Adhesive small bowel obstruction: Single band or matted adhesions? A predictive model based on computed tomography scan

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BACKGROUND: Preoperative identification of the cause of adhesive small bowel obstruction (ASBO) is crucial for decision making. Some computed tomography (CT) findings can be indicative of single adhesive bands or matted adhesions. Our aim was to build a predictive model based on CT data to discriminate ASBO due to single adhesive band or matted adhesions.

METHODS: A retrospective single center study was conducted, covering all consecutive patients with a preoperative CT scan, undergoing urgent surgery for ASBO between January 1, 2005, and December 31, 2017. Preoperative CT scans were blindly reviewed, and all the CT findings indicative of single adhesive band or matted adhesions described in literature were recorded. According to intraoperative findings, ASBOs were retrospectively classified into single band and matted ASBO. All observed CT findings were compared between the two groups. A predictive model based on logistic regression was developed, and its ability was quantified by discrimination and calibration. Internal cross-validation was conducted by bootstrap resampling.

RESULTS: A total of 116 patients were analyzed (males, 53.5%; median age, 68 years; single band ASBO in 65.5% of cases). The odds of single band ASBO were increased four times in presence of complete obstruction (odds ratios, 4.19; 95% confidence interval, 1.49–12.56) and seven times in presence of fat notch sign (odds ratios, 7.37; 95% confidence interval, 1.83–40.03). The predictive model combining all CT findings had an accuracy of 86% in single band ASBO prediction. Accuracy decreased to 79% in the internal validation. Sensitivity, specificity, and positive and negative predictive values were calculated at different cut-points of the predicted risk: using a 0.70 cut-point, the specificity is 80%, the sensitivity is 68%, and the positive and negative predictive values are 87% and 57%, respectively.

CONCLUSION: The proposed predictive model based on combination of specific CT findings may elucidate whether ASBO is caused by single bands or matted adhesions and, consequently, influence the clinical pathway. (*J Trauma Acute Care Surg.* 2021;90: 917–923. Copyright © 2021 American Association for the Surgery of Trauma.)

LEVEL OF EVIDENCE: Prognostic study, level IV

KEY WORDS: Small bowel obstruction; adhesive band; matted adhesions; CT scan; urgent surgery.

Small-bowel obstruction (SBO) represents as many as 16% of surgical admissions and more than 300,000 operations annually in the United States.[1] Adhesive small bowel obstructions (ASBOs) represent 50% to 75% of all SBOs.[2] Adhesions have been classified into two categories: single bands (>1 cm long and <1 cm diameter) and matted (dense, multiple, and tangled).[3] Single band ASBO is typically a high grade or complete obstruction, characterized by frequent progression to ischemia and a low rate of success of nonoperative management (NOM); adhesiolysis is often rapid with a low incidence of adhesiolysis-induced enterotomy; laparoscopic management is feasible and has become a widely accepted technique for treating ASBO.[4–8] Matted ASBO is typically a low grade or partial obstruction, characterized by rare progression to ischemia and a high rate of success of NOM; adhesiolysis is often long and difficult with a high incidence of iatrogenic injury; laparoscopic adhesiolysis has a high rate of conversion.[4] For these reasons, predicting when an ASBO is due to single adhesive bands or matted adhesions would be extremely useful for decision making. Computed tomography (CT) scan with intravenous contrast is the criterion standard for diagnosis.[9] Many CT findings have been described as predictors of single band ASBO or matted ASBO (i.e., beak sign, fat notch sign, whirl sign, closed-loop ASBO, small bowel feces sign, mesenteric free fluid, reduced bowel wall enhancement, pneumatosis[10–15]), but they have never been combined into a single predictive model. Our aim was to create a predictive model to discriminate an

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ASBO due to single adhesive band from ASBO due to matted adhesions using all those CT findings described previously.

PATIENTS AND METHODS

A retrospective single-center study was conducted, covering all consecutive patients admitted to our tertiary acute care center undergoing urgent surgery for ASBO between January 1, 2005, and December 31, 2017. Only patients with preoperative CT scan with intravenous contrast medium were included. Patients with cause of small bowel obstruction other than adhesions (e.g., carcinomatosis, hernias, bezoar, neoplasms, dynamic ileus) were excluded. Preoperative CT scans were blinded reviewed by a single acute care surgeon, who is used to checking imaging modalities in emergency patients for clinical decision making. The radiological signs were defined together with the radiologists. According to evidence available in the literature, the following CT findings were recorded: grade of ASBO (partial or complete), kind of ASBO (simple or closed-loop ASBO), location of transition point (abdomen or pelvis), and the presence of beak sign, fat notch sign, whirl sign, small bowel feces sign, mesenteric fluid, reduced wall bowel enhancement, and pneumatosis.[10–15] Computed tomography findings are described in Supplementary Table 1 (http://links.lww.com/TA/B959) and represented in Supplementary Figure 1 (http://links.lww.com/TA/B957). Adhesive small bowel obstructions were considered complete (high grade) when intestinal loops after transition point appeared completely collapsed; otherwise, ASBOs were considered partial (low grade). Adhesive small bowel obstructions were defined simple in presence of a single transition point. A closed-loop ASBO was characterized by multiple transition points.

According to intraoperative findings, ASBOs were retrospectively classified into two groups: single band and matted ASBO. In a preliminary analysis, CT signs and intraoperative findings were compared between the two groups by nonparametric tests (χ^2 test for categorical variables and Wilcoxon test for continuous variables). A predictive model based on the multivariable logistic regression was developed to estimate the association between patient's characteristics and the CT findings and the risk of single band ASBO, expressed in terms of odds ratios (ORs) and 95% confidence intervals (95% CIs). Pneumatosis was not included in the model because it was too rare (one case).

The effects of improvements over time were checked by comparing the models with and without the interaction between time and each variable included in the model by likelihood ratio test.

The model's predictive ability was quantified by the receiver operating characteristic (ROC) curve and the calibration plot. Sensitivity, specificity, and positive and negative predictive values were calculated at different cut-points of the predicted risk chosen to define the patients with single band ASBO. Finally, an internal validation was conducted by bootstrap resampling,[16] which consists of replicating the process of sample generation from an underlying population by drawing samples with replacement from the original data set, of the same size as the original data set. Then, models are developed in bootstrap samples and tested in the original sample.

After randomly sampling a subsample of patients, a radiologist reviewed CT scans to evaluate the interrater reliability.

RESULTS

In the study period, 171 patients underwent urgent surgery for small bowel obstruction. Overall, 116 patients were included in the study (males, 53.5%; median age, 68 years). Fifty-five patients were excluded because of the following reasons: patients without preoperative contrast-enhanced CT scan (n = 15), preoperative CT scan not available for the review (n = 15), and cause of small bowel obstruction other than adhesions (n = 25).

Among analyzed patients, intraoperative findings demonstrated single band ASBO in 76 patients (65.5%). The CT findings are summarized in the Table 1. Computed tomography analysis revealed complete ASBOs in 66 patients (56.9%) and closed-loop ASBOs in 47 cases (40.5%). The transition point was located in the pelvis in 53 patients (45.7%). Beak sign, fat notch sign, whirl sign, and small bowel feces sign were observed in 37 (31.9%), 38 (32.8%), 24 (20.7%), and 19 patients (16.4%), respectively. Mesenteric fluid and reduced bowel wall enhancement, which are CT signs of potential intestinal ischemia,[9] were observed in 62 (53.4%) and 15 patients (12.9%), respectively. Intestinal pneumatosis was observed only once.

Complete ASBO, closed-loop ASBO, beak sign, fat notch sign, mesenteric fluid, and reduced bowel wall enhancement were observed more frequently in patients with single adhesive band ASBO compared with patients with matted adhesions: complete ASBO in 74% of patients with single band ASBO

TABLE 1. Descriptive Analysis of CT Findings in Single Band ASBO and Matted ASBO

CT Findings	Study Population (n = 116)	Single Band ASBO (n = 76)	Matted ASBO (n = 40)	*p*
Complete ASBO, n (%)	66 (56.9)	56 (73.7)	10 (25.0)	<0.001
Closed-loop ASBO, n (%)	47 (40.5)	41 (53.9)	6 (15.0)	<0.001
Pelvic location of transition point, n (%)	53 (45.7)	29 (38.1)	24 (60.0)	0.026
Beak sign, n (%)	37 (31.9)	31 (40.8)	6 (15.0)	0.007
Fat notch sign, n (%)	38 (32.8)	35 (46.1)	3 (7.5)	<0.001
Whirl sign, n (%)	24 (20.7)	19 (25.0)	5 (12.5)	0.121
Small bowel feces sign, n (%)	19 (16.4)	9 (11.8)	10 (25.0)	0.074
Mesenteric fluid, n (%)	62 (53.4)	47 (61.8)	15 (37.5)	0.014
Reduced bowel wall enhancement, n (%)	15 (12.9)	14 (18.4)	1 (2.5)	0.039
Pneumatosis, n (%)	1 (0.9)	1 (1.3)	0	—

TABLE 2. Predictive Model of the Risk of Single Adhesive Band Based on Multivariable Logistic Regression

	Univariate OR (95% CI)	Multivariable OR (95% CI)
Sex	0.48 (0.22–1.07)	0.51 (0.17–1.47)
Age	0.99 (0.97–1.01)	0.99 (0.96–1.03)
Complete ASBO	8.40 (3.49–20.23)	4.19 (1.49–12.56)
Closed-loop ASBO	7.00 (2.63–18.62)	2.38 (0.58–11.10)
Pelvic location of transition point	0.41 (0.19–0.90)	0.63 (0.22–1.78)
Beak sign	3.90 (1.46–10.41)	1.91 (0.54–6.85)
Fat notch sign	10.53 (2.99–37.12)	7.37 (1.83–40.03)
Whirl sign	2.33 (0.80–6.81)	0.77 (0.17–3.68)
Small bowel feces sign	0.40 (0.15–1.09)	0.39 (0.10–1.46)
Mesenteric fluid	2.70 (1.23–5.95)	0.93 (0.30–2.83)
Reduced bowel wall enhancement	8.81 (1.11–69.64)	2.01 (0.21–46.44)

versus 25% of patients with matted ASBO, closed-loop ASBO in 54% versus 15%, beak sign in 41% versus 15%, fat notch sign in 46% versus 7%, mesenteric fluid in 62% versus 37%, and reduced bowel wall enhancement in 18% versus 2% ($p < 0.05$ for all). On the contrary, pelvic transition point and small-bowel feces sign were mostly observed in patients with matted adhesions: pelvic abdominal transition point in 38% of patients with single band ASBO versus 60% of patients with matted ASBO ($p = 0.026$) and small bowel feces sign in 12% versus 25% ($p = 0.074$). Whirl sign was common but not helpful in the classification of ASBO.

In our series, 68 patients (54.3%) were approached laparoscopically. The conversion rate was 44%; it decreased to 35.7% in single band ASBO and increased to 61.9% in case of matted ASBO ($p = 0.05$). Accidental intestinal perforations occurred in 6.6% of adhesiolysis for single band ASBO and in 30% of adhesiolysis for matted ASBO ($p = 0.001$). Intestinal ischemia and necrosis occurred in 47 (40.5%) and 11 patients (9.5%), respectively; intestinal ischemia occurred in 53.9% of single band ASBO and in 15% of matted ASBO ($p < 0.001$), and intestinal necrosis was present in 11.8% of single band ASBO and in 5% of matted ASBO ($p = 0.232$).

By univariate analysis (Tables 1 and 2), the odds of single band ASBO increased ($p < 0.05$) in presence of complete obstruction (OR, 8.40; 95% CI, 3.49–20.23), closed-loop ASBO (OR, 7.00; 95% CI, 2.63–18.62), beak sign (OR, 3.90; 95% CI, 1.46–10.41), fat notch sign (OR, 10.53; 95% CI, 2.99–37.12), mesenteric fluid (OR, 2.70; 95% CI, 1.23–5.95), and reduced bowel wall enhancement (OR, 8.81; 95% CI, 1.11–69.64); on the contrary, the presence of a pelvic transition point was associated with decreased odds of single band ASBO (OR, 0.41; 95% CI, 0.19–0.90) and consequently with increased odds of matted ASBO.

By multivariable logistic regression analysis (Table 2 and Supplementary Table 2, http://links.lww.com/TA/B960), two independent predictors of single band ASBO were identified: the odds were increased four times in presence of complete obstruction (OR, 4.19; 95% CI, 1.49–12.56) and seven times in presence of fat notch sign (OR, 7.37; 95% CI, 1.83–40.03). Although without statistical significance, the odds of single band ASBO seemed to increase in presence of a closed-loop ASBO and a beak sign (OR, 2.38; 95% CI, 0.58–11.10 and OR, 1.91; 95% CI, 0.54–6.85, respectively); on the contrary, the odds of single band ASBO seemed to decrease in presence of a pelvic transition point and small bowel feces sign (OR, 0.63; 95% CI, 0.22–1.78 and OR, 0.39; 95% CI, 0.10–1.46, respectively). Increasing calendar year had no effect on the variables included in the predictive model (likelihood ratio test, $p = 0.49$).

The area under the ROC curve of our predictive model was 0.86. It was 0.79 in the internal validation. The ROC curve and the calibration plot are reported in the Figure 1. In the

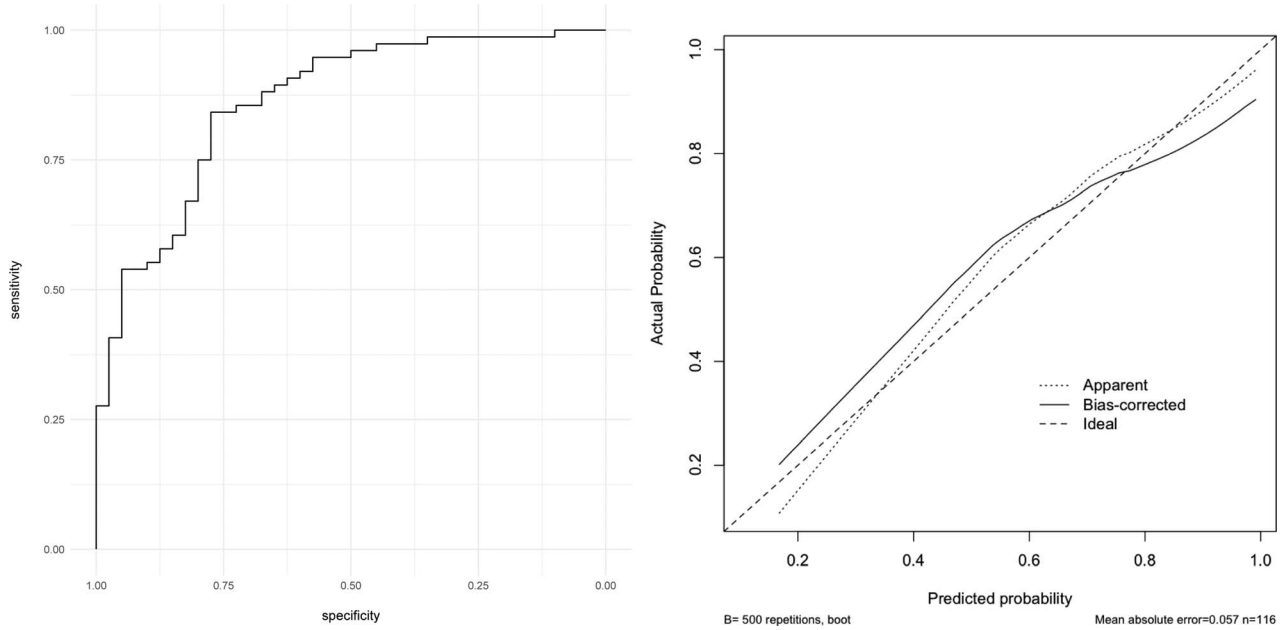
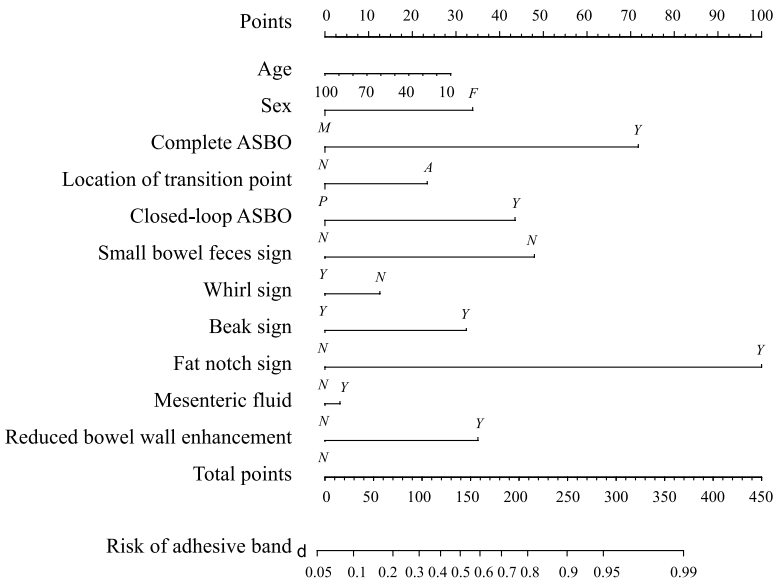


Figure 1. Predictive model's ROC curve and calibration: apparent is the calibration in our study, and bias-corrected is the calibration corrected from optimism based on the internal validation.



	Points
Age	
10	29
20	26
30	22
40	19
50	16
60	13
70	10
80	6
90	3
100	0
Sex	
F	34
M	0
Complete ASBO	
Y	72
N	0
Location of transition point	
Abdomen (A)	23
Pelvis (P)	0
Closed-loop ASBO	
Y	44
N	0
Small bowel feces sign	
Y	0
N	48
Whirl sign	
Y	0
N	13
Beak sign	
Y	32
N	0
Fat notch sign	
Y	100
N	0
Mesenteric free fluid	
Y	3
N	0
Reduced bowel wall enhancement	
Y	35
N	0

Total points	Risk of adhesive band ASBO
0	0.05
29	0.10
70	0.20
97	0.30
119	0.40
139	0.50
160	0.60
182	0.70
209	0.80
249	0.90
287	0.95
370	0.99

Figure 2. The risk-prediction nomogram for the risk of single band ASBO and calculated point values for nomogram.

internal validation, the estimated intercept is 0.12, and the estimated slope is 0.59, suggesting a slight overfitting of the model. The risk-prediction nomogram for the risk of single band ASBO is represented in the Figure 2. For example, the risk of single band ASBO estimated for a 62-year-old man with a complete ASBO, an abdominal transition point, a beak sign, and a fat notch sign (Supplementary Fig. 2, http://links.lww.com/TA/B958) is 0.96. Sensitivity, specificity, and positive and negative predictive values calculated at different cut-points of the predicted risk are reported in Table 3. Using a 0.70 cut-point of the predicted risk to define the patients with single band ASBO, the specificity is 80%, the sensitivity is 68%, and the positive and negative predictive values are 87% and 57%, respectively. Using higher cut-point, the specificity and positive predictive value increase, at the expense of sensitivity and negative predictive value.

The interrater reliability was measured by the κ statistic on 54 observations: the agreement among raters was 30% (95% CI, 3.6–56.3) for grade of the ASBO (partial or complete), 55% (95% CI, 32.6–77.4) for kind of ASBO (simple or closed-loop ASBO), 49.2% (95% CI, 25.1–73.3) for beak sign, 58% (95% CI, 35.3–81.4) for fat notch sign, 78.6% (95% CI, 58.7–98.5) for whirl sign, 67.3% (95% CI, 37.6–97) for small bowel feces sign, 66% (95% CI, 41.4–90.7) for reduced bowel wall enhancement, and 43.4% (95% CI, 19.5–67.2) for mesenteric fluid.

DISCUSSION

The main challenge in ASBO is to establish the need for surgery. Emergency surgery is clearly mandatory for patients with signs of strangulation or peritonitis. The decision-making process is more difficult for patients lacking these classical presentations.[17] A delay in surgery for ASBO places patients at higher risk of bowel resection.[18] The Gastrografin (Bayer, Leverkusen, Germany) challenge is safe and predicts the need for surgery.[4] Water-soluble contrast followed by an abdominal radiograph after at least 4 hours can accurately predict the likelihood of ASBO resolution; the number of false negative decreases after 8 hours from Gastrografin administration.[19] The correct management of those patients without signs of strangulation or peritonitis and a negative Gastrografin challenge remains undefined. Bowel ischemia and consequently

TABLE 3. Sensitivity, Specificity, and Positive and Negative Predictive Values Calculated at Different Cut-points of the Predicted Risk Chosen to Define the Patients With Single Band ASBO

Predicted Risk Threshold	Sensitivity (95% CI)	Specificity (95% CI)	Negative Predictive Value (95% CI)	Positive Predictive Value (95% CI)
>0.30	0.97 (0.91–1.00)	0.45 (0.29–0.61)	0.90 (0.68–0.99)	0.77 (0.67–0.85)
>0.40	0.91 (0.82–0.96)	0.62 (0.46–0.77)	0.78 (0.60–0.91)	0.82 (0.72–0.90)
>0.50	0.85 (0.76–0.92)	0.70 (0.53–0.83)	0.72 (0.55–0.85)	0.84 (0.74–0.92)
>0.60	0.82 (0.71–0.89)	0.77 (0.61–0.89)	0.69 (0.53–0.82)	0.87 (0.77–0.94)
>0.70	0.68 (0.57–0.79)	0.80 (0.64–0.91)	0.57 (0.43–0.70)	0.87 (0.75–0.94)
>0.80	0.58 (0.46–0.69)	0.85 (0.70–0.94)	0.51 (0.39–0.64)	0.88 (0.76–0.95)

high rate of conservative management failure are more frequent in single adhesive bands SBO.[11] Higher rate of accidental bowel perforation during adhesiolysis for matted ASBO has been described.[19] Some authors contraindicated laparoscopy in matted ASBO.[20] The ability to predict which kind of adhesion is responsible of bowel obstruction may greatly influence clinical pathway. Many predictive factors have been described: presence of a laparotomy, history of colorectal surgery, radiotherapy, and gynecologic inflammatory diseases have been related to matted adhesions; appendectomy and gynecologic procedures would lead to adhesive bands formation.[4,11,12,21] Computed tomography scan with intravenous contrast remains the criterion standard for diagnosis of ASBO, recommended by Bologna guidelines;[4] first, it is necessary to exclude other causes of SBO; second, it is the imaging modality of choice for acute bowel ischemia;[14] then, even if adhesive bands are not typically seen on CT, there are many related signs that can be observed. In 2009, Delabrousse et al.[12] analyzed 67 CT scans of patients undergone surgery for ASBO: matted ASBOs were typically simple, with pelvic transition point and small-bowel feces sign; a small-bowel feces sign did not exclude intraoperative finding of intestinal ischemia; closed-loop ASBOs, a whirl sign, and fat notch sign were never noted in matted in ASBO secondary to matted adhesions; a beak sign and a fat notch sign were described in 70% and 61% of ASBO cases from adhesive bands. In 2014, Millet et al.[10] identified CT findings associated with the effectiveness of non-surgical treatment: fewer than two beak signs and the presence of an anterior parietal adhesion were independent predictors of the effectiveness of nonoperative treatment. Thirty-eight percent of the patients with a whirl sign on CT scan were treated successfully without surgery.[10] Despite this evidence, no study included all the CT findings into a single predictive model to elucidate their role in diagnosis and clinical management. In our study, all these signs, identified on preoperative CT scan of patients with an intraoperative diagnosis of ASBO, were combined into a single predictive model. The

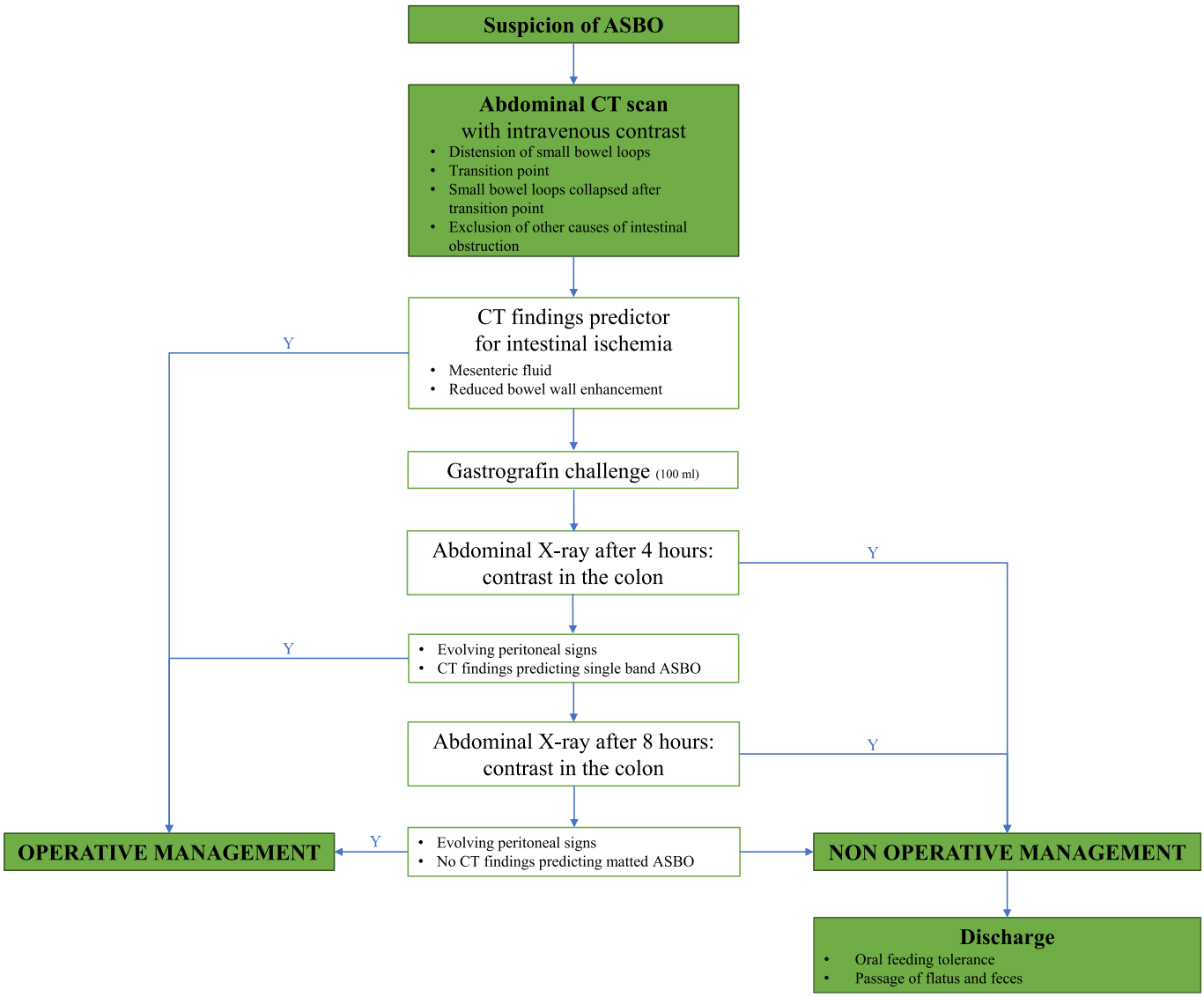


Figure 3. Algorithm for patients presenting with signs of bowel obstruction.

presence of a complete ASBO and the fat notch sign were highly associated to the risk of single band ASBO. The model described in our study predicts the type of adhesion responsible of ASBO with an accuracy of 86% according to the ROC curve. Good performances were confirmed after internally validation, with an accuracy of 79%. The model's calibration suggests a slight overfitting of the model. To improve predictions, methods for shrinkage of the coefficients toward zero could be applied. By applying, for example, a uniform shrinkage,[16] we could multiply the regression coefficients for a factor equal to 0.91 and obtain the shrunk regression coefficients. However, a further development of this work may involve an external validation. Mesenteric fluid and reduced bowel wall enhancement were mostly observed in patients with single adhesive band ASBO compared with patients with matted ASBO. These CT findings had been described as predictors of intestinal ischemia.[14] Our study confirms that adhesive bands are more often associated with CT findings indicative of intestinal ischemia than matted adhesions. The proposed predictive model of single band ASBO could have a major clinical impact. Except for patients with signs of strangulation or peritonitis (clear indications to surgery) and patients with successful Gastrografin challenge (indication to conservative management), the treatment of most patients with ASBO remains uncertain. Our predictive model could drive clinical decisions. We propose an early surgical approach to patients with high suspicion of single band ASBO (for example, with a nomogram-predicted risk above 0.70), while we suggest to insist with NOM if matted ASBO is highly suspected, provided that any CT or clinical suspicion of intestinal ischemia is excluded (Fig. 3).

Some limitations of the present study could be argued. First, it is a retrospective study in which we included only patients who have undergone surgery. We decided to exclude patients with successful NOM of ASBO because surgical exploration is the only way to clearly distinguish single band and matted ASBO. To validate our results, the algorithm presented in Figure 3 should be applied prospectively in patients with suspicion of ASBO. Second, the study took place over a long period; however, the patients' management in the authors' center did not have major modifications, and imaging modalities were adequate for the analysis. Third, CT scans were reviewed by a single acute care surgeon. This is a limitation of the study, even if in routine clinical practice acute care surgeons review themselves imaging modalities to determine clinical decisions. Moreover, a radiologist reviewed CT scans to evaluate the interrater reliability, which provided an adequate agreement for all CT findings. The agreement was weaker for the grade of ASBO. Adhesive small bowel obstruction was defined complete when intestinal loops after transition point appeared completely collapsed. The extent and degree to which the intestinal loops are collapsed are subject to interpretation, with many ambiguous cases, leading to disagreement among observers. In the future, it will be beneficial to clarify the radiological definition of complete and partial ASBO, to build consensus on ASBO classification.

Fourth, the sample size of the study population could have led to underestimate the contribution of some signs to ASBO diagnosis, especially of the rare ones; further studies, based on a larger sample size and involving an external validation, will be needed to confirm our results.

CONCLUSION

Specific CT findings may predict whether ASBO is caused by single bands or matted adhesions and potentially influence the clinical pathway, preferring a more conservative management in case of suspected matted adhesions and a more aggressive treatment in case of suspected single bands.

AUTHORSHIP

J.G. contributed in the conception and design of the study, acquisition of data, analysis and interpretation of data, drafting of the article; revised it critically for important intellectual content; and gave final approval of the version to be submitted. D.Z. contributed in the analysis and interpretation of data and drafting of the article and revised it critically for important intellectual content and final approval of the version to be submitted. D.P., L.S., S.M., M.C., and M.Z. supplied the acquisition of data. G.C. supplied the acquisition of data and revised the article critically for important intellectual content. A.B. supplied the design of the study and revised the article critically for important intellectual content. L.V. supplied the interpretation of data and drafting of the article; revised the article critically for important intellectual content; and gave final approval of the version to be submitted. H.K. supplied the design of the study, revised the article critically for important intellectual content, and gave final approval of the version to be submitted.

DISCLOSURE

The authors declare no conflicts of interest.

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