Retrospective Cohort Study

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A new clinical severity score for the management of acute small bowel obstruction in predicting bowel ischemia: a cohort study

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Background: Small bowel obstruction (SBO) is a common hospital admission diagnosis. Identification of patients who will require a surgical resection because of a nonviable small bowel remains a challenge. Through a prospective cohort study, the authors aimed to validate risk factors and scores for intestinal resection, and to develop a practical clinical score designed to guide surgical versus conservative management.

Patients and Methods: All patients admitted for an acute SBO between 2004 and 2016 in the center were included. Patients were divided in three categories depending on the management: conservative, surgical with bowel resection, and surgical without bowel resection. The outcome variable was small bowel necrosis. Logistic regression models were used to identify the best predictors.

Results: Seven hundred and thirteen patients were included in this study, 492 in the development cohort and 221 in the validation cohort. Sixty-seven percent had surgery, of which 21% had small bowel resection. Thirty-three percent were treated conservatively. Eight variables were identified with a strong association with small bowel resection: age 70 years of age and above, first episode of SBO, no bowel movement for greater than or equal to 3 days, abdominal guarding, C-reactive protein greater than or equal to 50, and three abdominal computer tomography scanner signs: small bowel transition point, lack of small bowel contrast enhancement, and the presence of greater than 500 ml of intra-abdominal fluid. Sensitivity and specificity of this score were 65 and 88%, respectively, and the area under the curve was 0.84 (95% CI: 0.80–0.89).

Conclusion: The authors developed and validated a practical clinical severity score designed to tailor management of patients presenting with an SBO.

Keywords: bowel resection, clinical score, general surgery, small bowel occlusion

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HIGHLIGHTS

- Small bowel obstruction is a common hospital admission diagnosis but remains a clinical challenge.
- Identification of patients requiring emergency surgery and by extension, bowel resection is the main goal of surgical physicians.
- A practical clinical severity score guiding patient's care.
- Early surgical relief of the small bowel obstruction increases the chance to avoid bowel resection.
- Avoiding unnecessary surgery could reduce patients' morbidity.

Introduction

Small bowel obstruction (SBO) is defined as a total or partial blockage of the intestinal lumen. It can result from incarcerated hernia, volvulus, intussusception, primary or secondary tumors, peritoneal carcinomatosis, strictures (secondary to inflammatory disorders, fibrosis, radiotherapy), gallstones, or foreign

bodies[1,2]. However, 60–70% of SBO results from adhesions, either as a single fibrous band or as multiple bands all over the abdominal cavity, and therapeutic strategy in those situations is more challenging[3,4]. In most cases, adhesions are the consequence of previous abdominal surgery, but they can also occur spontaneously in patients without any surgical history[5]. Postoperative adhesions incidence is related to the site of surgery, with a range from 0.05% after a cesarean section, 1% after an appendectomy and up to 10% after colorectal surgery[4,6,7]. In the absence of strangulation, evident ischemia or peritonitis, a significant proportion of patients can be treated conservatively with bowel rest, gastric decompression with a nasogastric tube, and intravenous (i.v.) fluid. Water-soluble contrast imaging is now routinely used during the nonoperative trial. A portion of cases will present a complete obstruction with bowel strangulation, compromising blood flow and resulting in bowel ischemia, commonly followed by perforation. Those patients frequently require a bowel resection when surgery is not performed within the first 6 h (https://emblog.mayo.edu/2015/01/04/the-truth-about-small-bowel-obstruction/). The identification of patients who are at risk or who will develop small bowel ischemia is essential, as it has been associated with a mortality rate of 30% compared to 3% without ischemia[8]. Potential complications of delayed management include aspiration pneumonia, sepsis and acute renal injury, with an increased 1-year mortality rate[9]. On the other hand, the identification of patients at low risk of bowel ischemia is equally important since it allows to avoid unnecessary surgery.

We previously designed and investigated a six-item SBO/small bowel resection risk score which included: abdominal pain greater than or equal to 4 days, abdominal guarding, leukocytosis ($\geq$ 10 G/ml), C-reactive protein (CRP) greater than or equal to 75, greater than or equal to 500 ml intra-abdominal free fluid and/or lack of small bowel contrast enhancement on computer tomography scanner (CT scan)[10,11]. Our initial score was able to predict small bowel resection with an area under the curve (AUC) receiver operating characteristic (ROC) curve of 0.87. However, no validation in a larger data set was yet available.

The primary objective of the present study was to validate our previous score developed in a cohort of 221 patients (2004–2007, referred as the historical cohort) in a cohort of 492 patients (2008–2016, referred as the current cohort).

When applied to the current cohort, the AUC was 0.78 (95% CI: 0.72–0.84). Because it was substantially less than the originally reported value of 0.87, we thus decided to improve the existing score using the most recent data set.

Therefore, the second objective was to provide an improved severity score for SBO with a simplified version of the score to allow its use in the absence of CRP (not routinely performed in most of the institutions) and i.v. contrast (usually not given to patients with an elevated creatinine).

Patients and Methods

Patients

The current cohort was used to validate the previous score[10]. Additionally, it has been used as the development cohort for the new clinical severity score. All adult patients ($n = 824$) presenting to our hospital with the International Classification of Disease-10 code K56.5 (intestinal adhesions with obstruction) between 2008 and 2016 were considered for inclusion in the study. The SBO episode occurring during the study period was defined as the index episode. Patients with an active abdominal oncological process (primary tumors, metastases, peritoneal carcinomatosis), an SBO occurring in the immediate postoperative period (i.e. 6 weeks), an incarcerated hernia, postradiotherapy or with large bowel obstructions ($n = 209$) were excluded from our analysis. Patients without a CT scan, with a CT scan without contrast or with missing data were also excluded ($n = 123$) (similar exclusion criteria were used for the validation cohort[10,11]). A total of 492 patients were included in the current cohort. Patient's assessment was standardized and included: a clinical exam, a complete blood count and a basic metabolic panel, CRP, lactate, and a CT scan of the abdomen. The conservative versus surgical management was left at the discretion of the surgeon on-call. Our previously published score was prospectively calculated for each patient, recorded as an additional information, but decision making was left at the on-call surgeon's discretion. Patients who did not respond to conservative management within 48 h were managed surgically. The use of laparoscopy versus open surgery, and the decision to resect/not to resect small bowel was based on the clinical judgement by the surgeon on-call. Patients were categorized in three groups depending on the management: conservative, surgical with bowel resection, and surgical without bowel resection.

We used as an external validation cohort for our newly developed score, patients from the historical cohort who presented at our hospital with an SBO between 2004 and 2007 ($n = 221$), as previously reported by our group[10,11].

Study variables

Patient's clinical and surgical characteristics were prospectively collected in patient's electronic chart. Postoperative complications were classified according to Clavien–Dindo[12].

Score validation and development

Our initial six-item score was calculated as previously described[10] and applied to the current cohort. ROC curve and AUC were computed. We defined 0.03 as the maximal AUC difference for validation.

For the elaboration of a new score, the 2008–2016 data set (current cohort) was used. In addition, we used the 2004–2007 data set (historical cohort) for external validation. We converted all variables to categorical or binary variables for score development when appropriate. Odds ratios (ORs) for small bowel resection was calculated for each variable independently. Variables with an OR greater than or equal to 2 and a P value less than 0.2 were included in the multivariate predictive model. Risk factors with a P value greater than 0.05 were removed one by one, until all retained predictors were statistically significant. To assess the performance of the model, we obtained a ROC curve and the corresponding AUC. The AUC represents the probability that a randomly chosen patient who required a resection would have a higher score than a randomly selected patient who was treated conservatively. A value of 0.5 corresponds to lack of discrimination and 1 to perfect discrimination.

Risk scores were calculated by adding one point per risk factor present. We used multiple permutations to derive two simplified versions of the original score and retained those with AUC greater

than or equal to 0.8 and including the most clinically meaningful variables.

We arbitrarily determine 70% as the individual predicted risk of resection. For external validation, we replicated analyses (AUC, proportion at risk $\geq 70\%$, sensitivity, and specificity) for the three scores in the 2004–2007 database (historical cohort).

Statistical analysis

Continuous variables were compared between groups using a Student *t*-test with Welch's correction or a Mann–Whitney *t*-test when appropriate. Categorical variables were compared by using a χ^2-test. A *P* value less than 0.05 was considered statistically significant.

Recurrence rate was assessed and time to recurrence was defined as the duration between the date of index SBO episode admission to the recurrence date of admission. For patients who did not experience a recurrence, we used the date of last follow-up or death. A univariate analysis was performed in order to identify possible variable associated with recurrence. A multivariate regression analysis was then performed using the Cox regression model. All statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corp.).

This work has been reported in line with the STROCSS criteria[13], Supplemental Digital Content 1, http://links.lww.com/JS9/A153.

Results

We first constituted the current cohort and assessed the previous score[10]. Between 2008 and 2016, 492 patients presented a bowel obstruction and met the inclusion criteria. Three hundred and forty-five patients (70.1%) had surgery, of which 103 (20.9%) had small bowel resection. The proportion of cases managed surgically did not change over the study period (Supplementary Fig. 1, Supplemental Digital Content 2, http://links.lww.com/JS9/A154). Hundred and forty-seven patients (29.9%) were treated conservatively. Demographics, clinical, biological, and radiological characteristics of included patients are described in Table 1. There were 294 (59.8%) female and 198 (40.2%) males overall, and no gender difference was observed between groups. Patients in the surgical groups were older and had higher BMI. Patients admitted for an initial SBO episode were more likely to be in the surgical group. Pain duration, absence of bowel movement, fever, and vomiting were not significantly different between groups. Patients treated surgically had higher leukocytosis, CRP, and CT signs of transition point, lack of small bowel enhancement, and intra-abdominal fluid.

Variables related to patients treated surgically are reported in Table 2. Among all patients operated ($n=345$), 204 (59.5%) were taken into the operating room in the first 24 h and 29.9% ($n=103$) needed a resection because of bowel ischemia. Of the 16 patients who had a lack of small bowel contrast enhancement on CT scan, but did not require surgical resection, the mean delay to surgery was 10.2 ± 5.8 h compared to 12.2 ± 8.9 h for patients with the same CT scan findings and who needed a resection ($P=0.42$). A higher percentage of patients were operated by laparoscopy in the nonresected group in comparison with the group with bowel resection (31.4 vs. 12.6%, $P<0.001$), and the conversion rate to laparotomy was significantly higher in the group with bowel resection (84.6 vs. 32.9%, $P<0.001$). No

Table 1

Comparison of clinical, biological, and radiological parameters of patients recorded during the first hospitalization for a SBO episode.

	Surgical, no resection	Surgical resection	Conservative	
	N = 242 [*n* (%)]	*N* = 103 [*n* (%)]	*N* = 147 [*n* (%)]	*P* value[a]
Sex				0.46
Female	147 (60.7)	65 (63.1)	82 (55.8)	
Male	95 (39.3)	38 (36.9)	65 (44.2)	
Age (years) (mean ± SD)	64.6 ± 18.2	71.6 ± 16.9	62.9 ± 18.4	< 0.001
Age (years)				< 0.001
22–59	91 (37.6)	21 (20.4)	64 (43.4)	
60–69	44 (18.2)	13 (12.6)	24 (14.3)	
70–79	45 (18.6)	30 (29.1)	27 (18.4)	
80–96	62 (25.6)	39 (37.9)	32 (21.8)	
BMI (kg/m^2) (mean ± SD)	23.9 ± 4.8	22.6 ± 3.4	24.0 ± 4.9	0.04
Previous SBO				< 0.001
Yes	38 (15.7)	17 (16.5)	56 (38.1)	
No	204 (84.3)	86 (83.2)	91 (61.9)	
Pain duration (days)				0.074
0–3	213 (88.0)	91 (88.3)	134 (91.2)	
≥ 4	29 (12.0)	12 (11.7)	13 (8.8)	
Absence of bowel movement (days)	1.8 ± 1.6	2.1 ± 2.1	1.5 ± 0.9	0.035
Absence of bowel movement (days)				0.083
0–2	208 (86.0)	84 (81.6)	134 (91.2)	
≥ 3	34 (14.0)	19 (18.4)	13 (8.8)	
Fever > 38°C				0.16
Yes	15 (6.2)	12 (11.7)	9 (6.1)	
No	227 (93.8)	91 (88.3)	138 (93.9)	
Vomiting				0.53
Yes	185 (76.4)	78 (75.7)	105 (71.4)	
No	57 (23.6)	25 (24.3)	42 (28.6)	
Abdominal guarding				< 0.001
Yes	82 (33.9)	42 (40.8)	13 (8.8)	
No	160 (66.1)	61 (59.2)	134 (91.2)	
Leukocytosis, (G/l) (mean ± SD)	11.2 ± 3.9	12.3 ± 5.3	10.8 ± 6.6	0.056
Leukocytosis, > 10 (G/l)				0.050
Yes	145 (59.9)	67 (65.0)	74 (50.3)	
No	97 (40.1)	36 (35.0)	73 (49.7)	
CRP (mg/l) (mean ± SD)	33.0 ± 69.1	43.5 ± 67.4	23.5 ± 40.1	0.041
CRP (mg/l)				0.035
0–9	138 (57.0)	54 (52.4)	82 (55.8)	
10–49	61 (25.2)	20 (19.4)	45 (30.6)	
50–470	43 (17.8)	29 (28.2)	20 (13.6)	
Creatinine (mean ± SD)	33.0 ± 69.1	43.5 ± 67.4	23.5 ± 40.1	0.157
Lactates (mean ± SD)	1.7 ± 0.9	2.0 ± 1.4	1.8 ± 2.0	0.536
Platelets (mean ± SD)	277.4 ± 98.5	297.2 ± 110.5	259.1 ± 93.1	0.012
CT–transition point				0.044
Yes	219 (90.5)	93 (90.3)	117 (79.6)	
No	23 (9.5)	10 (9.7)	30 (20.4)	
CT contrast enhancement				< 0.001
Yes	226 (93.4)	79 (76.7)	144 (98.0)	
No	16 (6.6)	24 (23.3)	3 (2.0)	
CT IAFF > 500 ml				< 0.001
Yes	62 (25.6)	45 (43.7)	13 (8.8)	
No	180 (74.4)	58 (56.3)	134 (91.2)	

[a] χ^2-test for binary or categorical variable (global *P* value), *t*-test for continuous variables

CRP, C-reactive protein; CT, computed tomography; IAFF, intra-abdominal free fluid; SBO, small bowel obstruction.

Table 2

Operative characteristics and data compared between the two surgical groups.

	Surgical, no resection	Surgical resection	
	N = 242	*N* = 103	*P* value[a]
ASA (mean ± SD)	2.5 ± 0.7	2.6 ± 0.7	0.21
Time before surgery (h) (mean ± SD)	33.9 ± 44.6	24.4 ± 30.3	0.026
Time before surgery (h) [median (minimum–maximum)]	17.7 (0.8–361.8)	15.7 (2.5–236.2)	0.054
Laparoscopy [*n* (%)]			< 0.001
Yes	76 (31.4)	13 (12.6)	
No	166 (68.6)	90 (87.4)	
Conversion rate [*n* (%)]			< 0.001
Yes	25 (32.9)	11 (84.6)	
No	51 (67.1)	2 (15.4)	

[a]Student's *t*-test with Welch's correction or Mann–Whitney *t*-test, or χ^2-test for binary or categorical variable.
ASA, American Society of Anesthesiologists.

Table 3

Comparison of outcomes after the first hospitalization for a SBO episode.

	Surgical, no resection	Surgical resection	Conservative	
	N = 242 [*n* (%)]	*N* = 103 [*n* (%)]	*N* = 147 [*n* (%)]	*P* value[a]
Length of hospital stay (days) (mean ± SD)	14.6 ± 15.7	17.4 ± 13.7	7.8 ± 13.7	< 0.001
Length of hospital stay (days)				< 0.001
1–6	58 (24.0)	7 (6.8)	99 (67.3)	
7–12	95 (39.2)	42 (40.8)	31 (21.1)	
13–174	89 (36.8)	54 (52.4)	17 (11.6)	
Postsurgical complications, Clavien–Dindo classification			NA	NA
0	166 (68.6)	57 (55.3)		
1	27 (11.1)	8 (7.8)		
2	32 (13.2)	20 (19.4)		
3	5 (2.1)	6 (5.8)		
4	6 (2.5)	5 (4.9)		
5	6 (2.5)	7 (6.8)		
SBO recurrence				< 0.0001
Yes	35 (14.5)	8 (7.8)	46 (31.3)	
No	207 (85.5)	95 (92.2)	101 (68.7)	

[a]χ^2-test for binary or categorical variable.
SBO, small bowel obstruction.

association was observed between delay to surgery and complication rate and severity.

Postoperative outcomes and SBO recurrence

Length of hospital stay was longer in the surgical group compared to the conservative group. Patients treated conservatively had more subsequent SBO recurrent episodes (Table 3). One hundred twenty-two patients (35.4%) presented postoperative complications (Table 3). Complications were more frequent and more severe in the group requiring small bowel resection ($P = 0.018$). SBO recurrence occurred more frequently in the conservative group (31.3%), followed by the surgical group without bowel resection (14.5%), and finally the surgical group with bowel resection resection (7.8%) (Table 3). Potential variables affecting SBO recurrence were assessed using a univariate/multivariate Cox proportional hazard model (Supplementary Table 1, Supplemental Digital Content 3, http://links.lww.com/JS9/A155). The presence of a previous SBO episode was significantly associated with an increased risk of recurrent SBO (adjusted hazard ratio: 2.2, 95% CI: 1.4–3.4, $P < 0.001$). Patient treated surgically for their index SBO episode was protective against further recurrence (adjusted hazard ratio: 0.5, 95% CI: 0.3–0.7, $P < 0.001$).

Performance of our previous SBO clinical score

We applied our previously published clinical score[10] (developed in the 2004–2007 SBO cohort) to our new 2008–2016 cohort. The AUC was 0.78 (95% CI: 0.72–0.84). Although the previous score function well in the new data set, the AUC was substantially less than the originally reported value of 0.87. We thus decided to improve the existing score using the most recent data set.

Elaboration of a new clinical severity score to predict the risk of small bowel resection

For the construction of the new clinical score, only the conservative group ($n = 147$) and the resection group ($n = 103$) were used (total $n = 250$). The external validation data set (historical cohort) included 33 patients who required resection and 82 patients who were treated conservatively, all with complete data.

We considered 13 variables measured at patient intake (Table 1). Four variables were not significantly associated with small bowel resection in univariate analysis: sex, duration of pain ($P = 0.52$ for conservative vs. surgery with resection, data not shown), fever, and vomiting. Of the four age groups, the two older strata were at higher risk of resection, and therefore, were grouped to define a single risk group, age 70 years and older. Of the three strata of CRP, only the highest (≥ 50) was associated with resection, and here too the variable was dichotomized. Nine variables remained for the multivariate logistic regression model. In this analysis, the association between leukocytosis and resection became weak and statistically nonsignificant, and was therefore withdrawn from the model. The final full model included eight variables (Table 4). The AUC of this logistic regression model was 0.863 (95% CI: 0.816–0.910). The OR ranged from 2.36 to 8.10, which suggested that some risk factors were more important than others. Nevertheless, in the interest of usability, we established a risk score as a simple sum of the risk factors present in a given patient. The score had thus a possible range of 0–8 (Table 5). The risk of resection increased gradually with the score, from 0% at score 0–100% for scores 5–7. No patient had a score of 8. Among 58 patients with a score of 4, 41 (70.7%) required a resection and 17 (29.3%) had a resolution of symptoms without surgery, whereas among 66 patients with a score of 3, 24 (33.4%) required a resection. We proposed that patients with scores from 4 to 8 be considered at high risk of ischemia and therefore likely to require surgical resection. By this definition, 84 (33.6%) of the 250 patients would be considered at high risk. The

Table 4

Risk factors for small bowel resection versus conservative treatment in patients with a small bowel obstruction, multivariate logistic regression model.

	Unadjusted OR (95% CI)	Adjusted OR (95% CI)	Adjusted OR *P* value
Age ≥ 70 years (vs. younger)	3.03 (1.79–5.12)	3.47 (1.74–6.92)	< 0.001
First episode of obstruction (vs. recurrence)	3.11 (1.68–5.77)	2.36 (1.07–5.22)	0.033
Absence of bowel movement ≥ 3 days (vs. 0–2 days)	2.33 (1.09–4.97)	4.07 (1.58–10.44)	0.004
Guarding present (vs. absent)	7.10 (3.55–14.18)	7.76 (3.17–19.04)	< 0.001
C-reactive protein ≥ 50 (vs. less)	2.20 (1.13–4.28)	3.10 (1.39–6.92)	0.006
CT scan: transition point (vs. none)	2.38 (1.11–5.13)	2.99 (1.05–8.54)	0.040
CT scan: lack of contrast enhancement (vs. presence)	14.58 (4.26–49.95)	8.10 (1.86–35.35)	< 0.001
CT scan: intra-abdominal fluid ≥ 500 ml	8.00 (4.01–15.94)	6.16 (2.58–14.60)	< 0.001

CT, computed tomography; OR, odds ratio.

AUC under the ROC curve of the eight-item score was 0.84 (95% CI: 0.80–0.89) (Fig. 1).

Elaboration of two alternative scores

Because not all patients can benefit from contrast injection during CT scan (contrast allergies, renal insufficiency), we considered a seven-item score that excluded the lack of contrast enhancement on CT scan. Finally, in order to facilitate daily use of the score, we also developed a brief four-item score that relied only on age, guarding, transition point and presence of 500 ml of free fluid on CT scan (Table 5). Both scores were associated with the risk of resection in a gradual manner. The seven-item score can be used similarly to the eight-item score, in that a score of 4 or greater defines the high-risk group. For the brief four-item score, a score of 2 or higher defined the high-risk category.

Comparison of the three scores

Selected items, AUC, validation AUC, high-risk thresholds, and sensibility-specificity are shown in Table 6. The discriminative ability was excellent for all three scores, although decreasing along with the reduction in items, as shown by the AUC under the ROC curves (Table 6, Fig. 1). The AUCs were 0.844 (eight-item score), 0.826 (seven-item score), and 0.802 (four-item score) (Table 6). For all three scores, the loss of discrimination was less than 0.03 in the external validation data set (i.e. – 0.023, – 0.015, and – 0.028, respectively).

The proportion of patients identified as being at high risk of resection (namely ≥ 0.70% risk of small bowel resection) went from one third for the eight-item score to one quarter for the four-item score (Table 6). However, when the threshold of high risk was redefined as the average of 11 values between 0.60 and 0.80, the proportions of high-risk patients were similar for the three scores. This difference between the three scores was less pronounced in the external validation data set.

Sensitivity decreased for the seven-item and four-item risk scores compared to the full eight-item score. However, specificity showed an opposite trend (Table 6). In the external validation data set, these values were comparable to those of the development data set.

The distribution of the clinical severity score was assessed among the three groups (Table 7). Sixty-five percent of patients in the surgical group with bowel resection had a score of greater

Table 5

Frequency distributions of the three clinical scores and probabilities of surgical resection in 250 patients with small bowel obstruction.

	Full 8-item score		Seven-item score (no contrast)		Brief 4-item score	
Score	*N* (%)	Percent with resection	*N* (%)	Percent with resection	*N* (%)	Percent with resection
0	5 (2.0)	0	5 (2.0)	0	78 (31.2)	12.8
1	33 (13.2)	6.1	34 (13.6)	8.8	111 (44.4)	36.0
2	62 (24.8)	16.1	62 (24.8)	16.1	*33 (13.2)*	78.8
3	66 (26.4)	36.4	76 (30.4)	40.8	*21 (8.4)*	95.2
4	*58 (23.2)*	70.7	*52 (20.8)*	73.1	*7 (2.8)*	100
5	*11 (4.4)*	100	*14 (5.6)*	100	–	–
6	*11(4.4)*	100	*4 (1.6)*	100	–	–
7	*4 (1.6)*	100	*3 (1.2)*	100	–	–
8	*0*	0	–	–	–	–

High-risk groups are italicized.

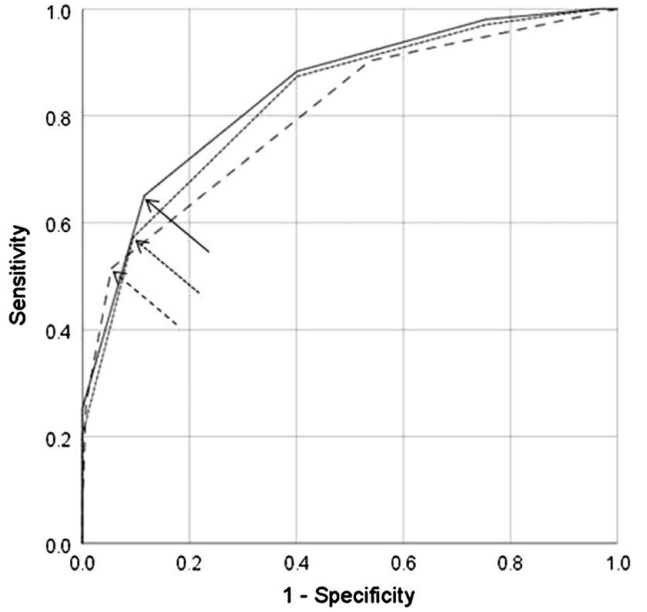


Figure 1. Receiver operating characteristic curves of the full eight-item score (solid line), the seven-item score (dotted line), and the brief four-item score (dashed line). Arrows point to thresholds for high risk (≥ 4 for the eight-item and seven-item scores, ≥ 2 for the four-item score).

Table 6

Comparison of three scores for the prediction of small bowel resection in patients with small bowel obstruction: full eight-item score, seven-item score (omitting injection of contrast on CT scan) and brief four-item score, in development data set and in external validation data set.

Number of items	8	7	4
Variables in score			
Age ≥ 70 years	✓	✓	✓
First SBO episode	✓	✓	–
≥ 3 days since BM	✓	✓	–
Abdominal guarding	✓	✓	✓
CRP ≥ 50 mg/l	✓	✓	–
Presence of transition point (CT)	✓	✓	–
Lack of SB contrast enhancement (CT)	✓	–	✓
Abdominal fluid ≥ 500 ml (CT)	✓	✓	✓
Area under ROC curve (AUC)	0.844	0.826	0.802
AUC in external validation set	0.821	0.811	0.774
Percentage at risk for threshold ≥ 0.70[a]	33.6	29.2	24.4
Percentage at risk for same threshold in external validation set	32.2	32.2	28.7
Sensitivity for risk threshold ≥ 0.70	65.0	57.3	51.5
Sensitivity for same risk threshold in external validation set	72.7	72.7	60.6
Specificity for risk threshold ≥ 0.70	88.4	90.5	94.6
Specificity for same risk threshold in external validation set	84.1	84.1	84.1

[a]Score ≥ 4 for eight-item score and seven-item score, and ≥ 2 for four-item score.
BM, bowel movement; SB, small bowel.

than or equal to 4 in comparison to 21.2 and 11.6% in the surgical group without resection and the conservative group, respectively. Mean and median score followed a similar trend.

Discussion

In this study, we address a common dilemma for the on-call surgeon in the emergency room and on the surgical floor: 'should I take this patient presenting an SBO to the operating room?'. We developed and validated an SBO score with two simplified versions to aid the surgeon in the daily clinical decision making. In this study, we observed a good performance of our previous SBO score in a new data set. However, the reduction of the AUC in this new data set was too important, dropping from 0.87 to 0.78, in order to validate this score.

We therefore decided to refine our initial scoring system and designed a new score, with the following eight items: age above 70 years, first SBO episode, greater than or equal to 4 days since the last bowel movement, small bowel transition point on CT scan, abdominal guarding, CRP greater than or equal to 50 mg/l, nonenhanced small bowel on CT scan, and CT scan free fluid greater than or equal to 500 ml. Four criteria were maintained from the previous score and four new criteria were added. Interestingly, we did not find significant associations between small bowel resection rate and leukocytosis, abdominal pain duration, vomiting, creatinine, lactate levels, and platelet levels. These criteria where thus abandoned.

Additionally, we present two simplified version of the score: seven-item score for patients with acute kidney insufficiency or contrast allergies (no CT contrast enhancement evaluation required) and one with only four items allowing a rapid clinical and radiological assessment without the need for laboratory values. All developed scores (the eight, seven, and four items) had excellent discrimination ability to predict the need for bowel resection (and thus an operation) in the current cohort. We were able to validate all three scores internally and externally. We also developed the latter simplified score keeping in mind that CRP is not routinely available/measured in most hospitals across the globe. Patients with five points or more in the seven and eight-item score, and four points in the four-item score had a 100% chance risk of small bowel resection. These patients should therefore be taken to the OR for a surgical exploration. For patients with an intermediate score, namely 2–4 for the eight and seven-item score, and 1–2 in the four-item score, a conservative approach with watchful waiting may be attempted. For patients with a low score, namely 0–1 for the eight and seven-item score, and 0 in the four-item score, a conservative approach is likely to be successful.

Table 7

Clinical severity score for each group.

	Surgical, no resection [*n* (%)]	Surgical resection [*n* (%)]	Conservative [*n* (%)]	*P* value[a]	*P* value[a]	*P* value[a]
	N = 242	*N* = 103	*N* = 147	No res vs. res	No res vs. cons	Res vs. cons
Clinical severity score						
0	1 (0.4)	0	5 (3.4)	< 0.001	< 0.001	< 0.001
1	9 (3.7)	2 (1.9)	31 (21.1)			
2	64 (26.5)	10 (9.7)	52 (35.4)			
3	81 (33.5)	24 (23.3)	42 (28.6)			
4	55 (22.7)	41 (39.8)	17 (11.6)			
5	24 (9.9)	11 (10.7)	0			
6	8 (3.3)	11 (10.7)	0			
7	0	4 (3.9)	0			
8	0	0	0			
Clinical severity score (mean ± SD)[b]	3.2 ± 1.2	4.0 ± 1.3	2.2 ± 1.0	< 0.001	0.001	< 0.001

One point was given for each present feature: age greater than or equal to 70 years old, first SBO episode, greater than or equal to 3 days since last bowel movement, abdominal guarding, CRP greater than or equal to 50 mg/l, change of bowel diameter, lack of contrast enhancement and abdominal fluid greater than or equal to 500 ml on CT scan. The score range from 0 to 8.
[a]χ^2-test for binary or categorical variable.
[b]Means comparison for continuous variables using analysis of variance.
CRP, C-reactive protein; CT, computed tomography; SBO, small bowel obstruction.

The management of SBO has been well described and algorithm for diagnosis and treatment have been proposed[14]. In addition to the items included in our score, the presence of the following factors warrants a surgical exploration: a persistent obstruction after a 72 h observation period, and a nasogastric drainage volume greater than 500 ml/24 h on the third day[14]. Comparing the criteria identifying peritonitis and/or ischemia from international guidelines[14] to our own data, the following can be highlighted: we abandoned leukocytosis (i.e. leukocytes $>10\ 000/mm^3$) given its weak and statistically nonsignificant relation with bowel resection, we lowered the 'CRP >75 mg/l' criteria to 50 mg/l since this threshold was already significantly associated with resection, and kept the 'free intraperitoneal fluid >500 ml' as is. Despite the profusion of guidelines regarding the management of SBO, no consensus exists when it comes to the use of a uniform score to predict the need for a surgical intervention. An 'a posteriori' classification of SBO exist and was designed to predict severity and outcomes. The results have been published by the American Association for the Surgery of Trauma[15]. It includes anatomical factors (whether an operation was needed an if a resection was performed), physiological factors (the presents of systemic inflammatory response syndrome, sepsis of septic shock), and the Charlson comorbid index[16]. This score is complex and not designed to predict the need for resection. Therefore, our proposed score and its declinations fulfill a need for standardization in the management of SBO.

The formation of adhesions is the most frequent long-term complication of virtually any type of surgery, and account for a significant number of emergency room visit, morbidity, and mortality in the context of abdominal surgery[17]. The challenge in the management of those patients is to identify which ones will benefit from a surgical management and which one who will not. Failure to recognize early enough the need for a surgical intervention can lead to bowel necrosis, sepsis, septic shock and death, especially in frail/older patients. On the other hand, performing unnecessary surgical explorations puts patients at risk of perioperative and postoperative complications and the development of new adhesions. An SBO score helps to standardize patient's presentation to the team and can guide the surgeon make the final clinical decision.

Finding a reliable and accessible predictor for bowel ischemia is crucial. It should be specific to bowel ischemia and sensitive enough, in order to rule out other pathologies. A recent systematic review analyzed all serological human markers for bowel ischemia investigated over the last few years[18]. Common laboratory values such as lactate dehydrogenase, white blood cells count, base excess, and creatine kinase did not demonstrate any strong association with bowel ischemia. More interestingly, lactate level was not predictive either for ischemia, which we confirmed in our data; lactate seems limited by being an unspecific marker for tissue hypoperfusion. Furthermore, it was demonstrated that bowel necrosis can occur even without a significant increase in lactate levels[19,20]. We found and validated a role for CRP to be one of the predictors of bowel ischemia in two different cohorts, including a total of more than 700 patients. However, CRP remains an unspecific marker of inflammation and its use is very center dependent, and thus probably not broadly applicable. Procalcitonin is another marker of inflammation and bacterial infection[21] that has attracted attention for its ability to predict bowel ischemia[22–25]. While its measurement is becoming more and more routinely performed, the use of procalcitonin should be encouraged as a useful marker for initial work-up for SBO.

In their systematic review, Derikx *et al.*[18] proposed other interesting markers for bowel ischemia such as D-Dimer, endothelin-1, ischemia modified albumin, a-Glutathione S-transferase and intestinal fatty acid binding protein, the latter being the most promising as it is specific to enterocytes. However, the turnover for these tests is still too long to be applicable and cutoff values are to be determined.

Over the last decades, the surgical management of acute SBO has refined with the appearance of laparoscopy[26], and progressively let more space for semi-interventional with the introduction of water-soluble contrast imaging as a dual diagnostic and therapeutic method[27]. The use of water-soluble contrast imaging potentially allows to reduce the need for surgery in selected patients[28], although we did not observe that trend in our cohort. In our population, 70.1% of patients presenting an index SBO episode were treated surgically and among them, 29.9% had a bowel resection. Our operative management rate is higher than those previously reported in the literature, namely ranging from 22 to 51%[9,27,29–32]. This might be explained by the fact that we specifically focused on adhesion-related SBO episodes and excluded hernia-, cancer-, and radiation-related SBOs. This could also be explained by our policy favoring surgical management which was justified by the 50% reduction in the need for readmission and 60% reduction in recurrent SBO symptoms, as shown by us and others[9–11,32]. This is especially true when a single adhesion causing recurring abdominal pain and obstruction is present[27]. The timing of surgery is another important parameter. A delay of 24 h or more is usually associated with higher mortality and postoperative complications rate[33]. We could however not reproduce this observation, potentially due to our more aggressive management including a smaller proportion of patients managed conservatively.

Our study has limitations. This is a monocentric design, which can lead to selection bias, limitations in the number of possible included patients, and conclusions that rely on local practices that are not necessarily transferable to other centers. We provided a simplified four-item score which retained excellent discrimination ability (AUC of 0.80 in the development cohort and 0.77 in the validation cohort) in order to be used more easily in other centers. This simplified score is based on objective and universally available variables to predict the need for small bowel resection; which represents an objective outcome by itself, and which should be similar and translatable to most centers. Another inherent limitation in all the developed predictive models and clinical scores is that they are founded on skewed datasets as clinicians already balance their management decisions based on available clinical variables (that may later be included into the score). Although the new score was not used to make clinical decisions *per se*, the attention directed to a part of the individual variables may have contributed to some degree of selection bias. Validation in prescore era cohort somehow mitigated the risk of confounding. Another possible bias is that we excluded patients without CT scan contrast injection. The simplified score did function relatively well without the 'i.v. contrast' information and patients without i.v. contrast should be included in future studies. The use of CRP in the full score can also represent a limitation which was addressed by the development of the simplified score as mentioned above. Finally, the objectivity of 'small bowel resection' as an outcome will remain conditional to the on-call surgeon clinical

decision and dependent upon the timing of the operation. In other terms, a similar situation, a strangulation might or might not result in a resection, depending upon how early is the surgical exploration. We thought about using a criterion such as 'intraoperative ischemic bowel loop presence/absence' but found that this was inconsistently reported and not a fully objective criterion either. It is also likely that this 'gray' zone (unclear if resection is needed) does not represent the majority of the SBO cases. Alternatively, one could also argue that an operation might be warranted and beneficial, even if the need for resection is absent, particularly in nonresolving/smoldering clinical situations. In this regard, we believe that the score should remain an aid but not a substitute for clinical judgment.

In conclusion, we developed and validated a score to guide the clinical decision to whether or not a given patient should be taken to the operating room for an acute SBO episode. We provided and validated two additional versions of our SBO score to accommodate most clinical situation. The decision to operate will always retain a subjective part based on the surgeon's experience and the clinical situation, however, our SBO score has proven helpful for standardized clinical decision, management, and outcomes evaluation.

Ethical approval

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Author contribution

C.-H.W. and R.P.H.M.: study design, data collections, data analysis, writing. R.R. and I.U.: data collections. M.C.: data collections, proofing, and correction of manuscript. C.T., P.G., P.M., P.-A.P., A.P., F.R., and F.S.: proofing and correction of manuscript. T.P.: data analysis, proofing, and correction of manuscript.

Conflicts of interest disclosure

None.

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Data statement availability

Due to the sensitive nature of the questions asked in this study, survey respondents were assured raw data would remain confidential and would not be shared.

Provenance and peer review

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