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ABOUT COVER

Editorial Board Member of *World Journal of Gastroenterology*, Dirk Jacob van Leeuwen, MD, PhD, FAASLD, Adjunct Professor, Section of Gastroenterology and Hepatology, Geisel School of Medicine at Dartmouth College, Hanover, NH 03756, United States. dirk.j.vanleeuwen@gmail.com

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ORIGINAL ARTICLE

Retrospective Cohort Study

Comprehensively evaluate the short outcome of small bowel obstruction: A novel medical-economic score system

Wei-Xuan Xu, Qi-Hong Zhong, Yong Cai, Can-Hong Zhan, Shuai Chen, Hui Wang, Peng-Sheng Tu, Wen-Xuan Chen, Xian-Qiang Chen, Jun-Rong Zhang

Wei-Xuan Xu, Qi-Hong Zhong, Yong Cai, Can-Hong Zhan, Shengli Clinical Medical College, Fujian Medical University, Fuzhou 350122, Fujian Province, China

Shuai Chen, Hui Wang, Peng-Sheng Tu, Wen-Xuan Chen, Xian-Qiang Chen, Jun-Rong Zhang, Department of General Surgery (Emergency Surgery), Fujian Medical University Union Hospital, Fuzhou 350001, Fujian Province, China

Corresponding author: Jun-Rong Zhang, MD, Attending Doctor, Chief Doctor, Surgeon, Surgical Oncologist, Department of General Surgery (Emergency Surgery), Fujian Medical University Union Hospital, No. 29 Xinquan Road, Fuzhou 350001, Fujian Province, China. junrongzhang@fjmu.edu.cn

Abstract

BACKGROUND
Small bowel obstruction (SBO) still imposes a substantial burden on the health care system. Traditional evaluation systems for SBO outcomes only focus on a single element. The comprehensive evaluation of outcomes for patients with SBO remains poorly studied. Early intensive clinical care would effectively improve the short-term outcomes for SBO, however, the full spectrum of the potential risk status regarding the high complication-cost burden is undetermined.

AIM
We aim to construct a novel system for the evaluation of SBO outcomes and the identification of potential risk status.

METHODS
Patients who were diagnosed with SBO were enrolled and stratified into the simple SBO (SiBO) group and the strangulated SBO (StBO) group. A principal component (PC) analysis was applied for data simplification and the extraction of patient characteristics, followed by separation of the high PC score group and the low PC score group. We identified independent risk status on admission *via* a binary logistic regression and then constructed predictive models for worsened management outcomes. Receiver operating characteristic curves were drawn, and the areas under the curve (AUCs) were calculated to assess the effectiveness of the predictive models.

RESULTS

Of the 281 patients, 45 patients (16.0%) were found to have StBO, whereas 236 patients (84.0%) had SiBO. Regarding standardized length of stay (LOS), total hospital cost and the presence of severe adverse events (SAEs), a novel principal component was extracted (PC score = 0.429 × LOS + 0.444 × total hospital cost + 0.291 × SAE). In the multivariate analysis, risk statuses related to poor results for SiBO patients, including a low lymphocyte to monocyte ratio (OR = 0.656), radiological features of a lack of small bowel feces signs (OR = 0.316) and mural thickening (OR = 1.338), were identified as risk factors. For the StBO group, higher BUN levels (OR = 1.478) and lower lymphocytes levels (OR = 0.071) were observed. The AUCs of the predictive models for poor outcomes were 0.715 (95%CI: 0.635-0.795) and 0.874 (95%CI: 0.762-0.986) for SiBO and StBO stratification, respectively.

CONCLUSION

The novel PC indicator provided a comprehensive scoring system for evaluating SBO outcomes on the foundation of complication-cost burden. According to the relative risk factors, early tailored intervention would improve the short-term outcomes.

Core Tip: A novel outcome indicator based on the standardized length of stay, total hospital cost and the presence of severe adverse events provided a comprehensive system for evaluating small bowel obstruction (SBO) outcomes. Furthermore, risk statuses associated with poor results were identified; specifically, for simple SBO patients, a low lymphocyte to monocyte ratio, as well as radiological features of a lack of small bowel feces signs and mural thickening, should be noticeable. For the strangulated SBO group, higher blood urea nitrogen levels and lower lymphocytes levels were recognized. Accordingly, early clinical intensive care was applicable for outcome improvement.

INTRODUCTION

Small bowel obstructions (SBO) result in over 300000 hospitalizations *per* year in the United States[1]. With the increasing public health burden, the average cost for SBOs ranges from $30000-$38000 individually, and the total cost for SBOs is estimated to be approximately 9-11.4 billion dollars[2,3]. Recently, the short outcomes of SBO were evaluated by using in-hospital mortality, major complications and the length of hospital stay[3-6]. There is still lack of an integrative medical-economic system to evaluate the overall outcomes for SBO, even though previous studies have confirmed the relationship between worse outcomes and higher hospital costs[7,8]. Furthermore, the question of how to comprehensively evaluate outcomes for patients with SBO remains uncharted.

Principal component analysis (PCA) is commonly used for dimension reduction[9,10], linear correlation resolution and data simplification. By summarizing and maximizing the information encoding a set of outcome variables, a novel principal component for evaluating the clinical and economic effects on SBO is available. For SBO, patients' statuses on admission, including longer pain duration, acute kidney injury and malnutrition, were found to be closely correlated with severe adverse events (SAEs), based on previous studies[3,5,7,11]. However, the risk factors for the integrative scoring system, including clinical and economic adverse events, have not been extensively evaluated. The method of how to fully evaluate the potential risk status regarding the high complication-cost burden is urgently needed.

As an urgent life-threatening problem, the physical status of strangulated SBO is considerably deteriorating[12-14]. To control this confounding factor[15,16] and to further identify the risk admission status, we divided patients into a simple bowel obstruction group and a strangulated bowel obstruction group for the stratification analysis. We also constructed a novel indicator combining standardized SAEs, length of stay (LOS) and total hospital cost for defining outcomes of SBO. Furthermore, we

established a representative model to distinguish high-risk statuses for both the simple small bowel obstruction (SiBO) and strangulated small bowel obstruction (StBO) groups to guide clinical intensive care for SBO.

MATERIALS AND METHODS

Patient population

From October 2016 to February 2021, 479 patients diagnosed with intestinal obstructions at Fujian Medical University Union Hospital were included in the study. After excluding 180 cases with large bowel obstructions, 4 cases with missing computed tomography (CT) images and 13 cases with incomplete clinical data, 281 patients were recruited for the final study (shown in Figure 1). The following stratification was made according to the pathological confirmation of intestinal ischemia: A simple bowel obstruction (SiBO, *n* = 236) group and a strangulated bowel obstruction (StBO, *n* = 45) group. For patients without acute peritonitis, conservative treatment was applied. Once patients with highly suspect of bowel ischemia or failure to conservative treatment, laparoscopy as well as laparotomy was adopted for SBO patients according to different intrabdominal pressures (shown in Table 1). The study protocol was approved by the Institutional Review Board of Fujian Medical University Union Hospital (Approval No. 2021YF005-02), and all of the patients provided written informed consent for the procedure.

CT findings

All of the patients with suspected SBO underwent CT scans before receiving treatment. The features of the CT scans that were recorded in this study were separated into mesenteric fluid, ascites, spiral signs, concentric circle signs, small bowel feces signs and edema of the bowel wall categories[17-20]. All of the CT scan images were cross-reviewed and evaluated by two senior general surgeons (Chen XQ and Zhang JR, and both surgeons had abundant experience in abdominal emergency surgery. The definitions of CT characteristics are shown in Supplementary Figure 1 and supplied in Supplementary Table 1[21-25].

Clinical characteristics and laboratory tests

Baseline demographics consisted of sex, age, body mass index (BMI), comorbidity, temperature, pain duration and history of abdominal pain. Biochemical parameters, including white blood cell count, neutrophil percentage, lymphocyte concentration, monocyte concentration, hemoglobin concentration, platelet concentration, albumin, alanine aminotransferase, aspartate aminotransferase (AST), calcium concentration, chloride concentration, potassium concentration, sodium concentration, blood urea nitrogen (BUN), serum creatinine, glucose, prothrombin time (PT), activated partial thromboplastin time (APTT), D-dimer (DDI) and fibrinogen, were collected within 24 h of admission. Combinations of inflammatory parameters, such as the neutrophil to lymphocyte ratio and lymphocyte to monocyte ratio (LMR), were calculated and recorded accordingly.

Outcome definition

Posttreatment outcomes were both clinically and economically evaluated.

Postoperative complications were defined as any deviation from the normal postoperative course during the index admission for SBO treatment, which was guided by the European Perioperative Clinical Outcome definitions[7,26]. The severity of complications was graded according to the Clavien-Dindo (CD) system[27], which is a validated classification system that categorizes complication severity based on the level of required treatment. Grade I was defined as complications without the need for pharmacological treatment or surgical, endoscopic and radiological interventions, as well as only minor interventions such as vomiting; grade II was defined as complications requiring pharmacological or other treatments, such as blood transfusions and total parenteral nutrition; grade III was defined as complications requiring surgical interventions or other interventional treatments; grade IV was defined as life-threatening complications, including central nervous system, cardiac and pulmonary complic-ations, as well as renal failure and those interventions requiring intensive care unit (ICU) management; and grade V was defined as death. CD grade I to grade III were classified as non-SAE, and CD grade IV to grade V were classified as SAE.

The LOS was defined as the number of days from admission to discharge. Total hospital cost was defined as the total expenditure for medical resource utilization during hospitalizations, which included fees for operations (materials and occupancy of the operating room), medications, radiology, laboratory tests, microbiology tests, ward stay, ICU days, feeding and blood products[28].

PCA

PCA was used to achieve data simplification by expressing multivariate outcome indicators with fewer dimensions. With standardized LOS, total hospital cost and the presence of SAEs, a novel principal

Table 1 Compared the clinical and laboratory characteristics of the patients with low or high principal component score

Characteristics	Simple obstruction (*n* = 236)		*P* value	Strangulated obstruction (*n* = 45)		*P* value
	Low PC score	High PC score		Low PC score	High PC score	
Baseline data						
Gender, *n* (%)			1.000[1]			0.421[2]
Male	117 (69.2%)	39 (69.6%)		18 (52.9%)	8 (72.7%)	
Female	52 (30.8%)	17 (30.4%)		16 (47.1%)	3 (27.3%)	
Age (yr)	60 (47, 69)	65 (53, 71)	0.081	63 (52.25, 70.00)	(61.0, 71.5)	0.321
BMI (kg/m^2)	20.70 (18.83, 22.98)	20.94 (18.21, 22.65)	0.196	20.20 (18.16, 22.00)	18.75 (17.72, 19.81)	0.228
Comorbidity, *n* (%)			0.245[1]			1.000[2]
None	128 (75.7%)	38 (67.9%)		27 (79.4%)	9 (81.8%)	
Yes	41 (24.3%)	18 (32.1%)		7 (20.6%)	2 (18.2%)	
Pain duration (d)	2 (1, 5)	6 (3, 12.5)	< 0.000	2.00 (1.00, 3.75)	2.0 (1.0, 4.0)	0.989
History of abdominal operation, *n* (%)			0.471[1]			0.603[2]
None	43 (25.4%)	17 (30.4%)		11 (32.4%)	2 (18.2%)	
Yes	126 (74.6)	39 (69.6%)		23 (67.6%)	9 (81.8%)	
Temperature (degrees Celsius)	36.6 (36.5, 36.8)	36.6 (36.5, 36.8)	0.401	36.6 (36.5, 36.8)	36.60 (36.50, 36.75)	0.956
CT characteristics						
Mesenteric fluid (%)			0.430			0.985[2]
None	32 (18.9%)	8 (14.3%)		1 (2.9%)	1 (9.1%)	
Yes	137 (81.1%)	48 (85.7%)		33 (97.1%)	10 (90.9%)	
Ascites (%)			0.849			1.000[2]
None	58 (34.3%)	20 (35.7%)		4 (11.8%)	1 (9.1%)	
Yes	111 (65.7%)	36 (64.3%)		30 (88.2%)	10 (90.9%)	
Spiral signs (%)			0.612[2]			0.436[2]
None	151 (89.3%)	52 (92.9%)		22 (64.7%)	5 (45.5%)	
Yes	18 (10.7%)	4 (7.1%)		12 (35.3%)	6 (54.5%)	
Concentric circle sign (%)			0.132[2]			0.745[2]
None	164 (97.0%)	51 (91.1%)		31 (91.2%)	11 (100%)	
Yes	5 (3.0%)	5 (8.9%)		3 (8.8%)	0 (0%)	
Small bowel feces sign (%)			0.006			1.000[2]
None	70 (41.4%)	35 (62.5%)		17 (50.0%)	5 (45.5%)	
Yes	99 (58.6%)	21 (37.5%)		17 (50.0%)	5 (54.5%)	
Mural thickness (median)	3.28 (2.30, 3.75)	3.63 (2.97, 4.53)	0.002	3.51 (3.16, 4.12)	3.42 (2.67, 4.07)	0.634
Laboratory data						
WBC (10^9/L)	6.770 (4.89, 9.52)	7.345 (4.87, 11.18)	0.387	8.70 (5.89, 12.23)	6.83 (10.01, 18.25)	0.384
NE%	75.50 (65.9, 83.3)	77.45 (68.5, 84.03)	0.422	83.60 (69.05, 86.90)	77.50 (73.30, 90.25)	0.853
Lymphocyte (10^9/L)	1.01 (0.74, 1.42)	0.94 (0.64, 1.34)	0.240	0.96 (0.65, 1.34)	0.60 (0.42, 0.76)	0.020
Monocyte (10^9/L)	0.420 (0.30, 0.58)	0.565 (0.34, 0.73)	0.011	0.570 (0.407, 0.735)	0.540 (0.33, 0.760)	0.721
NLR (ratio)	4.650 (3.03, 8.07)	6.115 (3.74, 9.30)	0.159	7.750 (4.085, 12.922)	9.030 (4.990, 15.565)	0.491
LMR (ratio)	2.286 (1.67, 3.42)	1.591 (1.13, 2.84)	0.002	1.681 (2.131, 1.141)	1.482 (0.957, 1.933)	0.459

Hb (g/L)	128.0 (115, 142)	120.5 (108, 133)	0.016	131.0 (110.0, 137.7)	129.0 (120.5, 145.0)	0.587
PLT (10^9/L)	205.5 (162.50, 250.75)	250.5 (180.25, 307.25)	0.002	213 (163, 260)	180.0 (152.0, 242.5)	0.256
Albumin (g/L)	35.9 (32.30, 40.45)	36.1 (31.80, 39.45)	0.403	34.6 (31.7, 39.6)	37.1 (28.6, 42.0)	0.977
ALT (U/L)	16 (11, 24)	16 (11, 22)	0.727	15.00 (12.00, 21.75)	15.00 (13.25, 27.75)	0.612
AST (U/L)	20 (16, 26)	21 (17, 25.5)	0.619	19.50 (17.00, 23.75)	36.50 (20.75, 45.25)	0.022
Ca (mmol/L)	2.19 (2.04, 2.32)	2.15 (2.02, 2.26)	0.152	2.19 (2.09, 2.31)	2.05 (1.95, 2.20)	0.062
Cl (mmol/L)	102.30 (100.0, 104.1)	100.15 (96.85, 104.03)	0.015	100.85 (98.13, 103.85)	102.00 (101.35, 104.15)	0.296
K (mmol/L)	4.035 (3.78, 4.34)	3.985 (3.74, 4.43)	0.957	4.00 (3.56, 4.31)	4.36 (3.62, 5.07)	0.290
Na (mmol/L)	138.40 (136.68, 140.48)	138.15 (135.50, 141.23)	0.533	138.05 (134.13, 140.30)	135.60 (134.75, 137.75)	0.334
BUN (mmol/L)	5.5 (4.3, 7.2)	5.4 (3.68, 8.23)	0.872	6.45 (4.00, 8.57)	10.6 (7.3, 15.3)	0.002
Glu (mmol/L)	6.78 (5.30, 8.67)	6.59 (5.16, 9.51)	0.515	8.165 (6.963, 9.300)	8.66 (6.78, 11.04)	0.428
PT (s)	13.6 (13.1, 14.3)	13.6 (13.28, 14.43)	0.825	13.45 (12.90, 13.90)	15.40 (14.20, 16.65)	0.004
APTT (s)	35.6 (33.3, 38.3)	36.1 (34.0, 40.9)	0.184	35.15 (32.18, 37.10)	41.6 (36.1, 45.0)	0.012
DDI (mg/L)	1.45 (0.71, 2.52)	1.94 (0.79, 4.67)	0.151	1.64 (0.88, 3.50)	5.75 (2.39, 6.72)	0.024
Fib (g/L)	3.49 (2.92, 4.37)	3.78 (3.25, 4.59)	0.150	3.69 (2.71, 4.60)	3.89 (3.17, 4.82)	0.548
Creatinine (umol/L)	70.0 (56, 81)	70.5 (54.75, 88.00)	0.512	67 (57, 76)	93 (80, 147)	0.003
Management			< 0.000[2]			0.215[2]
Conservative treatment	155 (91.7%)	17 (30.4%)		1 (2.9%)	0 (0%)	
Laparoscopy	11 (6.5%)	8 (14.3%)		8 (23.5%)	0 (0%)	
Laparotomy	3 (1.8%)	31 (55.4%)		25 (73.5%)	11 (100%)	
CD, *n* (%)			< 0.000[2]			< 0.000[2]
Grade I	141 (83.4%)	20 (35.7%)		5 (14.7%)	0 (0%)	
Grade II	28 (16.6%)	32 (57.1%)		28 (82.4%)	2 (18.2%)	
Grade III	0 (0%)	1 (1.8%)		1 (2.9%)	0 (0%)	
Grade IV	0 (0%)	3 (5.4%)		0 (0%)	9 (81.8%)	
Grade V	0 (0%)	0 (0%)		0 (0%)	0 (0%)	
SAE, *n* (%)			0.018[2]			< 0.000[2]
None	169 (100%)	53 (94.6%)		34 (100%)	2 (18.2%)	
Yes	0 (0%)	3 (5.4%)		0 (0%)	9 (81.8%)	
Fee (¥)	12070 (8830, 19935)	54322 (41370, 74623)	< 0.000	51828 (33575, 66954)	83553.0 (74146.0, 142409.5)	< 0.000
Length of stay (d)	5 (4, 8)	16 (13.75, 22.50)	< 0.000	14.00 (10.25, 17.00)	28.0 (18.5, 35.5)	< 0.000

[1]were compared using the χ^2 test.

[2]were adjusted *P* values or Fisher's exact test.

SiBO: Simple small bowel obstruction; StBO: Strangulated small bowel obstruction; PC score: Principle component score; BMI: Body mass index; WBC: White blood cell; NE%: Neutrophil percentage; NLR: Neutrophil to lymphocyte ratio; LMR: Lymphocyte to monocyte ratio; Hb: Hemoglobi; PLT: Platelet; ALT: Alanine aminotransferase, AST: Aspartate aminotransferase; Ca: Calcium; Cl: Chloride; K: Potassiun; Na: Sodium; BUN: Blood urea nitrogen; Glu: Glucose; PT: Prothrombin time; APTT: Activated partial thromboplastin time; DDI: D-dimer; Fib: Fibrinogen; CD: Clavien-Dindo; SAE: Severe adverse event.

component was extracted: PC score = 0.429 × LOS + 0.444 × total hospital cost + 0.291 × SAE. Furthermore, the patient population was classified in the following manner according to the quartile PC score: The low PC score group (below the 75% quartile) and the high PC score group (in the upper 75% quartile). This analysis was performed in R V.4.1.3 (R Foundation for Statistical Programming, Vienna, Austria) by using the psych packages.
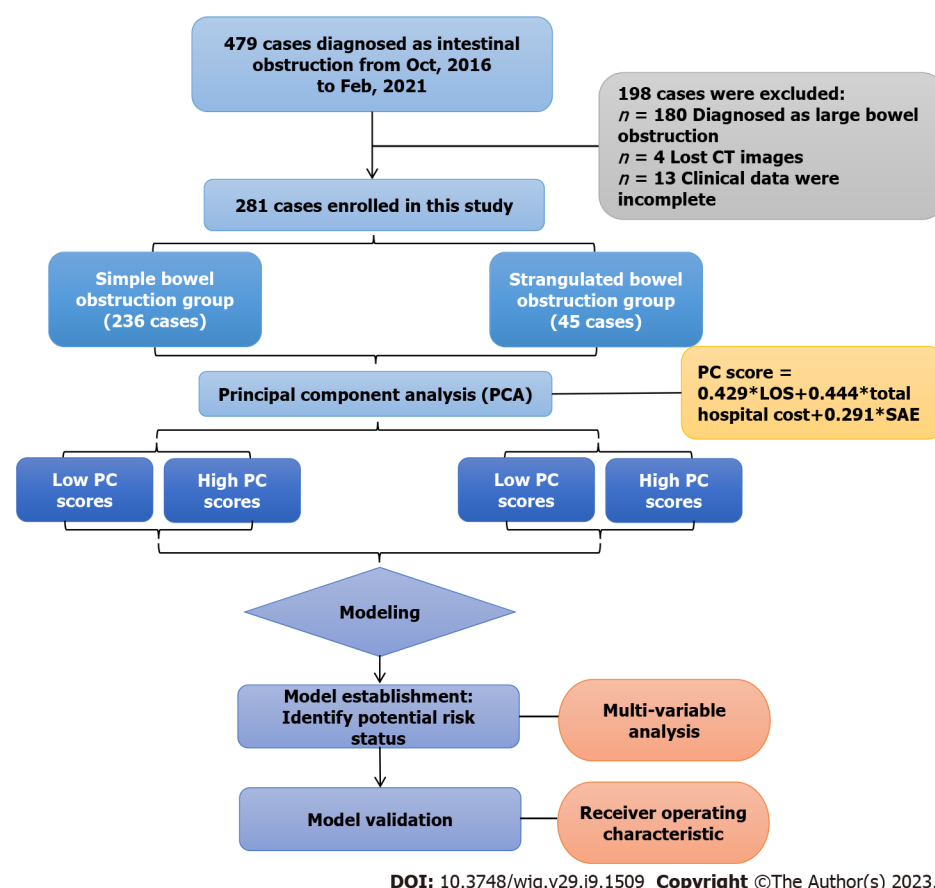
DOI: 10.3748/wjg.v29.i9.1509 **Copyright** ©The Author(s) 2023.

Figure 1 Workflow of this study. CT: Computed tomography; PC: Principal component; LOS: Length of stay; SAE: Severe adverse event.

Statistical analysis

Categorical variables were compared by using the χ^2 test or Fisher's exact test between the two groups. Data are presented as the mean ± SD or median for continuous variables. Independent t tests or Kruskal-Wallis tests were applied according to the characteristics of the variables. The association of admission status with higher PC scores was evaluated by using univariate logistic regression and summarized with an odds ratio (OR) and 95% confidence interval (CI). After setting the variables with a significance level of $P < 0.05$ and variance inflation factors < 5, a multivariate logistic regression with "binomial" method was performed, and independent risk factors were determined. We extracted the following risk score formulas based on these independent risk factors: Risk score 1 (RS1) = [0.291 × (bowel wall thickness) - 1.150 × (small bowel feces sign) - 0.421 × (LMR)] and RS2 = [-2.632 × (lymphocyte concentration) + 0.391 × (BUN concentration)] for the SiBO group and StBO group, respectively. Receiver operating characteristic curves and the area under the curve were calculated to assess the accuracy of the models. All of the statistical analyses were performed in R Version.4.1.3. The statistical methods of this study were reviewed by Yin YR.

RESULTS

Outcome analysis

For 281 patients with SBO who were included in this study, posttreatment outcomes were evaluated by LOS, total hospital cost and the presence of SAEs. *Via* the univariate analysis, admission risk status, including lower LMR ($P = 0.005$), higher BUN concentration ($P = 0.022$), higher glucose concentration ($P = 0.007$) and higher DDI concentration ($P = 0.001$), was significantly associated with higher hospital costs. Patients with SAE had lower levels of lymphocyte concentration ($P = 0.003$), higher levels of AST ($P = 0.027$), higher levels of potassium ($P < 0.000$), higher levels of BUN ($P < 0.000$), higher levels of serum creatinine ($P < 0.000$) and coagulation and fibrinolysis disturbances, including longer PT ($P = 0.001$), APTT ($P = 0.012$) and higher levels of DDI ($P < 0.000$). Furthermore, at admission, lower LMR ($P = 0.003$), higher monocyte concentration ($P = 0.003$), lower hemoglobin concentration ($P = 0.038$), higher level of glucose ($P = 0.049$), higher level of DDI ($P = 0.004$) and abnormal electrolyte and metabolic changes, such as lower calcium concentration ($P = 0.042$), lower chloride concentration ($P = 0.003$) and lower sodium concentration ($P = 0.043$), were closely related to a longer LOS (Figure 2 and Supplemen-
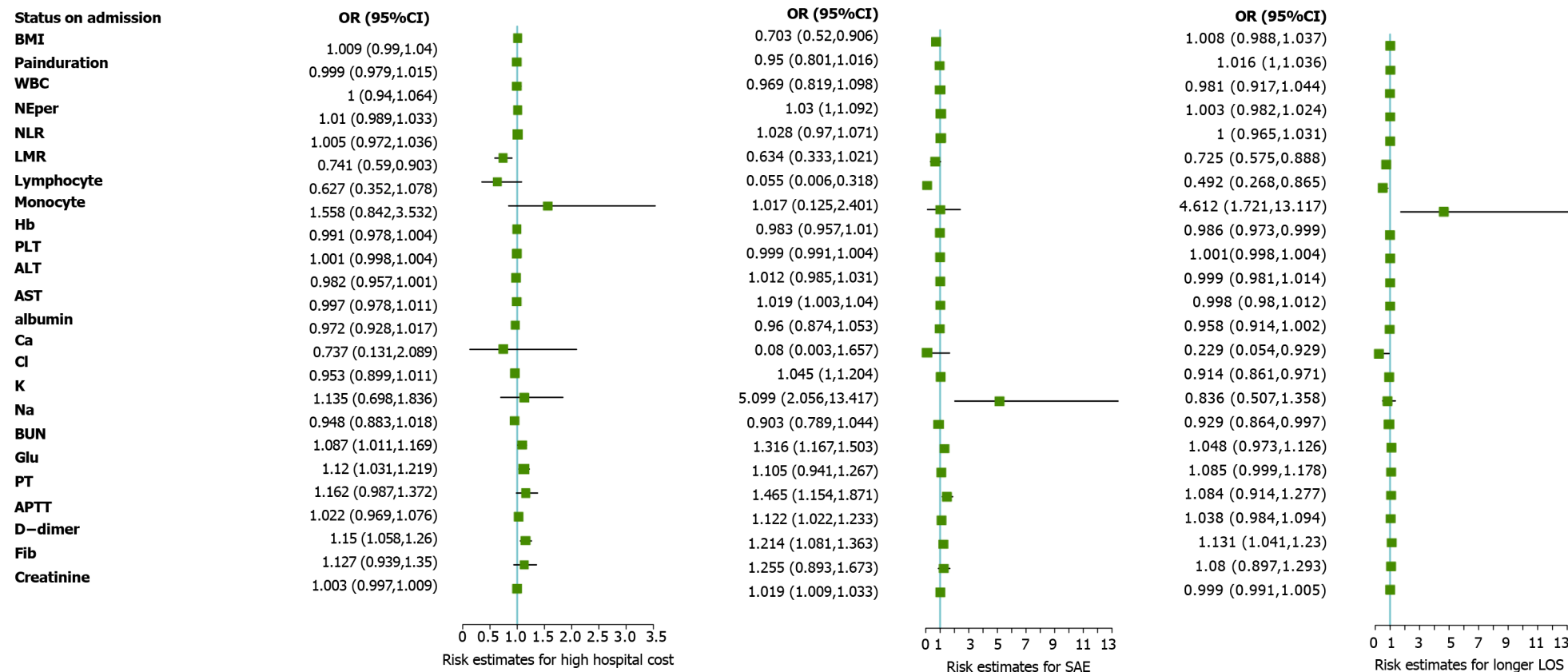
Figure 2 Risk factors for worse outcome of small bowel obstruction. Risk estimates for high hospital cost; Risk estimates for severe adverse event; Risk estimates for longer length of stay. OR: Odds ratio; CI: Confidence interval; BMI: Body mass index; WBC: White blood cell; NE%: Neutrophil percentage; NLR: Neutrophil to lymphocyte ratio; LMR: Lymphocyte to monocyte ratio; Hb: Hemoglobin; PLT: Platelet, ALT: Alanine aminotransferase; AST: Aspartate aminotransferase; Ca: Calcium; Cl: Chloride; K: Potassiun; Na: Sodium; BUN: Blood urea nitrogen; Glu: Glucose; PT: Prothrombin time; APTT: Activated partial thromboplastin time; DDI: D-dimer; Fib: Fibrinogen; SAE: Severe adverse event; LOS: Length of stay.

tary Table 2).

PCA

After maximizing the possible information and variation of the above-mentioned outcome indicators, including total hospital cost, LOS and SAEs, data simplification was performed. *Via* PCA, one principal component was extracted (Supplementary Figure 2). The PC score was calculated according to weights given to each outcome indicator: PC score = 0.429 × LOS + 0.444 × total hospital cost + 0.291 × SAE (Figure 1).

Of the 281 patients with SBO who were included in this study, 45 patients (16.0%) were found to have StBO, whereas 236 patients (84.0%) were found to have SiBO. The low PC score group (< 75% quartile) and high PC score group (> 75% quartile) were identified according to the quartile PC score. For both the SiBO and StBO groups, no significant difference was observed between the two PC score groups for sex, age, BMI, comorbidity status, temperature or history of abdominal operation (all *P* values > 0.05, Table 1). For patients with SiBO, a higher PC score was significantly related to longer pain duration (*P* < 0.000), higher monocyte concentration (*P* = 0.011), lower LMR (*P* = 0.002), lower hemoglobin concentration (*P* = 0.016), lower platelet count (*P* = 0.002) and low level of chloride (*P* = 0.015). Through the univariate analysis of radiological characteristics, we determined that a lack of small bowel feces signs and mural thickening were risk factors for a high PC score. In contrast, in the StBO group, low levels of lymphocytes (*P* = 0.020), high levels of AST (*P* = 0.022), high levels of BUN (*P* = 0.002) and coagulation and fibrinolysis disturbances, including abnormal DDI concentrations (*P* = 0.024), PTs (*P* = 0.004) and APTTs (*P* = 0.012), were significantly associated with higher PC scores. None of the risk radiological characteristics were observed in this stratification.

Univariate and multivariate analyses of risk statuses

Via the univariate analysis of the admission clinical-laboratory features, we determined potential risk status, including longer pain duration (*P* = 0.048), higher monocyte concentration (*P* = 0.003), lower LMR (*P* = 0.006), lower hemoglobin concentration (*P* = 0.033), lower platelet count (*P* = 0.036) and low level of chloride (*P* = 0.031), as well as radiological characteristics of mural thickening (*P* = 0.033) and lack of small bowel feces sign (*P* = 0.006), for high PC scores in the SiBO stratification. *Via* the multivariate analysis, independent risk factors consisting of radiological findings of small bowel feces sign (OR = 0.316), mural thickening (OR = 1.338) and LMR (OR = 0.656) were identified (all *P* values < 0.05, Table 2 and Figure 3). For StBO stratification, low levels of lymphocytes (*P* = 0.038), high levels of AST (*P* = 0.027), longer PTs (*P* = 0.015), high levels of BUN (*P* = 0.004) and creatinine (*P* = 0.022) seemed to be related to high PC scores. Finally, we found that only lymphocytes (OR = 0.071) and BUN (OR=1.478) were independent risk factors for high PC scores (all *P* values < 0.05, Table 2 and Figure 3).

Based on the regression coefficient for each factor, we calculated risk scores and built prediction models for worse outcomes: RS1 = [0.291 × (bowel wall thickness) - 1.150 × (small bowel feces sign) - 0.421 × (LMR)] for the SiBO group and RS2 = [-2.632 × (lymphocyte concentration) + 0.391 × (BUN concentration)] for the StBO group. Furthermore, receiver operating characteristic curves were drawn with areas under the curve of 0.715 (95%CI: 0.635-0.795) and 0.874 (95%CI: 0.762-0.986) for the SiBO and StBO stratifications, respectively (Figure 4).

DISCUSSION

Given that approximately 9-11.4 billion dollars are the costs *per* year in the United States, SBO still imposes a substantial burden on the health care system[2]. In contrast to the traditional evaluation systems that only focus on a single element[3-6], in this study, the standardized LOS, total hospital cost and the presence of SAEs were considered as integrative systems to evaluate the clinical-economic outcomes of SBO *via* PCA[9]. Previous studies have confirmed the close relationship between patients' statuses on admission (including longer pain duration, acute kidney injury and malnutrition) and adverse outcomes, which provides a potential target for improving outcomes[3,5,7,11]. Commonly, severe statuses, including severe inflammatory reactions, electrolyte disturbances and hemostatic abnormalities, tend to occur in strangulated bowel obstruction[22]. Following the formula that assigned weights to each component, we determined PC score = 0.429 × LOS + 0.444 × total hospital cost + 0.291 × SAE; thus, the posttreatment outcome of SBO could be calculated and precisely evaluated (Figure 1).

For people with SiBO, only low LMR is observed, as radiological features (such as a lack of small bowel feces signs and mural thickening) were independent risk factors for high PC scores *via* the multivariate analysis. The area under the curve (AUC) of the predictive model based on the comprehensive scores for SiBO was 0.715 (95%CI: 0.635-0.795). As acute intestinal failure accompanies the obstructive bowel[26], when mechanical obstruction develops, the bowel lumen dilates along with the accumulation of air and intestinal fluid; thus, enteric stasis initiates bacterial proliferation with the intestinal gas produced by the fermentation of ingested food[22]. Conversely, when obstruction is incomplete or mild, the lasting bowel absorptive function can allow for fluid reabsorption across the bowel wall, thus leading to the small bowel feces sign as an independent protective factor for SBO[18, 29]. Furthermore, progressive bowel dilation accompanied by compromised venous reflux increases intramural tension, which causes mural edema, secondary intestinal absorptive dysfunction and the loss of mucosal integrity (both functionally and physically)[22,30]. Similarly, as a potential effect on decreasing mural edema, the use of gastrografin challenge has been identified as the standardized management for SBO[31,32]. Moreover, in this study, the LMR was much lower in the high PC group, which may be due to the immune system becoming weakened as a result of the underlying malnutrition, as well as an excessive compensatory anti-inflammatory response[33-37].

Table 2 Univariate and multivariate analyses of risk factors for high principal component score

Characteristics	Simple obstruction (*n* = 236)				Strangulated obstruction (*n* = 45)			
	Univariate		Multivariate		Univariate		Multivariate	
	OR (95%CI)	*P* value	OR (95%CI)	*P* value	OR (95%CI)	*P* value	OR (95%CI)	*P* value
Pain duration (d)	1.019 (1.002, 1.041)	0.048[1]						
Small bowel feces sign (+)/(-)	0.424 (0.225, 0.783)	0.006[1]	0.316 (0.158, 0.612)	< 0.000[1]				
Mural thickening (cm)	2.119 (1.084, 4.375)	0.033[1]	1.338 (1.098, 1.664)	0.003[1]				
Lymphocyte (10^9/L)					0.097 (0.007, 0.665)	0.038[1]	0.071 (0.003, 0.539)	0.033[1]
Monocyte (10^9/L)	5.472 (1.809, 17.780)	0.003[1]						
LMR (ratio)	0.708 (0.541, 0.891)	0.006[1]	0.656 (0.496, 0.836)	0.001[1]				
Hb (g/L)	0.983 (0.969, 0.998)	0.033[1]						
PLT (10^9/L)	1.003 (1.001, 1.007)	0.036[1]						
AST (U/L)					1.075 (1.018, 1.156)	0.027[1]		
Cl (mmol/L)	0.931 (0.871, 0.993)	0.031[1]						
BUN (mmol/L)					1.383 (1.133, 1.786)	0.004[1]	1.478 (1.169, 2.061)	0.004[1]
PT (s)					1.568 (1.141, 2.418)	0.015[1]		
APTT (s)					1.109 (0.999, 1.264)	0.076		
DDI (mg/L)					1.196 (1.006, 1.513)	0.067		
Creatinine (umol/L)					1.034 (1.011, 1.071)	0.022[1]		

[1]indicates that the parameters have statistical difference (*P* < 0.05).

SiBO: Simple small bowel obstruction; StBO: Strangulated small bowel obstruction; OR: Odds ratio; CI: Confidence interval; LMR: Lymphocyte to monocyte ratio; Hb: Hemoglobin; PLT: Platelet; AST: Aspartate aminotransferase; Cl: Chloride; BUN: Blood urea nitrogen; PT: Prothrombin time; APTT: Activated partial thromboplastin time; DDI: D-dimer.

Once SiBO deteriorated into StBO, the risk factors were dynamically changed. None of the radiological characteristics were found to be related to the outcomes. In particular, coagulation and fibrinolysis disturbances (including abnormal DDI, PT and APTT), kidney injury (such as increasing BUN and creatinine levels) and relevant lymphocytes were confirmed as being risk factors. Finally, only BUN and lower lymphocyte counts were identified as being independent risk factors for high PC. Partially due to the impaired mucosal barriers[22,38], lactic acid from intestinal anaerobic glycolysis gradually accumulates, which adversely deteriorates renal function with increasing levels of BUN in the peripheral blood[39]. Similarly, it is difficult to correct conventional enteral interventions and intestinal mucosal malnutrition due to the weakened immune status[33,40], which may explain why a lower level
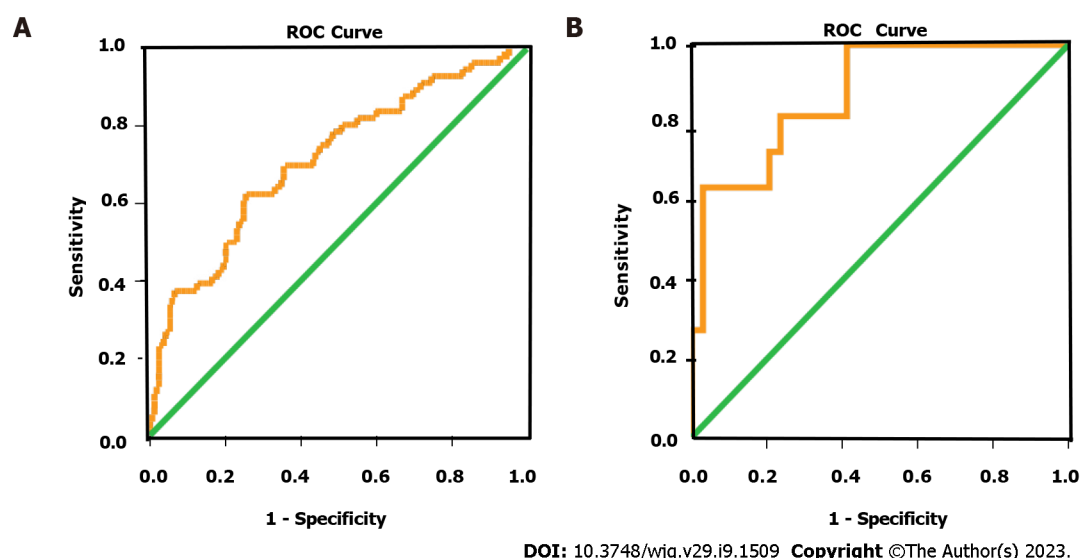
Figure 3 Receiver operating characteristic curve for high principal component score prediction. The areas under the curve were 0.715 (95%CI: 0.635-0.795), 0.874 (95%CI: 0.762-0.986), respectively. A: Receiver operating characteristic curve of simple small bowel obstruction group for high principal component score prediction. B: Receiver operating characteristic curve of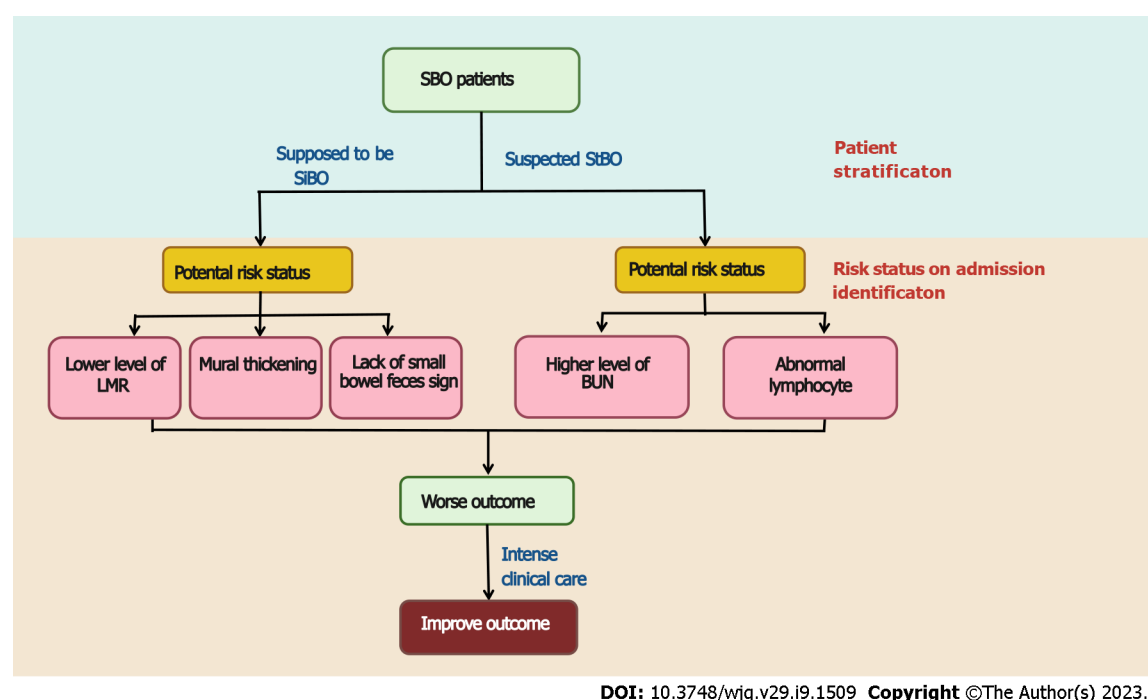 strangulated small bowel obstruction group for high principal component score prediction. ROC: Receiver operating characteristic.

Figure 4 Proposal early clinical intensive care for small bowel obstruction patients on admission. SBO: Small bowel obstruction; SiBO: simple small bowel obstruction; StBO: Strangulated small bowel obstruction; LMR: Lymphocyte to monocyte ratio; BUN: Blood urea nitrogen.

of lymphocytes is a risk factor for poorer outcomes. The predictive model for StBO yielded an AUC of 0.874 (95%CI: 0.762-0.986), which provided an excellent differentiating ability.

There were a few limitations to the present study. Primarily, this was a retrospective study conducted in a single center. In addition, the sample size of the initial models was relatively small. However, in both group (SiBO or StBO) the patients evaluated were consecutively enrolled and this could reproduce a real-world situation. Adequately powered and well-designed studies are required to confirm these findings and to establish causality.

CONCLUSION

The novel PC indicator provided a comprehensive scoring system for evaluating SBO outcomes on the foundation of complication-cost burden. According to the relative risk factors, early tailored intervention would improve the short-term outcomes.

ARTICLE HIGHLIGHTS

Research background

Small bowel obstruction (SBO) still imposes a substantial burden on the health care system. Traditional evaluation systems for SBO outcomes only focus on a single element. There is still lack of an integrative medical-economic system to evaluate the overall outcomes for SBO. Moreover, patients' statuses on admission, including longer pain duration, acute kidney injury and malnutrition, were found to be closely correlated with severe adverse events (SAEs). However, the risk factors for the integrative scoring system, including clinical and economic adverse events, have not been extensively evaluated.

Research motivation

SBO still imposes a substantial burden on the health care system. Traditional evaluation systems for SBO outcomes only focus on a single element. The comprehensive evaluation of outcomes for patients with SBO remains poorly studied. Early intensive clinical care would effectively improve the short-term outcomes for SBO, however, the full spectrum of the potential risk status regarding the high complication-cost burden is undetermined.

Research objectives

In this study, we aim to construct a novel indicator combining standardized SAEs, length of stay (LOS) and total hospital cost for defining outcomes of SBO. Furthermore, we established a representative model for distinguishing high-risk statuses on admission for the simple SBO (SiBO) or strangulated SBO (StBO) groups. Given that SBO still imposes a substantial burden on the health care system, we believe our findings will provide a new insight for comprehensively evaluation outcomes of SBO as well as a guideline for early intervention.

Research methods

In this study, we evaluated posttreatment outcomes of SBO both clinically and economically. Principal component analysis (PCA) was used to achieve data simplification by expressing multivariate outcome indicators with fewer dimensions. By summarizing and maximizing the information encoding in standardized LOS, total hospital cost and the presence of SAEs, a novel principal component was extracted: PC score = $0.429 \times$ LOS + $0.444 \times$ total hospital cost + $0.291 \times$ SAE. Furthermore, the patient population was classified in the following manner according to the quartile PC score: The low PC score group (below the 75% quartile) and the high PC score group (in the upper 75% quartile).

Research results

In this study, a novel outcome indicator based on the standardized LOS, total hospital cost and the presence of SAEs provided a comprehensive system for evaluating SBO outcomes (PC score = $0.429 \times$ LOS + $0.444 \times$ total hospital cost + $0.291 \times$ SAE). Furthermore, risk statuses associated with poor results were identified; specifically, for SiBO patients, a low LMR, as well as radiological features of a lack of small bowel feces signs and mural thickening, should be noticeable. For the StBO group, higher blood urea nitrogen levels and lower lymphocytes levels were recognized. Accordingly, early clinical intensive care was applicable for outcome improvement. In the future, adequately powered and well-designed studies are required to confirm these findings and to establish causality.

Research conclusions

In this study, PCA was innovatively used for dimension reduction, linear correlation resolution and data simplification. Furthermore, a novel comprehensive system for the evaluation of SBO outcomes was constructed and the potential risk status associated with poor results were identified.

Research perspectives

Large-scale and prospective studies are going to be designed to confirm these findings and to establish causality.

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