASA score, fewer comorbidities), and have less preoperative sepsis. A propensity score was created and utilized to address this selection bias. When patients were grouped into quintiles based on their propensity score the groups were similar with respect to patient and operative characteristics. Additionally, the propensity score slightly reduced the multivariable model effect estimates for mortality and major complications further suggesting this study did control for some baseline differences between the laparoscopic and open cases. Regardless, the fact that we cannot control for all selection bias or completely characterize the surgeon's operative approach algorithm must be acknowledged in this study. NSQIP does not provide surgeon or hospital specific data, so the individual surgeon's experience, level of ability, and referral or practice patterns are unavailable. It is conceivable that surgeons who are more skilled and comfortable with laparoscopy or institutions with readily available laparoscopic equipment and staff comfortable with the techniques are the ones undertaking laparoscopic adhesiolysis. This could potentially improve the outcomes in this group, but this cannot be quantified by this database. O'Connor et al. [18] report a conversion rate of 29 % in their systematic review, ranging from 6 to 73 % in the literature; however, based solely on NSQIP coding we are unable to identify accurately cases of conversion from laparoscopic to open. Additionally, this study was unable to capture rates of intraoperative and missed enterotomies, as these variables are not available in NSQIP. Finally, the sampling strategy of NSQIP only captures a small proportion of cases at participating hospitals, so these results may not be widely generalizable.

Despite these limitations, this study remains the largest to date examining the differences in postoperative outcomes between patients undergoing open and laparoscopic adhesiolysis. Our rich clinical data on patient comorbidities, operative factors, and 30-day outcomes allows us to risk adjust for numerous factors that have not been previously considered. We observed a significant reduction in postoperative complications, mortality, and postoperative length of stay with the laparoscopic approach. These results align with much of the current literature suggesting that in the appropriately selected patient, laparoscopy can be a safe, feasible, and potentially beneficial way to approach acute adhesion-related SBOs. Given the high cost and widespread, stable prevalence in the United States, more studies should explore specifically when laparoscopy should be used in acute adhesive SBO.

Acknowledgments None.

Disclosures Drs. Kristin Kelly, James Iannuzzi, Aaron Rickles, Veerabhadram Garimella, John R.T. Monson, and Fergal Fleming have no conflict of interest or financial ties to disclose.

Appendix

See Table 3.

Table 3 Patient and operative characteristics by propensity quartile and surgical approach

	1			2			3		
	Open	Laparoscopic	*p*	Open	Laparoscopic	*p*	Open	Laparoscopic	*p*
Total group	1,858 (96.6)	66 (3.4)		1812 (94.2)	112 (5.8)		1,684 (87.5)	240 (12.5)	
Male sex	805 (43.4)	27 (40.9)	0.689	728 (40.2)	61 (54.5)	0.003	694 (41.3)	103 (42.9)	0.626
Mean age, years (±SD)	68.8 ± 15.4	67.7 ± 14.7	0.55	65.4 ± 16.1	68.9 ± 14.9	0.028	65.9 ± 16.4	67.4 ± 16.8	0.171
Race									
White	1,155 (66.8)	42 (67.7)	0.207	1,191 (72.5)	76 (73.1)	0.203	1,209 (77.5)	192 (83.8)	0.051
Black	486 (28.1)	14 (22.6)	–	369 (22.5)	19 (18.3)	–	278 (17.8)	26 (11.4)	–
Other/Unknown	87 (5)	6 (9.7)	–	83 (5.1)	9 (8.7)	–	73 (4.7)	11 (4.8)	–
Cardiac comorbidity	262 (14.1)	11 (16.7)	0.557	244 (13.5)	15 (13.4)	0.982	214 (12.7)	30 (12.5)	0.928
Pulmonary comorbidity	334 (18)	11 (16.7)	0.785	233 (12.9)	16 (14.3)	0.662	165 (9.8)	25 (10.4)	0.764
Hepatic insufficiency	181 (9.7)	6 (9.1)	0.861	141 (7.8)	12 (10.7)	0.266	129 (7.7)	19 (7.9)	0.891
Renal insufficiency	91 (4.9)	2 (3)	0.486	74 (4.1)	5 (4.5)	0.844	41 (2.4)	8 (3.3)	0.408
Neurological comorbidity	258 (13.9)	7 (10.6)	0.447	230 (12.7)	15 (13.4)	0.829	173 (10.3)	34 (14.2)	0.069
Bleeding disorders	247 (13.3)	5 (7.6)	0.176	213 (11.8)	15 (13.4)	0.603	168 (10)	28 (11.7)	0.418
Chemotherapy, radiation, or disseminated cancer[a]	181 (9.7)	8 (12.1)	0.523	127 (7)	10 (8.9)	0.443	60 (3.6)	3 (1.2)	0.06
Diabetes mellitus	275 (14.8)	9 (13.6)	0.793	268 (14.8)	17 (15.2)	0.911	252 (15.0)	23 (9.6)	0.026
ASA class III, IV, V	1,640 (88.3)	54 (81.8)	0.109	1,290 (71.3)	82 (73.2)	0.665	1,235 (73.3)	183 (76.6)	0.288
Dependent functional status	508 (27.4)	9 (13.6)	0.013	376 (20.8)	21 (18.8)	0.61	297 (17.6)	52 (21.7)	0.130
BMI ≥ 30	225 (13)	9 (14.3)	0.768	308 (17.8)	12 (11.2)	0.08	289 (18.3)	35 (15.3)	0.256
>10 % weight loss in prior 6 months	140 (7.5)	3 (4.5)	0.363	95 (5.2)	4 (3.6)	0.437	61 (3.6)	13 (5.4)	0.176
Current smoker with 1 year	546 (29.4)	13 (19.7)	0.088	427 (23.6)	28 (25)	0.729	369 (21.9)	55 (22.9)	0.725
>2 drinks/day in 2 weeks before surgery	68 (3.7)	2 (3.0)	0.788	64 (3.5)	4 (3.6)	0.983	46 (2.7)	6 (2.5)	0.836
Steroids for chronic condition	154 (8.3)	3 (4.5)	0.275	121 (6.7)	11 (9.8)	0.202	65 (3.9)	12 (5.0)	0.399
Preoperative HCT ≤36	785 (42.9)	30 (46.9)	0.525	724 (40.6)	50 (45.9)	0.28	608 (36.5)	86 (36.0)	0.883
Transfusion of >4 units pRBC within 72 h of surgery	15 (0.8)	1 (1.5)	0.534	6 (0.3)	0 (0)	0.542	3 (0.2)	0 (0)	0.513
Preoperative sepsis									
None	1,038 (55.9)	40 (60.6)	0.746	1,211 (66.8)	73 (65.2)	0.635	1,235 (73.3)	158 (65.8)	0.051
Sepsis/septic shock	247 (13.3)	8 (12.1)	–	110 (6.1)	5 (4.3)	–	40 (2.4)	7 (2.9)	–

Table 3 continued

	1			2			3		
	Open	Laparoscopic	*p*	Open	Laparoscopic	*p*	Open	Laparoscopic	*p*
SIRS	573 (30.8)	18 (27.3)	–	491 (27.1)	34 (30.4)	–	409 (24.3)	75 (31.2)	–
Wound class III, IV	642 (34.6)	15 (22.7)	0.046	314 (17.3)	16 (14.3)	0.407	148 (8.8)	26 (10.8)	0.301
Emergency operation	1200 (64.6)	32 (48.5)	0.007	979 (54)	57 (50.9)	0.518	959 (56.9)	137 (57.1)	0.968
Operative time (±SD)	119.3 ± 76.5	106.9 ± 52.7	0.193	102.3 ± 73	94.8 ± 49.6	0.281	81.5 ± 60.6	75.7 ± 54.8	0.162
Small bowel resection	1649 (88.8)	61 (92.4)	0.351	792 (43.7)	39 (34.8)	0.065	133 (7.9)	15 (6.2)	0.370

	4			5		
	Open	Laparoscopic	*p*	Open	Laparoscopic	*p*
Total group	1,545 (80.3)	380 (19.7)		1286 (66.9)	636 (33.1)	
Male sex	550 (35.7)	128 (33.7)	0.469	332 (25.9)	139 (21.9)	0.059
Mean age, year (±SD)	61.5 ± 16.6	60.3 ± 17.1	0.236	52.3 ± 16	50.7 ± 14.5	0.03
Race						
White	1221 (85.2)	294 (82.8)	0.439	1151 (93.7)	552 (92.6)	0.067
Black	148 (10.3)	45 (12.7)	–	47 (3.8)	35 (5.9)	–
Other/unknown	64 (4.5)	16 (4.5)	–	30 (2.4)	9 (1.5)	–
Cardiac comorbidity	187 (12.1)	50 (13.2)	0.575	95 (7.4)	37 (5.8)	0.2
Pulmonary comorbidity	87 (5.6)	22 (5.8)	0.905	29 (2.3)	11 (1.7)	0.448
Hepatic insufficiency	93 (6.0)	16 (4.2)	0.172	56 (4.4)	13 (2)	0.01
Renal insufficiency	25 (1.6)	3 (0.8)	0.227	5 (0.4)	2 (0.3)	0.799
Neurological comorbidity	111 (7.2)	23 (6.1)	0.437	41 (3.2)	16 (2.5)	0.414
Bleeding disorders	137 (8.9)	28 (7.4)	0.35	68 (5.3)	16 (2.5)	0.005
Chemotherapy, radiation, or disseminated cancer[a]	10 (0.6)	2 (0.5)	0.788	1 (0.1)	1 (0.2)	0.611
Diabetes mellitus	185 (12.0)	46 (12.1)	0.944	77 (6.0)	35 (5.5)	0.67
ASA class III, IV, V	871 (56.4)	208 (54.7)	0.556	273 (21.3)	118 (18.6)	0.158
Dependent functional status	181 (11.7)	33 (8.7)	0.092	69 (5.4)	16 (2.5)	0.004
BMI ≥ 30	358 (24.2)	81 (22.3)	0.426	397 (32.0)	233 (37.8)	0.013
>10 % weight loss in prior 6 months	50 (3.2)	6 (1.2)	0.085	34 (2.6)	10 (1.6)	0.139
Current smoker with 1 year	244 (15.8)	63 (16.6)	0.708	140 (10.9)	63 (9.9)	0.51
>2 drinks/day in 2 weeks before surgery	35 (2.3)	8 (2.1)	0.85	19 (1.5)	8 (1.3)	0.7
Steroids for chronic condition	33 (2.1)	6 (1.6)	0.49	8 (0.6)	0 (0)	0.046
Preoperative HCT ≤36	466 (30.5)	127 (340)	0.198	377 (29.9)	172 (28.4)	0.508
Transfusion of >4 Units pRBC within 72 h of surgery	3 (0.2)	2 (0.5)	0.254	2 (0.2)	1 (0.2)	0.993
Preoperative sepsis						
None	1,268 (82.1)	335 (88.2)	0.016	1,213 (94.3)	602 (94.7)	0.601
Sepsis/septic shock	14 (0.9)	3 (0.8)	–	2 (0.2)	0 (0)	–
SIRS	263 (17.0)	42 (11.1)	–	71 (5.5)	34 (5.3)	–
Wound class III, IV	111 (7.2)	27 (7.1)	0.957	84 (6.5)	28 (4.4)	0.061
Emergency operation	717 (46.4)	195 (51.3)	0.086	330 (25.7)	142 (22.3)	0.11
Operative time (±SD)	78.7 ± 54.1	70.6 ± 44.7	0.007	81.7 ± 57.3	75.6 ± 53.6	0.026
Small bowel resection	3 (0.2)	1 (0.3)	0.791	0	0	–

Propensity quintiles: 1 = least likely to have laparoscopic surgery; 5 = most likely to have laparoscopic surgery

Results are presented as number (% of group), unless otherwise indicated

ASA American Society of Anesthesiologists; *HCT* hematocrit; *SIRS* systemic inflammatory response syndrome; *SD* standard deviation

[a] Chemotherapy within last 30 days, radiation therapy within last 90 days

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