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ORIGINAL SCIENTIFIC REPORT

Disease Severity and Cost in Adhesive Small Bowel Obstruction

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Abstract

Background Adhesive small bowel obstruction (ASBO) severity has been associated with important clinical outcomes. However, the impact of ASBO severity on hospitalization cost is unknown. The American Association for the Surgery of Trauma (AAST) developed an Emergency General Surgery (EGS) disease severity grading system for ASBO. We stratified patients' ASBO severity and captured hospitalization costs hypothesizing that increased disease severity would correlate with greater costs.

Methods This was a single-center study of hospitalized adult patients with SBO during 2015–2017. Clinical data and estimated total cost (direct + indirect) were abstracted. AAST EGS grades (I–IV) stratified disease severity. Costs were normalized to the median grade I cost. Univariate and multivariate analyses evaluated the relationship between normalized cost and AAST EGS grade, length of hospital and ICU stay, operative time, and Charlson comorbidity index.

Results There were 214 patients; 119 (56%) were female. AAST EGS grades included: I (62%, $n = 132$), II (23%, $n = 49$), III (7%, $n = 16$), and IV (8%, $n = 17$). Relative to grade I, median normalized cost increased by 1.4-fold for grade II, 1.6-fold for grade III, and 4.3-fold for grade IV disease. No considerable differences in patient comorbidity between grades were observed. Pair-wise comparisons demonstrated that grade I disease cost less than higher grades (corrected $p < 0.001$). Non-operative management was associated with lower normalized cost compared to operative management (1.1 vs. 4.5, $p < 0.0001$). In patients who failed non-operative management, normalized cost was increased 7.2-fold. Collectively, the AAST EGS grade correlated well with cost (Spearman's $p = 0.7$, $p < 0.0001$). After adjustment for covariates, AAST EGS grade maintained a persistent relationship with cost.

Conclusion Increasing ASBO severity is independently associated with greater costs. Efforts to identify and mitigate costs associated with this burdensome disease are warranted.

Level of evidence III, economic/decision.

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Introduction

Adhesive small bowel obstruction (ASBO) is an emergency general surgery (EGS) disease with considerable healthcare burden [1]. Management is based on small bowel integrity and consists of decompression with or without enteric contrast administration or adhesiolysis with or without bowel resection and anastomosis [2]. Recently, ASBO has been shown to account for a sizeable proportion of annual EGS operations and hospitalization costs in the USA [3]. Although costs related to ASBO have been found to be higher than previously estimated [4], these findings have not accounted for the heterogeneity of ASBO severity. Further, costs of ASBO may be influenced by the management modality and provider, which can impact the timing of operation and, by extension, disease severity at the time of intervention.

ASBO can be defined as partial or complete; however, binary classification limits equitable comparisons of outcomes and management across patient populations and healthcare systems. The American Association for the Surgery of Trauma (AAST) developed an EGS grading system which facilitates disease severity categorization based on clinical, radiologic, operative, or pathologic criteria [5]. Application of the AAST EGS grade demonstrates that disease severity was associated with relevant clinical outcomes and therapeutic strategies in large multi-institutional datasets both in the USA and globally [6, 7]. In this study, we performed a cost analysis in patients with varying degrees of ASBO. We hypothesized that total hospitalization costs (combined indirect and direct costs of hospitalization) from admission to dismissal would be associated with increasing disease severity as defined by the AAST EGS grading system.

Methods

This was a single institution retrospective review undertaken by the authors. Institutional review board approval was obtained prior to initiating the investigation, and the requirement for informed consent was waived.

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Patient cohort

Patients were identified from an institutional small bowel obstruction database. Adults ($\geq$ 18 years old) diagnosed with ASBO during 2015–2017 were included. ASBO was diagnosed using cross-sectional computed tomography. The diagnosis was made when dilated loops of small bowel with a transition point were present in the clinical setting of nausea, vomiting, abdominal pain with distension. The following exclusion criteria were applied: presence of external/internal hernia, a history of abdominopelvic malignancy, and a laparoscopic or open abdominal exploration within the preceding 6 weeks.

Patient characteristics, management, and outcomes

The following characteristics were extracted from institutional records including patient demographics, previous operative management, prior admission for ASBO, and previous history of open abdomen therapy or temporary abdominal closure. At the time of admission, data regarding physiologic parameters, laboratory findings, overall degree of organ dysfunction (normal, systemic inflammatory response syndrome, sepsis, multiple organ dysfunction) as defined by sepsis criteria [8], and days of obstipation were collected. Management was recorded, and this included non-operative management utilizing nasogastric decompression (with or without enteric contrast administration) or operation (adhesiolysis with or without bowel resection and anastomosis). Patients who failed non-operative management were defined as no contrast in colon after enteric contrast administration or worsening abdominal examination. Hospital duration of stay and need for intensive care utilization were recorded. Development of any complication including acute kidney injury (increase in serum creatinine level threefold from baseline), surgical site infection (superficial, deep, or organ space), and anastomotic complication (leak or dehiscence) was captured.

AAST EGS grade

The AAST EGS grade is a set of proposed disease severity definitions based on clinical, radiologic, operative, and pathologic criteria [5]. It demonstrates construct validity in populations with ASBO [6, 7]. Revised definitions of disease severity are seen in Table 1. AAST EGS grades were assigned based on radiologic and, in patients who underwent surgery, operative findings. Clinical data were not considered in grade determination due to lack of standardized, prospective capture of symptoms in the hospital record. Pathological criteria were also not utilized as the

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Table 1 American Association for the Surgery of Trauma grading system for adhesive small bowel obstruction

AAST grade	Description	Clinical criteria	Pathologic criteria
I	Partial SBO	Some flatus; normal or hypoactive bowel sounds; minor abdominal distention	N/A
II	Complete SBO; bowel viable and not compromised	Minimal to no flatus; hypoactive bowel sounds; distension without generalized tenderness	N/A
III	Complete SBO with compromised, but viable bowel	No flatus; absent bowel sounds; abdominal distension with localized tenderness	N/A
IV	Complete SBO with non-viable bowel or perforation with peritoneal contamination	Obstipation; abdominal distension with diffuse tenderness, rebound, guarding abdominal distension with evidence of peritonitis	Bowel gangrene or perforation
AAST grade	Description	Imaging criteria (CT findings)	Operative criteria
I	Partial SBO	Normal imaging or minimal intestinal distension	Minimal intestinal distension with no evidence of bowel obstruction
II	Complete SBO; bowel viable and not compromised	Intestinal distension with transition point; delayed contrast flow with some distal contrast; no evidence of bowel compromise	Intestinal distention with transition point; no evidence of bowel compromise
III	Complete SBO with compromised, but viable bowel	Intestinal distension with transition point and no distal contrast flow; evidence of complete obstruction or impending bowel compromise	Intestinal distention with impending bowel compromise
IV	Complete SBO with non-viable bowel or perforation with peritoneal contamination	Evidence of localized perforation or free air; bowel distension with free air or free fluid	Intestinal distension with perforation and diffuse peritonitis

AAST American Association for the Surgery of Trauma, *CT* computed tomography, *SBO* small bowel obstruction

discrimination of severity notably due to lack of bowel resection and available specimens for lower disease severity grades.

Cost of hospitalization

The primary outcome was the total cost of a patient's hospitalization. This included internal cost of services provided to patients, including direct and indirect ("overhead") costs. This was calculated as the sum of all direct and indirect costs that were the result of resource utilization from hospital admission to dismissal. We elected to use the total cost of care, as opposed to the total charged or billed for care, because cost is considered a more accurate measure of expenses incurred. Total hospitalization costs were utilized as this was the most reliable surrogate for burden incurred by the disease available. Further, total hospitalization cost more accurately accounts for the indirect utilization of resources related to a patient's care than direct cost alone (i.e., the direct cost of a bag of saline ignores the costs of storage). The total hospital cost incurred by each patient was divided by the median cost of AAST grade I disease to produce a "normalized" cost that complies with institutional policies that restrict the reporting of cost. The association of cost with predictors such as Charlson comorbidity index [9] and length of hospital stay was evaluated secondarily.

Statistical analysis

Patients were stratified by AAST disease severity grade. All normally distributed continuous variables were described using means with standard deviation (SD). Continuous variables with gross skewness were reported using a median with interquartile range (IQR). Study of the relationship between AAST EGS grade and covariates was accomplished using the Cochran–Armitage test for trend and linear regression. The relationship between cost and predictors was evaluated using linear regression or one-way analysis of variance where appropriate. When the assumptions of linear regression were not met, Spearman's Rho and Theil–Sen estimator of fit were used. Similarly, a Kruskal–Wallis test was utilized when the assumptions of one-way analysis of variance were unmet. Individual pair analyses were performed using two-sample hypothesis testing, and alpha was adjusted for multiple comparisons using a Bonferroni correction. All data analyses were performed using JMP Pro 13 (SAS Institute Inc.) with alpha set at 0.05. Figures were generated using GraphPad Prism 7 (©2017 GraphPad Software, Inc.).

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Results

In this study, 214 patients were reviewed. Among these, 119 (56%) were female and the median age was 70 [57–78] years. The median BMI was 28.1 [24–34.7] kg/m^2. The median Charlson comorbidity index was 4 [2–7]. Disease severity as measured by the radiologic AAST EGS grade included: I (62%, $n = 132$), II (23%, $n = 49$), III (7%, $n = 16$), and IV (8%, $n = 17$). Patient characteristics, physiologic parameters, management approach, and clinical outcomes stratified by the AAST EGS grade are presented in Tables 2 and 3.

Costs of hospitalization varied by AAST EGS grade. For grade I, the median normalized cost was 1.1 [0.6–1.5], for grade II 3.4 [1.4–7.8], for grade III 3.6 [1.9–6.2], and for grade IV 4.6 [1.1–19.2]. Relative to grade I, median normalized cost increased by threefold for grade II, 3.3-fold for grade III, and 4.2-fold for grade IV disease (Fig. 1). Pair-wise comparisons demonstrated that grade I disease cost was less than higher grades (corrected $p < 0.001$). There were no differences in median normalized cost between grades II, III, and IV. Collectively, the AAST EGS grade correlated well with cost (Spearman's $p = 0.7$, $p < 0.001$). Cost was estimated to increase by 0.14 per increase in AAST EGS grade (Spearman's $p = 0.30$; $p < 0.0001$) (Fig. 1). Patients with low disease severity (grade I) accounted for the lowest variation in cost but the greatest proportion of total hospitalization costs at 62%

Table 2 Cohort characteristics by AAST grade

	I ($n = 132$)	II ($n = 49$)	III ($n = 16$)	IV ($n = 17$)	p
Age, years, median (IQR)	69.5 (57–79)	65 (55–78)	72 (55–79)	72 (59–77)	0.72
Charlson index, *n* (%)					
0	10 (7.5)	7 (14.3)	1 (6.3)	0 (0)	0.65
1	13 (9.9)	4 (8.2)	2 (12.5)	2 (11.8)	
≥ 2	109 (82.6)	38 (77.5)	13 (81.2)	15 (88.2)	
Development of complications *n* (%)	12 (9)	4 (8)	2 (12.5)	5 (22)	0.04
Length of hospital stay, days, median (IQR)	2 (1–6)	3 (2–5)	5 (2–10)	8 (2–19)	0.003
Gastrografin administration, *n* (%)	90 (69)	24 (49)	9 (56)	5 (35)	0.02
Operative approach, *n* (%)					
Laparoscopy	14 (33)	8 (25)	1 (14.3)	0 (0)	0.0001
Laparoscopy converted to laparotomy	7 (17)	11 (34)	4 (57)	2 (17)	
Laparotomy	21 (50)	13 (41)	2 (28.7)	10 (83)	
Operative time, minutes, *median (IQR)*	42 (25–59)	68 (46–89)	109 (59–133)	134 (82–226)	< 0.0001
Presentation					
Obstipation duration, days, *median (IQR)*	0 (0–1)	0 (0–1)	1 (0–1)	2 (0–10)	0.06
Presence of peritonitis, *n* (%)	1 (0.8)	5 (10)	2 (12.5)	5 (30)	0.001
Heart rate, bpm, *median (IQR)*	77 (66–82)	82 (70–94)	84 (75–96)	90 (78–100)	0.08
Temperature, C, *median (IQR)*	37 (37)	37 (37)	37 (37)	37 (37)	0.61
Sex, female, *n* (%)	71 (54)	31 (63)	9 (56)	8 (47)	0.60

Patient characteristics, procedural parameters are stratified by AAST EGS grade in the table

Table 3 Outcomes by AAST grade

	I ($n = 132$)	II ($n = 49$)	III ($n = 16$)	IV ($n = 17$)	p
Bowel resection and anastomosis, *n* (%)	7 (5.3)	7 (14.2)	3 (19)	11 (65)	0.0001
Open abdomen therapy, *n* (%)	7 (5.3)	4 (8.1)	2 (12.5)	4 (24)	0.0001
Diffuse peritoneal contamination, *n* (%)	0 (0)	2 (4)	3 (18.7)	5 (29.4)	0.002
Intensive care unit admission, *n* (%)	8 (6.1)	7 (14.2)	3 (18.7)	7 (41)	0.0001
Acute kidney injury, *n* (%)	6 (4.5)	3 (6.1)	1 (6.2)	4 (24)	0.03
Pneumonia, *n* (%)	3 (2.2)	3 (6.1)	1 (6.2)	1 (5.8)	0.56
Total parental nutrition, *n* (%)	9 (6.8)	9 (18.4)	3 (18.7)	6 (35.2)	0.003

Patient clinical outcomes are stratified by AAST EGS grade in the table

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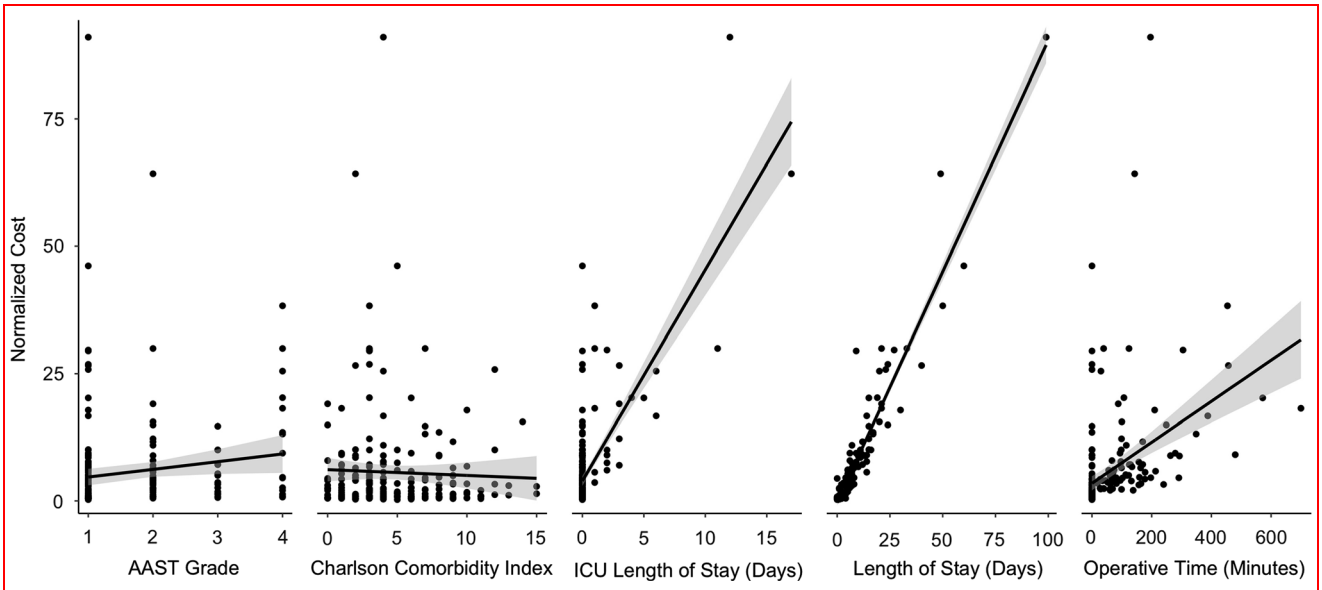

Fig. 1 Linear regression of normalized cost and covariates. Nonparametric, linear regression of normalized cost by AAST EGS grade ($p = 0.30$), duration of hospital stay ($p = 0.92$), operative duration ($p = 0.66$), and age-adjusted Charlson comorbidity index ($p = 0.02$). The region surrounding each fitted line represents the 95% CI

compared to grade II (23%), grade III (8%), and grade IV (7%).

Cost was also associated with several indices and clinical outcomes. Normalized costs were increased when patients were managed by a medical team in comparison with a surgical team (3.3 vs. 2, $p = 0.05$). In patients managed by medical teams compared to surgical teams, however, there was no difference in median age-adjusted Charlson comorbidity index (6 [2–9] compared to 4 [2–7], $p = 0.22$) and median duration of stay was increased (7 [1.5–17] vs. 3 [1–7] days, $p = 0.04$). In patients who received non-operative management, either nasogastric decompression ($n = 22$) or nasogastric decompression and enteric contrast administration ($n = 128$), median total hospitalization costs were higher in the nasogastric decompression alone (1.5 [0.7–7.7] vs. 0.8 [0.5–1.4], $p = 0.004$) and the median duration of stay was prolonged (3 [1–9] vs. 2 [1–3] days, $p = 0.009$).

The rates of operation for each AAST EGS grade were I (31.8%), II (65%), III (45%), and IV (71%). Non-operative management was associated with lower normalized cost compared to operative management (1.1 vs. 4.5, $p < 0.0001$). In patients who failed non-operative management (defined as no contrast in colon after enteric contrast administration or worsening abdominal examination) and subsequently required an operation, normalized total hospital costs were increased 7.2-fold. Moreover, there was a 1.5-fold increase in median costs in patients who underwent laparotomy compared to laparoscopy. Figure 2 demonstrates the differences in median cost

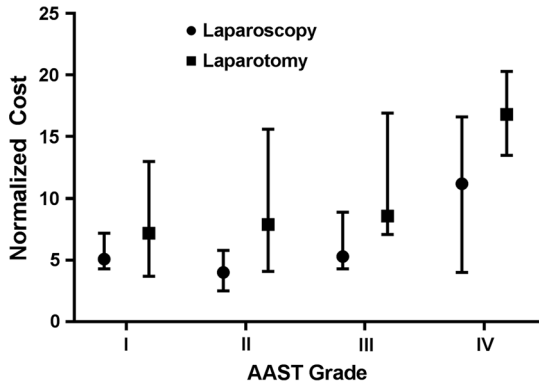

Fig. 2 Comparison of costs by AAST grade (I–IV) for laparoscopy and laparotomy. Grade IV contains cost of patients who attempted laparoscopy but required conversion to an open procedure

between laparoscopy and laparotomy for each AAST grade. Grade IV patients as shown in Fig. 2 are those who required laparoscopy but converted to an open procedure. Those patients who required intensive care utilization demonstrated higher median normalized costs (16.7 [8.2–28.1]) in comparison with those who did not (1.5 [0.8–4.2]), $p = 0.001$. Cost was not associated with age-adjusted Charlson comorbidity index (Spearman's $p = 0.02$; $p = 0.7$), but was strongly associated with length of hospital stay (Spearman's $p = 0.92$; $p < 0.0001$), operative duration (Spearman's $p = 0.67$; $p < 0.0001$), and intensive care unit duration of stay (Spearman's $p = 0.45$; $p < 0.0001$). Further, in patients that developed a

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Table 4 Multivariable regression that identifies factors predictive of total hospitalization costs

Characteristic	Estimate	95% CI	*P* value
Duration of hospital stay (days)	0.73	0.71–0.74	< 0.001
Intensive care unit stay (days)	1.4	1.2–1.4	< 0.001
Operative duration (min)	0.0008	− 0.001 to 0.002	0.38
Charlson comorbidity index	− 0.001	− 0.04 to 0.04	0.94
AAST EGS grade			
I	Reference		
II	0.67	0.25–1.1	< 0.001
III	0.72	0.1–1.4	0.02
IV	1.03	0.3–1.8	0.006

complication ($n = 23$), the median normalized total hospital costs were overwhelmingly higher in comparison with those that did not (1.8 vs. 9.0, $p < 0.0001$). Finally, after adjustment for covariates, regression demonstrated a persistent relationship between AAST EGS grade and cost (Table 4).

Discussion

This study evaluated total hospitalization costs in patients with ASBO and utilized the AAST EGS grade to stratify disease severity. Several factors were strong predictors of cost, notably hospital duration of stay and operative time as well as increasing ASBO severity. These factors are likely inter-related given that worse disease severity may necessitate operation which can in turn prolong hospital duration of stay. We interpret these data to be utilized to identify patients with potentially higher costs based on disease severity.

ASBO can be a relapsing disease [10]. As a result, patients are at an increased risk for prolonged hospital admission, operation, and complication or malnutrition which can impact costs [11]. Krielen et al. determined that inpatient costs were directly related to duration of hospital stay, surgical management, need for intensive care, and utilization of total parental nutrition [4]. The present study echoes similar predictors of cost but also that incremental change in patient disease severity contributed to total hospitalization costs. By understanding the impact of disease severity, hospital expenditures might be better compared and reimbursement strategies improved for patients with ASBO [12].

In this study, the normalized total hospitalization costs for patients managed on a medical service were higher in comparison with a surgical service. We confirm the findings outlined by Aquina et al. which determined that medical teams managing patients with ASBO had greater healthcare utilization [13] and also the results of Malangoni et al. [14]. Similarly, Bilderback et al. suggested but did not render conclusive the hypothesis that patients managed by surgical teams had reduced healthcare expenditures [15]. This was likely due to high ASBO heterogeneity, which the present study accounted for by using the AAST EGS grading system. In fact, the rates of surgery were higher for patients with grade II disease compared to grade III disease in this study. This likely can be accounted for differences in patient selection for operation and failure of non-operative therapy. Despite the differences in healthcare utilization between medical and surgical teams, we recommend early surgical consultation in patients with ASBO or management of all patients with ASBO by surgical teams in the effort to mitigate costs attributed to the need for early surgical intervention, failure of non-operative therapy, and avoidance of costly complications.

Scott et al. estimated the burdens of EGS diseases and determined that ASBO was a considerable contributor to both morbidity and mortality [3]. Hospitals that care for patients with ASBO are likely to incur increasing cost due to changes in population and increasing rates of emergency general surgery operations [16]. Moreover, ASBO comprises a significant proportion of healthcare costs nationally, but is region-dependent [17]. This study's information encourages providers to estimate severity early in order to anticipate hospitalization costs. One method to minimize costs is to minimize the extent of operation by utilizing laparoscopy or non-operative therapy. Patients who underwent laparoscopy demonstrated lower total hospitalization costs compared to those who underwent laparotomy. While laparoscopy appeared effective in patients with lower disease severity, as AAST EGS grade increased, the rates of laparoscopy decreased and the rates of laparoscopic conversion to laparotomy increased. This highlights the difficulty and severity of ASBO in patients and the impact on total hospitalization costs. Laparoscopy, however, demonstrated a 1.5 times reduction in total hospitalization costs and might be best utilized in patients with disease severity and clinical characteristics amenable to

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this approach. Laparoscopic management of ASBO may reduce duration of stay and total hospitalization costs, but early diagnosis, careful patient selection, and minimally invasive skills are necessary [18]. In an international, randomized multicenter trial, Sallinen et al. found that for well-selected patients (likely a single adhesive band) laparoscopy was found to be associated with reduced duration of hospital stay and quicker return of bowel function as well as reduced opioid utilization compared to patients who underwent laparotomy [19]. Furthermore, patients who underwent non-operative management for lower disease severity demonstrated the lowest total hospitalization costs, suggesting the need for early diagnosis and a trial of enteric contrast administration for the appropriate patient.

This study demonstrates referral bias which might select for patients with variable physiologic status, comorbidities, or disease severity which can impact management and total hospitalization costs. ASBO may not be managed uniformly and therefore require referral for definitive management. This study was not able to report whole dollar amounts due to institutional policy, and therefore, direct comparisons regarding costs, management, and outcomes may be obscured. Nevertheless, we recommend utilization of ASBO AAST EGS grading system in order to better classify disease severity. Despite these limitations, estimating disease severity utilizing the AAST EGS grade might better guide hospital expenditures and improve cost containment by applying non-operative therapy to well-selected patients.

Conclusion

Increasing ASBO severity is independently associated with greater costs. Non-operative therapy may minimize some of the costs associated with open adhesiolysis. Patients with ASBO might be best managed with a surgical team, and total hospitalization costs appeared to be less in comparison with those managed by a medical team. The practicality of utilizing disease severity for adjustment of outcomes and costs is important and informs interventions aimed at reducing cost. Further efforts to identify and mitigate costs associated with this burdensome disease are warranted.

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Compliance with ethical standards

Conflict of interest All the authors declare that they have no conflict of interest.

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